NR 2001:10

x2001 – Exposure Assessment in Epidemiology and Practice

Mats Hagberg, Bengt Knave, Linnéa Lillienberg and Håkan Westberg (Eds)

ARBETE OCH HÄLSA | VETENSKAPLIG SKRIFTSERIE

ISBN 91-7045-607-0 ISSN 0346-7821 http://www.niwl.se/ah/

Dept of Occupational Medicine

ICOH Industrial Hygiene

Arbetslivsinstitutet

National Institute for Working Life

ARBETE OCH HÄLSA

National Institute for Working Life
S-112 79 Stockholm
Sweden

ISBN 91–7045–607–0
ISSN 0346–7821
http://www.niwl.se/ah/
Printed at CM Gruppen, Bromma

Preface

This book contains the extended abstracts to the X2001 Conference on Exposure Assessment in Epidemiology and Practice in Göteborg, Sweden, June 10-13, 2001. The excellent work performed by the contributing scientists has made this book a first-class, up-to-date, state of the art review on what is known about exposure assessment today.

The outstanding scientific quality of the extended abstracts was secured through the work of five international programme committees. The chairmen for the committees were: Chemical, Patricia Stewart; Ergonomic, Alex Burdorf; Physical, Ulf Bergqvist; Psychosocial, Annika Härenstam and Biological, Jean-Francois Caillard.

Financial support to the conference and thereby to the publishing of this book was made possible by contributions from The National Institute for Working Life, Stockholm, Sweden; The Swedish Council for Working Life and Social Research, Stockholm and Volvo. Without the excellent skills of the organizing committee - Ulrika Agby (administration and layout), Ann-Sofie Liljenskog Hill (administration) and Christina Lindström Svensson (administration) - the production of this book would not have been possible.

We want to express our gratitude to the contributing authors, session chairmen and to the participants who presented papers and contributed in the discussions, for making X2001 an outstanding meeting.

Göteborg in June 2001

Mats Hagberg
Department of Occupational Medicin
Göteborg University, Göteborg

Bengt Knave
The National Institute for Working Life
Stockholm

Linnéa Lillienberg
Occupational and Environmental Medicine
Sahlgrenska University Hospital, Göteborg

Håkan Westberg
Occupational and Environmental Medicine
Örebro Regional Hospital, Örebro

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How to design efficient measurement strategies for workplace exposures

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Environmental and Occupational Health Group, Institute for Risk Assessment Sciences, Utrecht University, Utrecht, The Netherlands, e-mail: h.kromhout@vet.uu.nl

Introduction

The purpose of an exposure survey and the available budget will to a large extent determine the number of measurements to be taken. However, required accuracy and precision, feasibility and patterns of variability in exposure concentrations will be the key factors in the design of an efficient and at the same time effective measurement strategy.

Measurements of workplace exposures are crucial not only for evaluations of hazards and risks present in the workplace but also to design and evaluate subsequent control measures. Developments in portable measuring devices have resulted in increased numbers of personal exposure measurements and often at the same time with higher temporal resolution. Nowadays, dosimeters exist that are able to create thousands of 1-second average exposure levels. However, at the same time a tendency can be seen in which practising occupational hygienists tend to shunt away from proper assessment of occupational exposure. It seems that they are increasingly encouraged to rely on limited validated expert systems like EASE and one-stop approaches like COSHH Essentials in which proper exposure assessment has no role. In occupational epidemiology an opposite development is ongoing, that moves away from expert approaches. Currently more often actual measured exposure concentrations are being used in order to derive quantitative relations between exposure and health effects.

Whatever the purpose, efficient measurement strategies are urgently needed in order to make the best of the available limited budgets.

Considerations for designing efficient measurement strategies

Efficient measurement strategies can only be designed when we have a clear idea what we want to discern from the collected data. Exposure concentrations in the workplace have been known for their extreme variability especially when shorter averaging times are being considered. Long-term trends in exposure concentrations at an average rate of 6% have been described recently for workplace exposure situation in western industrialised countries (1). Variability in yearly average concentrations will however be much smaller when compared to variability in 8-h shift-long measurements that are estimated to vary between 3 and 4000 fold (2,3). For 10-sec point estimated levels of magnetic field exposure for workers in the utility industry it was estimated that levels on average varied an additional 50-fold (4). To what extent exposures vary is depending on a lot of factors some concerned with the exposure itself, but the majority linked to work content, tasks performed, production, environment and personal characteristics. In addition analytical and sampling error play a (minor) role.

With knowledge of the components of variability more efficient measurement strategies can be designed. For a survey focussed at hazard control, restricting monitoring to groups of workers subjectively assigned a high risk will be more cost-efficient. However the subjective method used to distinguish groups of workers should of course be valid. Limited validation studies of expert systems like EASE (5), however, point at considerable imprecision and lack of accuracy. In addition worst-case measurement strategies will yield data that will only be of limited value for subsequent epidemiological studies. Lack of data for groups exposed to low(er) concentrations will hamper research that gains most from variability in average concentrations between groups or between individuals.

On the other hand surveys relying on measuring randomly selected workers on randomly selected days will in most cases provide all essential (statistical) characteristics of the exposure (except very infrequent occurring exposure situations) but at much higher costs. However, a few recent studies have shown that “self-assessment” can yield accurate data at much lower costs, since the involvement of the costly expert is restricted to designing and statistical evaluating the collected data (6-10). Of course restrictions are numerous and quality control and motivation of self-assessors will be of crucial importance, but it shows that measurement strategies involving randomly chosen workers and days can be carried out without skyrocketing costs.

Conclusions

Recent developments in instruments, measurement strategies and self-assessment approaches together with increasing knowledge of sources of exposure variability enables the exposure assessor to design more effective and cost-efficient measurement strategies. The time has arrived that we can design efficient measurement strategies that will keep us from being “penny wise but pound foolish”.

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The modern work-style – assessing exposures in future jobs

Härenstam A [(1)], Bodin L [(2)], Karlqvist L [(1)], Nise G [(3)], Schéele P [(3)] & the MOA Research Group.

[(1)] *National Institute for Working Life, Stockholm, Sweden, e-mail: annika.harenstam@niwl.se.*
[(2)] *Örebro Medical Centre Hospital, Sweden.*
[(3)] *Division of Occupational Health, Department of Public Health Science, Karolinska Institute, Stockholm, Sweden.*

Introduction

Over the last decades, working conditions have changed considerably. Working life is now characterised by an increasing degree of complexity and differentiation of working conditions within the work force (1). Population studies are particularly important at times of major change in order to identify new exposure patterns and inequalities in working conditions and health between groups. Established knowledge may no longer be valid and surveys may fail to ask the questions relevant to understanding the health-promoting and hazardous aspects. There is a need to develop analytic strategies for the identification of social settings as arenas for intervention. A person-oriented multidisciplinary strategy might be an alternative to a traditional risk-identifying variable-oriented approach (2). Other alternatives are qualitative explorative studies and multilevel analyses by combining data on individual as well as structural levels.

One aim of the present study was to develop a person-oriented, multivariate approach to occupational-health studies that is: (a) capable of identifying groups with similar conditions in contemporary working life; (b) relevant for studies of associations between work and health; and (c) an appropriate basis for preventive actions at a contextual level. In order to identify characteristics and early indicators of changes in modern working life, qualitative analyses of interviews and multilevel analyses on individual and organisational data, were performed. This presentation focuses mainly on the results of the person-oriented approach.

Methods

The study had a cross-sectional, exploratory, extended case study design. Eighty work sites and a sample of employees at each work site were chosen by means of a strategic selection process. In view of the exploratory objective– designed to obtain knowledge about contemporary working life (including new phenomena) – the study group of 102 women and 101 men is characterised by variation. The data were collected within an interdisciplinary Swedish study – the MOA Study (standing for Modern Work and Living Conditions for Women and Men: development of methods for epidemiological studies) – between 1995 and 1997.

Two methodological perspectives (internal and external) were adopted. Data at the individual level were obtained through external assessments, observations, interviews and questionnaires, and at the organisational level, through interviews with managers. In order to identify groups with small, within-group differences, cluster analysis was chosen as the most appropriate technique (3). The 32 chosen variables covered aspects of working and living conditions such as: supporting and straining psychosocial factors, ergonomic-physical and occupational-hygiene exposures, employment conditions, work/leisure balance, work location in time and space, and changes. The next step was to investigate whether the clusters congregated in specific areas of the labour market or types of organisations. Finally, the clusters were compared with reference to individual characteristics, such as demographic data, self-reported life-style factors and health.

Results

The final analysis produced eight clusters. Their characteristics are summarised in figure 1. Both new and well-known patterns were distinguished. The results illuminate the significance of structural factors, as the clusters were concentrated in different industrial sectors or social positions. The "boundary-less" cluster identified working and living conditions on the increase (4), particularly among well-educated, young employees. The "restrained" seemed to reveal and explain problems arising in the welfare services. The conditions in the "locked" cluster describe situations related to on-going privatisation, contract-work, and increasing use of information technology (5). The characteristics of the "changed" cluster fit well with other reports on the working conditions within lean organisations (6). The "exposed", "heavy and monotonous" and "mobile" clusters describe still frequent prevailing conditions, particularly in labour intensive work sectors.

Figure 1. Characteristics of the identified eight clusters.

Boundaryless; merging work and private spheres, time pressure, high mental work load, long work hours, little time for relaxation, imbalance between spheres, good physical work environment

Restrained; high psychological demands, many obstacles and lack of resources at work, deteriorated working conditions, straining domestic work, little time for relaxation

Changed; increasing responsibilities and demands, more work tasks, high physical and mental work load, many social contacts and conflicts at work

Decent; high control, supportive psychosocial climate, access to resources at work, seldom time pressure and overtime work, office work hours, good work/leisure balance

Exposed: chemical/physical exposures at work, physically demanding time-bound tasks, many superificial customer contacts, irregular work hours, many hours of domestic work

Locked; time-bound, repetitive work in awkward sitting positions, low support, small control possibilities, irregular work hours, many superficial customer contacts, many hours of domestic work, imbalance between spheres

Mobile; low mental and high physical demands, unregulated work hours, very physically and socially active leisure time

Heavy & monotonous; high physical demands, solitary, insecure work, few learning possibilities, passive leisure time

There were also differences between the clusters regarding demographic data, life-style factors and health. Working conditions seem to simultaneously develop along different lines in contemporary working life, as recognised by other researchers (1,7). The person-oriented analysing approach, and the qualitative analyses of interviews, helped to make conditions visible that seem to be important for health. Unsatisfactory ergonomic and physical/chemical working conditions, in combination with insecure positions and small possibilities for development, were congregated in the same clusters of employees. Furthermore, changeableness, work/leisure balance, and the opportunity of controlling work hours seem to be important factors for certain groups. Time-bound work in awkward positions and many customer contacts in combination with result monitoring, are examples of aspects worthwhile studying in relation to health.

Discussion

The study was performed at a time when epidemiological methods and analytic strategies were being debated and the term "risk-factor epidemiology" has been proposed (8). The strategies presented here are in line with a proposed development of a more socially oriented perspective. The relatively small study group and the cross-sectional design naturally limits generalisability. On large population samples, questionnaires are recommended by economic reasons, and the model based on only self-reported data, is now being tested. In order to investigate mechanisms involved in inequalities in health, a time dimension should be added. We do suggest, however, that the main characteristics of the clusters are representative of Sweden during the study period.

Conclusions

A person-oriented approach seems to reveal characteristic exposure patterns in contemporary working life. The combination of psychosocial, ergonomic-physical and occupational hygiene factors showed how these conditions are intermingled and, in combination, create settings with different risks of ill health. Finally, we conclude that a person-oriented, multivariate approach can be recommended for the identification of exposure patterns in the future as a complement to traditional risk-identification strategies.

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Validation of expert assessment of occupational exposures

Fritschi L [(1)], Nadon L [(2)], Benke G [(3)], Lakhani R [(2)], Latreille B [(2)], Parent ME [(2)], Siemiatycki J [(2)]

(1) Department of Public Health, University of Western Australia, Perth, Australia, linf@dph.uwa.edu.au
(2) Institut Armand-Frappier, Montreal, Canada
(3) Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Australia

Introduction

Assessment of occupational exposures poses difficulties in the community setting because the range of occupations encountered makes it impossible to carry out measurements in all settings. The expert assessment method (1) is considered to be the best available method of assessing exposures in community-based studies (2) but there been very little hard evidence of its validity. The present study was undertaken to examine the validity of occupational exposure assessment by raters.

Materials and Methods

The gold standards for the study were industrial hygiene measurements that had been carried out and recorded in a government database between 1978 and 1989 (3). A brief description of each of the monitored jobs was written up and these descriptions were used by three expert raters to allocate exposures. The raters received a sheet for each job containing the following information: job title, company, company address, a 5 to 10 word description of the main tasks, and a start and end date. There were 50 available monitoring results from 47 different subjects each of which were assessed for 20 different exposures. For each substance, for each job, the raters were asked how likely it was that the subject had been exposed to the substance, the frequency of exposure during a usual working week and the level of exposure (using the same criteria as for the monitored results).

Each of the 50 known monitoring results was compared to the rater's assessment. The rater was considered to be correct if he or she had stated that the correct substance exposure was possible, probable or definite in that job. Sensitivity was calculated as the proportion of correct responses over the total number of possible correct responses.

Results

The raters correctly stated that exposure was present in 45 of the 50 the monitored exposures with a mean sensitivity of 90%. If we discount exposures which were classified as 'possible' exposures, they allocated an average of 73% of the correct exposures.

About a third of the known exposures were allocated correct levels of exposure by the raters. There was a tendency to over-estimate level slightly with 35% of levels overestimated and 28% underestimated. Frequency of exposure was estimated correctly for half of the assessments, with about the same proportion of frequency ratings underestimated (26%) and overestimated (23%).

Other than the monitored exposures, there were an additional 466 exposures coded by the three raters, an average of 3.3 extra exposures per job. Raters allocated between 0 and 9 extra exposures per job. The extra exposures tended to be rated at lower frequency, level and confidence.

Discussion

This study has shown that the expert assessment method is a valid measurement of occupational exposures with a sensitivity of 90%. Each of the three individual raters had sensitivities higher than the mean sensitivity of 64% found in a recent study which used the same set of monitored jobs (3). In that study, the raters were experienced occupational hygienists or occupational physicians, who had not previously used the expert assessment method.

Under usual circumstances, the raters usually discuss their assessments between themselves. For this validation study we asked them to assess the jobs independently. Only two monitored exposures were missed by all three raters so it is likely that the usual panel approach would have increased the sensitivity of this method.

The job descriptions were minimal, with only a few words to describe the main tasks done by the worker. In the Siemiatycki method, a much more detailed work history is taken. In this current study, the raters were therefore working with much less information than they would have been provided with under usual circumstances.

The validity of expert assessments is likely to be different according to the mix of substances in the validation data set. However, we were unable to examine substance specific validity because of the small sample size.

The raters allocated an average of 3 to 4 extra exposures per job. In the previous paper by Benke et al (3) any additional exposures were considered to be incorrect. However, in our 'gold standard' jobs, monitoring had not been performed to confirm the absence of exposure. The jobs which were used in this study would have been monitored because of some concern about exceeding regulatory standards for one or two substances and not to ascertain all possible exposures in that job. We contend that the extra exposures allocated by the raters are relevant to epidemiologists who are interested in cumulative exposure. The extra exposures are probably less relevant to practicing occupational hygienists who are primarily interested in exposures which are present at high levels. In support of this argument, we found that 24% of the monitored exposures were rated at high level compared to only 6% of the extra exposures.

In conclusion, we found that experienced expert raters are able to give a valid assessment of community-based exposures. Because of their experience, they are able to identify exposures of interest to epidemiologists even when these exposures are not at a level which would justify monitoring by hygienists.

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Comparison of self-assessed and expert-evaluated exposure data for use in examining occupational risk factors for prostate cancer in a case-control study

Sass-Kortsak A[(1)], Purdham J[(1)], Bozek P[(1)], Kreiger N[(1,2)], Lightfoot N[(1,2,3)]

[1.] *Department of Public Health Sciences, University of Toronto, Toronto, Canada*
[2.] *Division of Preventive Oncology, Cancer Care Ontario, Toronto, Canada*
[3.] *Northeastern Ontario Regional Cancer Centre, Cancer Care Ontario, Sudbury, Canada*
email: a.sass@utoronto.ca

Introduction

Population-based case-control studies have frequently relied on self-reported questionnaire responses to provide occupational exposure data. More recently, using questionnaire data, expert evaluated semi-quantitative assessments (i.e. low, medium, high or definite, probable, possible) have been used. A case-control study examining occupational and other risk factors for prostate cancer, conducted in northeastern Ontario, Canada, provided an opportunity to compare these two methods.

Methods

Cases, aged 45 to 84 years, were identified through the Ontario Cancer Registry with a first primary cancer of the prostate diagnosed during the period of January 1995 to December 1998. Male population controls were age frequency-matched to cases. Cases and controls received a mailed questionnaire which sought to obtain a detailed occupational history. For each of their jobs (current and all previous, greater than 1 year in duration), each subject was asked to provide start/stop dates, job title, a description of both the job duties and the industry/employer, and use of protective equipment. In addition, for each job subjects were asked to indicate self-assessment of exposures (ever/never, frequency and intensity), for a selected list of workplace hazards, including dusts, metals/metal compounds, combustion products, diesel exhaust, asphalt fumes, welding fumes, lubricating oils/grease/oil mists, ionizing radiation, polychlorinated biphenyls, asbestos and sunlight at work.

Subsequently, a second, independent set of exposure variables was obtained through a process of expert judgement. An experienced occupational hygienist reviewed the occupational history component of each participant's file, blind to case/control status and all other information, and based on the job title, description and dates, ranked exposures to workplace hazards for intensity (low, medium or high, relative to current occupational exposure limits), frequency (daily, or less than daily) and exposure period (less than 2 hours/day, more than 2 hours/day). Workplace hazards included the materials described above, with the exception that metals and metal compounds were assessed individually by element (i.e. nickel, cadmium, chromium, lead and mercury) rather than in total, and PAH exposure was evaluated as airborne and skin contact separately.

2,390 subjects (756 cases and 1634 controls) with a total of 8,240 jobs were included in the analyses. For both the self-assessed and expert- evaluated exposures, a *Cumulative Lifetime Exposure Index* for each workplace hazard was derived by taking the sum of the product of intensity, frequency and job duration.

Results

Using the self-assessed exposures, statistically significantly elevated risks for prostate cancer were found for diesel exhaust (age-adjusted odds ratio (OR)=1.27, 95% confidence interval (CI)=1.02-1.58) and sunlight (OR=1.31, 95% CI=1.05-1.64) exposures. The age-adjusted ORs for PAHs, as the sum of diesel exhaust, asphalt, combustion products and lubricating oils/greases, approached significance (OR 1.21, 95% CI 0.98-1.50). Using similar analyses with the expert-evaluated exposures, sunlight was associated with a significantly elevated risk (OR 1.35, 95% CI 1.08-1.68), however, there was no elevation of risk for PAH exposures.

For the purposes of this report, direct comparisons were made between self- and expert-assessed exposures, for sunlight, PAH, and asbestos, hazards for which such comparisons could be readily made. The Pearson Correlation Coefficients for the *Cumulative Lifetime Exposure Indices* are presented in Table 1, calculated excluding those subjects for whom both the self-reported cumulative index and the expert-based cumulative index was zero. All correlation coefficients were statistically significant ($p<0.0001$)

Table 1: Pearson Correlation Coefficients

	n	R^2
PAH	1442	0.41
Asbestos	743	0.42
Sunlight	1347	0.68

To further examine the potential for misclassification, particularly at the extremes, the cumulative indices were classified as never, low and high, where the split between low and high was based on the median. For asbestos, there was 77% perfect agreement, with a weighted Kappa of 0.60 (Table 2). Of the 1461 subjects for whom the expert-evaluated cumulative exposure index was zero, 87 (6%) self-reported an exposure greater than zero. The expert-assessment indicated greater than zero exposure for 15% of subjects self-reporting no exposure. Conversely, of the 298 subjects for whom the expert-assessed index was high, 46% reported no exposure.

Table 2 Asbestos Expert- versus Self-Assessed Cumulative Lifetime Exposure

		EXPERT			
		0	Low	High	Σ
SELF	0	1374	172	79	1625
	Low	49	123	83	255
	High	38	63	136	237
	Σ	1461	358	298	2117

Using the same 3x3 tables for sunlight and PAHs, the weighted Kappa values were 0.73 and 0.42, respectively. Based on an expert-assessed exposure of zero, 14%, and 49% of subjects self reported greater exposures, for sunlight and PAHs, respectively.

Discussion

Although they were relatively small, risk estimates for prostate cancer were affected by the method used to determine exposure and, generally, fewer elevated risks were identified using expert-assessed exposures.

The correlations between self- and expert-assessed exposure indices were, not surprisingly, heavily influenced by the large number of subjects for whom there was no exposure assessed by either method (i.e. Expert = Self = zero). Disagreement increased in the higher exposure categories, with a tendency for self-assessed indices to be higher than expert. The highest degree of agreement between the methods was found with sunlight, likely because outdoor jobs, where sunlight exposure would occur, can fairly readily be distinguished from indoor jobs. Chemical exposures are more difficult to identify and quantify. Asbestos is a relatively well known hazard, while PAHs consist of a group of complex chemicals, not necessarily recognized by workers, perhaps explaining the poorer agreements found.

Conclusion

This study has demonstrated that there is some agreement between the two methods. Dichotomous exposure classification (Ever/Never) results in relatively good agreement between the two methods, indicating either could be used. However, this will not allow analyses of dose-response relationships and, therefore most studies would require semi-quantitative measures. The potential for misclassification of exposure appears to increase with the level of detail, and is also dependent upon the nature of the workplace hazard being considered.

Expert assessment: Inter-rater agreement in a multi-centre study

’t Mannetje A [1], Fevotte J [2], Fletcher T [3], Brennan P [1], Legoza J [4], Szeremi M [4], Brzeznicki S [4], Gromiec J [4], Ruxanda-Artenie C [4], Stanescu-Dumitru R [4], Ivanov N [4], Shterengorz R [4], Hettychova L [4], Krizanova D [4], Cassidy A [4]

[1.] *Unit of Environmental Cancer Epidemiology, International Agency for Research on Cancer, Lyon, France, e-mail: mannetje@iarc.fr.*
[2.] *Laboratoire de Médecine du Travail, Lyon, France.*
[3.] *London School of Hygiene and Tropical Medicine, London, UK.*
[4.] *Members of the exposure assessment teams of the participating countries.*

Introduction

One of the methods for retrospective exposure assessment in population based case-control studies, is the case-by-case expert assessment. In this method, a detailed job description, obtained from each study subject by an interviewer, is evaluated by one or more experts (e.g. industrial hygienist, occupational physician, chemist) following a standardized approach. An exposure code is assigned to a list of exposures of interest.

A multi-centre lung cancer case-control study using local experts for exposure assessment, offered a good opportunity to investigate the range in performance of experts, who were trained uniformly but worked independently. In particular we compared their inter-rater agreement. It also offered the possibility to compare the agreement between experts for different exposures and study the causes behind disagreement and how it could be reduced in the future.

Methods

The context is a multi-centre lung cancer case-control study, coordinated by the International Agency of Research on Cancer (IARC). The inter-rater trial included 8 centres, each with one to two experts: three centres from Slovakia, and one centre each from Russia, UK, Poland, Hungary and Romania. The trial was initiated in November 1999, after most of the experts had attended 3 centrally organized workshops, and had accumulated some experience in assessing exposure of their own study subjects.

The trial consisted of assessing exposures for 19 job descriptions from 6 study subjects from different centres, including frequently occurring jobs such as a painter, carpenter, machinist, welder, quarry worker, boiler operator, lathe operator and electronics fitter. For each job, the experts assessed exposure to a list of 70 occupational agents, for which three indices of exposure had to be assessed (confidence, intensity, frequency). All indices had a 3-point scale. Frequency indicates the proportion of the working week; intensity the estimated concentration relative to an agreed concentration in air; confidence the opinion of the coder of the likelihood of exposure: possible, probable, certain. Detailed benchmarks were included in the protocol to optimise equal interpretation of each scale by all experts involved in the study.

Results of the trial were analysed by using each job-exposure decision as a separate observation. Since 70 exposures could be assessed for each of the 19 jobs, a total of 1330 job-exposure decisions were made by each centre. Cohen’s kappa statistic was calculated for agreement on the presence of exposure, confidence, frequency and intensity. Agreement with a reference assessment (that of the main person leading the training workshops) was also calculated.

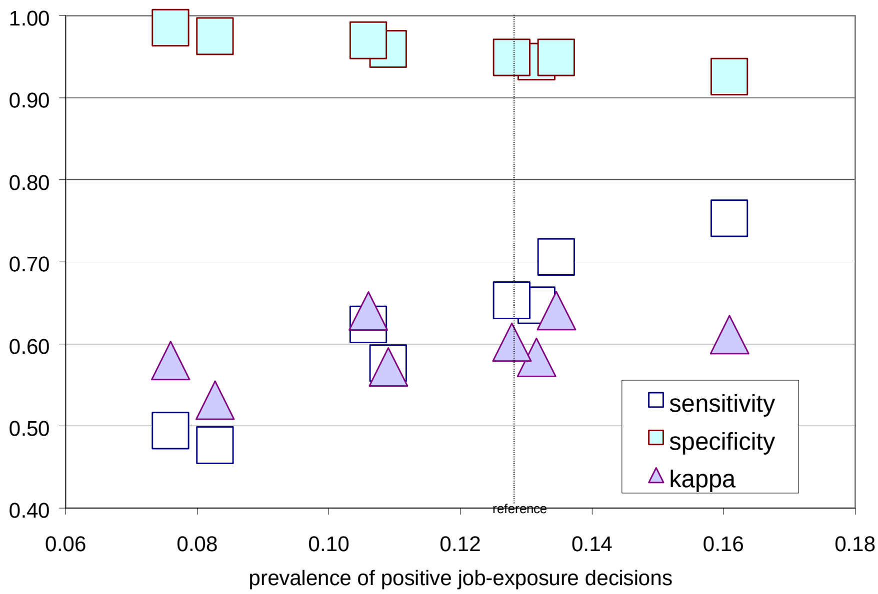
Results

The chance adjusted agreement between centres in presence of exposure (confidence 1/2/3=yes versus 0=no) is fair, indicated by a kappa of 0.55. In pairs, the agreement between 2 centres is always in the range of fair to good (kappa=0.45-0.63). The agreement in confidence of exposure was fair (kappa=0.45), mainly due to agreement in confidence 0 and confidence 3 assessments (kappa of 0.55 and 0.58). The agreement in frequency and intensity of exposure was lower (kappa=0.42 and 0.41).

By exposure, great differences were seen in agreement. For eight out of 70 exposures excellent agreement (κ>0.75) was achieved (arc and gas welding fumes, sand, wood dust, cement dust, diesel engine emissions, inorganic pigment dust and wood combustion fumes). For 16 out of 70 exposures the agreement was fair to good (κ=0.40-0.75), while for the remaining part of the exposures agreement was poor (n=15) or could not be calculated because it was not assessed (n=31).

For some exposures, low agreement appeared to have been partly generated by real

Figure I: *Measures of agreement with reference assessment, by centre*



differences in use of materials between countries (engine fuels, metal pigments, type of asbestos). When these exposures were excluded from analysis, overall agreement improved (κ=0.60). For some other exposures disagreement was partly generated by differences in interpretation of the protocol for exposure assessments (PAHs and respirable free silica).

It was also studied how far the experts diverge from a standard assessment done by the workshop leader. Figure 1 plots the different measures of agreement of each of the centres with the reference assessment, against the prevalence of positive job-exposure decisions. The 'reference' assessed a total of 170 exposures (out of 1330 job-exposure decisions), which can be expressed as a prevalence of positive job-exposure decisions of 0.13 (indicated by the dotted line in the graph). The prevalence of positive job-exposure decisions of the participating centres ranged between 0.08 and 0.16. Of the 170 exposures assessed by the reference, 48% to 75% were also assessed by the individual centres, as indicated by the sensitivity. The specificity was above 0.9 for all centres. The chance adjusted agreement (kappa) of each centre with the 'reference' for presence of exposure (conf 1/2/3= yes, conf 0=no) did not differ greatly between centres (between 0.53 and 0.64).

Discussion

When several experts work independently on exposure assessments in a multi-centre study, it is essential to train the experts according to a common protocol and evaluate their performance. In a multi-centre lung cancer case-control study the overall agreement between experts appeared to be good for presence of exposure, but only fair for intensity and frequency. As also seen in other studies, the agreement depended greatly on which exposure was assessed. The trial also pointed out some systematic differences in application of the guidelines between experts, and some true differences in exposure profiles of the same occupations between countries. Only a small part of the disagreement could however be due to this. The results of the trial can be used as an indication of reliability of the experts but also as a means to recognize in which areas the performance of the experts should be improved (e.g. intensity, frequency, some exposures).

Conclusions

Experts involved in a multi-centre lung cancer case-control study, showed fair to good agreement rates with each other and with a standard assessment. The range in performance of experts, who were trained uniformly but worked independently, appeared to be small. The trial pointed out that the uniform training of the experts was successful, but also highlighted some areas in which the performance of experts could be improved.

Retrospective exposure assessment and quality control in a multicentre nested case control study

Tinnerberg H [(1)], Heikkilä P [(2)], Huici-Montagud A [(3)], Bernal F [(3)], Forni A [(4)], Lindholm C [(5)], Wanders S [(6)], Wilhardt P [(7)], Bonassi S [(8)], Hagmar L [(1)] and the European study Group of Cytogenetic Biomarkers and Health

[1.] *Dep. of Occup. and Environ. Med, University Hospital, Lund, Sweden, e-mail: hakan.tinnerberg@ymed.lu.se,*
[2.] *Finnish Institute of Occup. Health, Helsinki, Finland,*
[3.] *Centro Nacional de Condiciones de Trabajo, Barcelona, Spain,*
[4.] *Dipt. di Medicina del Lavovro, Clinica del Lavoro "Luigi Devoto", Milan, Italy,*
[5.] *Finnish Center for Radiation and Nuclear Safety, Helsinki, Finland,*
[6.] *Dep. of Occup. and Environ. Med, Telemark Central Hospital, Skien, Norway,*
[7.] *Danish National Institute of Occup. Health, Copenhagen, Denmark,*
[8.] *Dep. of Environ. Epidemiology, Istituto Nazionale per la Ricerca sul Cancro, Genova, Italy*

Introduction

Cytogenetic biomarkers of genotoxic effects, such as chromosomal aberrations (CA), have been used in the identification of populations exposed to genotoxic agents. The underlying assumption has been that such biomarkers may not only reflect hazardous exposure but also predict the cancer risk for the exposed group. Recently, the European Study Group on Cytogenetic Biomarkers and Health (ESCH) updated cancer incidence and mortality data from a Nordic and an Italian cohort, and the analysis supported the cancer risk predictivity of CA frequency (1). One of the most important modifiers of the association could be exposure to carcinogens, related to an increase in both CA and cancer risk. To clarify this, a case-control study nested within the two cohorts was conducted. The study showed that exposure to occupational carcinogens or tobacco smoking did not modify the relative risk of cancer predicted by CA (2).

The aim of this paper is to describe the exposure assessment strategy used, how quality control (QC) was performed and the outcome of the QC.

Methods

The exposure assessments were performed by five occupational hygienists (OH), one from each country. Two independent OHs verified the reliability of the exposure assessment procedure. The exercise was divided into six steps:

1) The literature from the original cytogenetic studies were reviewed and a matrix comprising 24 exposure indices was constructed and criteria for exposure classification were established. The exposure assessments were semiquantitative (no, low, intermediate and high exposure) with the exception of three agents for which the subjects were classified only as exposed or non-exposed.

2) The cases and controls were identified. There were 93 incident cancer cases in the Nordic and 62 deceased cancer cases in the Italian cohort. For each case, four matched controls were selected. The total number of cases and controls was 582. The examination for CAs were performed between 1965 and 1990.

3) Data on the exposures were collected. Availability of information and best-fit procedures varied for the countries. The subjects or their next-of-kins were approached by a postal

questionnaire, followed by telephone interviews conducted by the OHs. Besides the questionnaires, information on the working histories and exposures were compiled from the companies, the original cytogenetic studies, medical records, interviews with co-workers, safety- and occupational health care personnel, and exposure data banks, when feasible.

4) In order to harmonise the occupational exposure assessments, a set of brief job descriptions, and assessed exposures were translated into English and sent to the independent OHs. Based on the descriptions, 27 subjects were selected for the harmonization of the criteria. The selection was done in order to cover as many agents as possible at various exposure levels. All exposure information for these subjects was sent to the five participating OHs and the exposures were assessed. Inconsistencies and borderline exposures were thereafter discussed at a meeting.

5) The occupational exposure was assessed, blind with respect to case-control status, from the year of finishing school until end of follow up.

6) Final assessments were submitted to a QC procedure. Fifty-five subjects were randomly selected, and their occupational histories were translated into English. The occupational histories included 193 unique exposure periods, and exposure status and level was assessed for 24 exposure agents in each period. A new period was defined as a change in exposure status assessed by at least one OH for at least one agent. Thus, each OH assessed the exposure status and level for altogether 4632 (193x24) period-exposure combinations. The assessments of the OHs for all 4632 combinations were compared to find the degree of agreement. Furthermore, the exposure of the subjects in the epidemiologic study was classified in three groups; 1) intermediate or high exposure to IARC group 1 carcinogenic chemicals; 2) other exposures defined in the matrix; 3) no exposure.

Results

For the majority (93%) of the period-exposure status combinations, all the OHs assessed that the subjects were not exposed (Table 1). The degree of total agreements on the exposure status was 95%. Out of 90 subjects assessed as exposed by all OHs, 49% were classified at the same exposure level. Out of the 222 periods whose exposure status were deviating, 69 % of the classifications where in the low exposure category.

Table 1. The number of agreements in exposure status by 5 OHs in the QC round.

No of OHs classifying period as exposed	0	1	2	3	4	5
No of combinations	4320	96	56	36	34	90

The classifications used for the epidemiological study, were restricted for the time period five years before CA-test. In this period, 33 out of 55 subjects were assigned the same exposure by all OHs. For 13 subjects one OH deviated, for 8 subjects two OHs deviated and for one subject were all three levels assigned. For 10 of the 22 subjects where at least one OH deviated on the exposure assessment, the original assessor was one of the OHs with another opinion then the others.

Discussion

In a first step an exposure matrix was constructed based on the exposures in the original cytogenetic studies. Exposure statuses and levels were estimated by using a quantitative definition of the boundaries of each category. There is likely to be less error and variation in the interpretations among raters when assigning a semiquantitative or quantitative estimate than when assigning an ordinal score (3).

The harmonisation was an important step. Several misunderstandings in the coding principles could be ruled out and further it resulted in more accurate definitions of exposure categories and cut-off limits. During the harmonisation it was also obvious that actual work practices differed between the countries, and identified occupations and situations that were particularly troublesome.

The degree of total agreements on the exposure status was high (95%). However, out of 312 combinations when at least one OH had assigned exposure, only about 30 % were assigned exposure by all OHs. There are several reasons for this dicrepancy, such as that the OHs have different experience and knowledge, but also that the information the assessment was based upon was translated into English, and all details originally obtained could not be written down. If the QC, instead of administrated only by e-mail, would have been performed as a round-table, several misunderstandings could have been avoided. However, when using the criteria for classification that was used in the epidemiologic study, 60% of the subjects would have been classified in the same exposure category of all 5 OHs. Furthermore, for almost half the number of the subjects where the assessments deviated the original OH was among the OHs with another opinion, indicating that he/she had more/other information or experince than the others.

Conclusions

A useful multicentre procedure with a harmonisation procedure for exposure assessment in nested case-control studies is presented. The QC procedure indicated that some of the inconsistencies in the assessments between the OHs were due to different level of information between the original OH and the others.

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Validation of the EASE expert system for dermal exposure to zinc

Hughson GW [(1)], Cherrie JW [(1), (2)]

[1.] *Institute of Occupational Medicine, Edinburgh, UK*
[2.] *University of Aberdeen, Dept. of Env. and Occ. Medicine, UK*
e-mail: graeme.hughson@iomhq.org.uk

Introduction

The EASE expert computer system was developed to assist exposure assessment for both new and existing substances. The model can be used to predict exposure both by inhalation and the dermal route using task and situation specific information about the substance and methods of control. The aim of this study was to measure typical dermal zinc exposures for a range of different industrial situations and compare the measured levels with the corresponding EASE predictions.

There are two principal criteria that are used in the EASE model to predict dermal exposure: the dermal contact level (possible values – *none, incidental, intermittent and extensive*) and the pattern of use (*closed system, limited use* – termed 'inclusion into matrix or non-dispersive use' in the model, and *uncontrolled release* – termed 'wide dispersive use.' The exposure predictions or 'end-points' can take one of five ranges, from 'very low' to 5 - 15 mg cm^{-2} day^{-1}.

Assessments of dermal zinc exposure were carried out in two galvanising factories, a zinc refinery and four factories producing zinc powder products. The tasks carried out at these factories could be categorised in terms of three different EASE exposure ranges or 'endpoints'.

Methods

Samples were collected using moist wipes. Recovery trials were carried out to determine the sampling efficiency of the wipe method by measuring the recovery of known amounts of zinc oxide and zinc dust applied to the skin of human volunteers. Control samples were collected from non-occupationally exposed individuals to establish a biological baseline or background level of environmental exposure.

Samples were obtained using three serially applied wipes to the palms, backs of the hands and forearms using a 25 cm^2 template pressed up against the skin. The three wipes corresponding to each anatomical area were bulked together to form a sample corresponding to a skin area of 25 cm^2. Samples were collected twice during the working shift and once at the end of shift. End of shift samples were also collected from the forehead, neck and chest.

Results

The swab sampling method had an average efficiency of 102 %, with individual recoveries ranging between 70 – 126%. The average zinc concentration on the hands of the control group was 0.6 µg cm^{-2}. This corresponds to a total mass of approximately 1.2 mg of zinc on the skin of both hands. The residual zinc concentration on the skin of non-occupationally exposed individuals corresponds to the practical detection limit for the method.

The tasks representing the lowest potential for exposure were within the galvanising industry and metal handling areas of the zinc refinery. These tasks were assessed in terms of EASE criterion as 'non-dispersive use with intermittent direct handling'. Tasks within the zinc powder products manufacturing industry were classified as ‘wide dispersive use’ with either intermittent or extensive direct handling. The measured dermal exposures for each of the scenarios are summarised according to the EASE classification and predicted exposure in Table 1, below.

Table 1 Comparison of predicted dermal zinc exposures versus measured exposures

EASE Category	Predicted range ($\mu g\ cm^{-2}$)	Measured range ($\mu g\ cm^{-2}$)	Geometric mean exposure ($\mu g\ cm^{-2}$)	GSD ($\mu g\ cm^{-2}$)	n
1	100 – 1,000	9 – 68	21	1.7	29
2	1,000 – 5,000	60 – 330	160	1.7	17
3	5,000 – 15,000	290 - 1,092	655	1.6	13

EASE category:
1 – Non dispersive use with intermittent direct handling (galvanising factory and zinc refinery)
2 – Wide dispersive use with intermittent direct handling (zinc oxide/zinc dust production – furnace/warehousing)
3 – Wide dispersive use with extensive direct handling (zinc oxide/zinc dust production – bagging/other dusty jobs)

Discussion

From these results it can be seen that EASE consistently over-estimated dermal zinc exposures, generally by an order of magnitude. However, as the EASE predictions increased so did the average measured exposures.

Validation of the sampling technique showed that sample recoveries could vary between 70 – 126 %. This implies the field measurements may be subject to measurement errors of about ±30%. Given the high level of variation in the manufacturing processes and the way individual operators carry out their work, it would appear to be sufficiently accurate for most purposes.

Higher dermal zinc levels were measured on the palms of the hands compared with the backs of the hands. The ratio of zinc concentrations on the palms to backs was approximately 3:1 using all of the available data.

The measurements of cumulative exposure by this technique are based on the assumption that concentrations of zinc will continue to increase indefinitely with time. In practice, the dermal zinc loading may of course reach a ‘steady state’ level early on and there may also be self-cleaning of the skin as contact is made with tools, surfaces and clothing.

Conclusions

The dermal exposure measurements were lower than the predicted levels generated by the EASE model. EASE consistently predicted dermal exposures that were too high, by about one order of magnitude. However, the EASE predictions increased in line with the measured exposures. The computer model was not principally developed to predict dermal exposure to dusts or powders and this may be the reason for the relative inaccuracy of the predictions. It is clear that further work is necessary to refine the EASE model in order to improve its reliability in these circumstances.

The dermal exposure results for the zinc powder manufacturing industry may be usefully extrapolated to estimate exposures in end-user applications or for tasks involving contact with other similar powdered substances. However, the exposed subjects did not perceive a risk from dermal contact with the zinc products, and although gloves were worn, these had little effect in reducing dermal exposures. The level of contact with more hazardous substances is therefore likely to be lower, due to behavioural and organisational factors resulting from increased risk awareness. Caution will therefore be required when using these data to estimate dermal exposures for other similar situations.

Dermal exposure assessment of non-volatile acrylates by tape sampling method

Surakka J., Rosén G. and Fischer T.

National Institute for Working Life, S-112 79 Stockholm, Sweden
e-mail: jouni.surakka@niwl.se

Introduction

Occupational skin exposure assessment to chemicals is an important issue of growing interest[1]. However, methods to measure dermal exposure to irritants and allergens, such as acrylates, have been lacking. Acrylates are reactive and biologically active, and well known as skin irritants and contact sensitizers. They are practically non-volatile and remain on the skin, clothes and other surfaces for a long time after deposition. Therefore dermal exposure to UV-coatings (ultraviolet radiation curable coatings), used widely in the wood working industry causes a significant potential risk for harmful dermal exposure at the workplaces. This paper describes some of the key points about the project that was performed to broaden our knowledge regarding dermal exposure assessment to acrylates.

Methods

Different non-invasive skin sampling techniques - surrogate skin (patch), removal (e.g., washing, wiping, scraping, brushing, tape-stripping), and fluorescent tracer techniques - were evaluated concerning their advantages and limitations for assessing occupational skin exposure to an acrylate compound in UV-coatings. Tape stripping method met the requirements set for a good method and was developed further. Various parameters were tested for their effect on removal efficiency of the two selected tracers on three different surfaces (Table 1).

Table 1. Parameters tested to find the best performing tape for measuring skin exposure to an acrylate compound.

Parameter	**Test surface**		
	Glass	Guinea pig skin	Human skin
Tested tapes (n)	12	9	2
Number of test (n)	3	6	4
Deposited dose (µl)	5	5, 2.5	1, 2 and 2.5
Deposition time (min)	20	1, 15, 30, 120	30
Sampling time (min)	1	0.5-2	2
Successive strippings (n)	2	3 or 2	2 and 1
Test compounds (n)	TPGDA	TPGDA	TPGDA and UV-coating

A quantitative gas chromatographic method was developed for analysis of TPGDA (*tripropylene glycol diacrylate*), a major constituent of UV-lacquers from the tape. A pilot study was performed to verify the suitability of the developed method for workplace measurements and to aid to plan a sampling strategy for the field measurements. Workers dermal exposure to UV-coatings was measured at three to four occasions during work-shift (Figure 1) at two different working days at seven workplaces employing the developed tape sampling method. Additionally, workers were interviewed at both measuring rounds to find out other factors related to risk for skin exposure. Statistical analyses were performed to test for differences between two independent samples and to compare the mean exposure levels between groups.

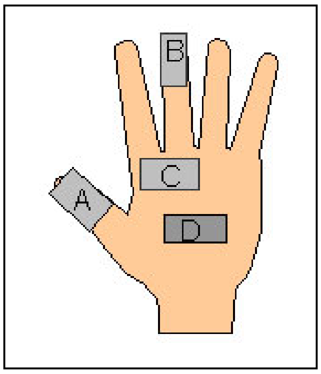

Figure 1. Sampling points for measuring dermal exposure to an acrylate compound. Point D is on the dorsum of the hand. Each skin site was sampled with a single tape-stripping. Additional sample from the middle of the forehead was collected at the end of the work shift.

Results

Several variables affect removal efficiency of a contaminant, such as the type of adhesive layer and tape, applied dose, deposition time on the skin, tape adhesion time, and the number of tape strippings. Fixomull®- tape was the best performing tape and a single sampling with it removed 85% of the TPGDA and 63% of the TPGDA in UV-coating at exposed skin sites with good accuracy[2].

Skin exposure was found on 16 of 23 workers at 6 of the 7 workplaces, and from 36 (5.4%) of the 664 samples taken from the hands and the foreheads of the workers. Skin contamination could be found from all the measured skin sites and at all measuring moments during the work shift. The average TPGDA mass on the positive skin samples (n=36) was 30.4 µg and for the first and second round it was 30.6 µg and 28.3 µg, respectively.

No statistically significant differences were found at skin contamination levels within two distinctive worker groups – controllers, who handle acrylates frequently during work shift, and the other workers.

Based on the questionnaire on average 79 % of the workers had found UV-coatings from their skin more than once within a week. Working clothes had been found to be sticky due to contamination with UV-coatings at 45% of the cases[3].

Discussion

Several variables affect dermal exposure and therefore the method to be developed for measuring purposes have to be selected based on the properties of the specified chemical. Factors such as vapour pressure, lipid/water solubility, exposure time and behaviour of the substance on the nonviable epidermis (stratum corneum) can guide the scientist. Type of industry or occupation as well as work tasks are factors that can also affect the selection of the method – i.e. the sampling should not take too long time. To find the optimal tape for measuring skin exposure several critical factors have to be considered and tested of which removal efficiency is of great importance[2].

Several factors were found to impact on workers dermal exposure to the studied acrylate compound, such as job activities, work experience, personal habits and hygiene, use and type of protective measures as well as attitude towards them, type of operation, and engineering of the workplace[3].

Study design and sampling strategies play important role in order to map the actual dermal exposure and in order to be able to incorporate statistical methods to aid in dermal exposure assessment.

Conclusions

For industrial chemicals, no substantial data on dermal exposure are available. The large number of samples collected from the skin together with questionnaires to the workers provides detailed information about the workers dermal exposure to acrylates. This study provides the first overview of the dermal exposure in wood working industry, indicating that skin exposure happens on a daily basis and that there is a risk for harmful skin exposure which may lead to allergy.

From the results could be concluded, that the developed tape sampling method is well fitted for screening purposes – both at high and low levels of contamination and in different occupational settings.

The tape sampling method provides a powerful tool to quantitative assessment of skin contamination to acrylates. Tape sampling is applicable for investigation of skin contamination to many compounds with low vapour pressure, but need to be validated for each purpose.

There is great need to develop dermal exposure assessment methods for other industries and occupations where harmful dermal exposure takes places[4]. Further studies are warranted to develop methods for monitoring skin exposure to other allergens and hazardous compounds, such as oxidative hair dyes known to cause significant skin problems (hand eczema) among hairdressers.

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Quantification of naphthalene dermal exposure using non-invasive tape stripping of the stratum corneum, extraction, and normalization against keratin

Nylander-French L.A., Lacks G.D., Mattorano D.A.

Department of Environmental Sciences and Engineering, School of Public Health, The University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA.
leena_french@unc.edu, gregory_lacks@unc.edu, dfm7@cdc.gov

Introduction

Dermal exposure to hazardous chemicals in the workplace is an important occupational hygiene issue and a growing field of interest to health professionals in both occupational hygiene and dermatology. Methods developed to measure the quantity of chemical contaminants deposited directly on the skin under occupational or experimental conditions include the use of passive exposure patches, clothing, skin swabs, liquid rinses, and tracers. While these direct methods for measuring dermal exposure provide information on the mass of a chemical contaminant that has been deposited on the skin, they fail to relate the amount of contamination on the skin to the amount actually absorbed into and through the skin and consequently made available for the uptake by the body (total body dose). We have further developed and evaluated a non-invasive tape stripping method of the stratum corneum using adhesive tape to determine the amount of naphthalene as a marker for dermal exposure to jet fuel.

Materials and Methods

Two sites on the ventral surface of each arm (four sites total) on 22 subjects (11 females and 11 males, age 33 ± 9 years) were exposed to 25 µl of jet fuel (JP-8). There were four sites corresponding to 5, 10, 15, or 20 min of JP-8 exposure. For all subjects 5- and 10-min sites were on the right arm and the 15- and 20-min sites were on the left arm. A control tape-strip sample was collected from an unexposed site on each wrist for GC/MS. Five sequential tape-strip samples from an unexposed site were collected from 12 individuals for keratin analysis. In addition, keratin samples (five sequential tape strips) from sites exposed to 5, 10, 15, or 20 min of JP-8 were collected from three individuals. JP-8 was applied neat, nonoccluded, using a mircopipette and the application chamber. After the desired exposure time elapsed, adhesive tapes (Cover-Roll^{TM}, Beiersdorf AG, Germany), precut to 2.5 cm × 4.0 cm, were applied to the exposed site and removed after a two-minute adhesion time. The samples were extracted with 5 ml of nanograde acetone containing 20 µl of 25 µg/ml naphthalene-d8 as an internal standard and analyzed by chromatography/mass spectrometry.

The amount of keratin protein was determined from separate samples, collected in a similar manner as the samples for naphthalene analysis, by extracting the samples in a buffer and quantified using a modified Bradford Method (Amresco^{TM}, Solon, OH). A standard curve was obtained using human keratin (Sigma, St. Louis, MO). Confirmation of the extraction of keratin was verified by western blotting using a monoclonal mouse anti-human cytokeratin antibody (Dako^{TM} Corporation).

The study was approved by the Institutional Review Board on Research Involving Human Subjects, School of Public Health, the University of North Carolina at Chapel Hill.

Results

The average amount of naphthalene collected on the first tape strip at the 5-min site was 21,550 ng (12.4 µl JP-8) and decreased to 242 ng (0.14 µl JP-8) at the 20-min site. The average amount of naphthalene collected on the second tape strip decreased from 147 ng (0.08 µl JP-8) to 22 ng (0.01 µl JP-8) from 5 to 20 min. The total amount of naphthalene collected with two sequential tape strips ranged from 21,697 ng at the 5-min site to 265 ng at the 20-min site. There was no significant difference between males and females, age, ethnicity, or skin pigmentation at the significance level of 0.05.

For unexposed sites, the average amount of keratin removed by the tape strip varied from 44 µg for the first tape strip to 22 µg for the fifth tape strip. The amount of keratin removed by a tape strip decreased with sequential tape stripping. There was a no significant difference in the removal of keratin per tape strip between sex, age, ethnicity, or skin pigmentation at the significance level of 0.05. For the exposed sites, the average amount of keratin varied from 43 µg for the first tape strip to 22 µg for the fifth tape strip. There was a no significant difference in the removal of keratin per tape strip between the different exposure times at the significance level of 0.05. The correlation between the removal of keratin per tape strip from unexposed and exposed sites was 0.6 for the first tape strips and 0.9 for the second tape strips.

Discussion

After a single tape stripping from the stratum corneum there was a rapid decay and/or removal of naphthalene after a single exposure of compound over a twenty-minute exposure. A second tape strip demonstrated subsequent penetration of the stratum corneum by naphthalene. Although no significant differences were observed by amount of keratin removed with samples evaluated thus far, larger population studies may show factors which might influence the amount of stratum corneum removed via tape stripping.

The techniques developed may have a wide range of applications from determining the actual amount of compound absorbed into the skin, assessing exposure in field studies, development of better models for the prediction of exposure, and determining risk. In addition, normalization of a tape-strip sample against keratin may prove to be required for future determination of keratin adducts per unit amino acid residues.

A new sophisticated method to evaluate liquid contamination by using fluorescence tracer

Ojanen K[(1)], Vanne A[(2)], Makinen M[(1)], Karjalainen P[(2)]

[1.] *Kuopio Regional Institute of Occupational Health, Kuopio, Finland, e-mail: Kari.Ojanen@occuphealth.fi*
[2.] *University of Kuopio, Department of Applied Physics, Kuopio, Finland*

Introduction

Traditionally contamination, especially skin contamination has been evaluated during work operations by three different methods:

1. By fixing tags of fabric or special paper to the object studied
2. Taking samples directly from the surface studied
3. Using fluorescent whitening agent, FWA

While using the tags there is a supposition of even amount of the studied agent on the larger area around each tag. On the other hand tags can be fixed onto such places where the contamination is supposed to be greatest, and thus get the estimation of worst possible contamination. This method is, however laborious and needs always chemical analysis.

The sample can also be taken directly from the surface studied, for example the contamination of hands can be studied by washing hands using water-alcohol mixture and by wiping from the other parts of e.g. body. The method how to wash the hands is also standardised. This method also supposes that all 100% of the agent can be washed and wiped from the surface.

Some agents which are wanted to be studied are fluorescent by themselves. In that case if we want to estimate how great the contamination of some surface is, we need only fluorescent light and a calculation method to evaluate the amount. However, most of the liquids of interest are not fluorescence. Therefore FWA must be added to the liquid in interest.

Some methods to use fluorescence tracer to evaluate contamination have been introduced since 1989 (e.g. Fenske et al.) but these methods and equipment are quite expensive, not suitable for field studies and the error of the estimation has been reported to be even $\pm$70%.

New method

The goal of our project was to develop a new method using FWA. It should be portable, sheep, and fast to use. It means that the equipment should be as simple as possible and the calculation method to estimate the contamination should be able to compensate the simple equipment. At the beginning of the project the minimum demand was to be able to calculate the area contaminated, but soon we found out that also the amount of the tracer could be calculated quite reliably.

The hardware of the system consists of two ultraviolet tube lamps, digital camera (3,4 megapixels resolution) and an effective PC computer. The software has been done by using Matlab® application software.

The area which is illuminated by only two lamps is not even. It means that the intensity of the same tracer spot is different in different places of the illuminated area. Therefore, the effect of the uneven illumination must be corrected by calculation. The calibration of the illuminated area is done by taking digital pictures of known tracer spot in different places of the illuminated area and then calculating a correction surface for the area. In fact, this means that we can use many kind of illumination conditions in this method, if needed. Including this illumination calibration we also need dimension calibration. It is done simply by marking to the illuminated area a known unit of measure.

Digital camera divides the picture into pixels, in our case into 3,4 million pixels. Adding together the number of the fluorescence tracer pixels in the picture we get the contaminated area. The intensity of the fluorescence tracer spot is also not even. So, every pixel in the tracer spot area can get a different intensity value according to how much fluorescence tracer there is. Adding together these intensity values the amount of the FWA can be calculated also.

In the taken picture of the studied surface can be some other than fluorescence tracer spots. These not interesting spots or areas must be eliminated from the picture before calculations. All colours can be divided into three components, red, green and blue (RGB). We did use as a contamination surface pure white cotton (cotton is the most common material of overalls used at worksites). In our case, we found that when using the green component of the picture taken from the contaminated white cotton fabric, even if there were other than tracer spots (e.g. dirt, used oil...) the tracer spot could be thresholded very effectively from the background. The other possibilities in our software is to use other two (red or blue) colour components or grey scale thresholding.

Results

In the laboratory experiments several tests were done by using different spot volumes. Also blindfold tests were done so that the person who made the measurements did not know the volumes of the spots. In these tests the relative error was less than 10%.

One demand for this system was to be able to use it in field conditions. So, in summer 2000 we installed the lamps into a van, installed the program into a lap top computer and used the system in a study "Exposure to and health effects of chemical and biological agents in mechanical wood harvesting". The FWA was mixed into the harvester chain oil and pesticide tank, respective. The operator was dressed by a white cotton overall. After the working period the overall was undressed and hanged evenly on to the illuminated area of the lamps. The photos were taken and the analyse could be done in some minutes.

Conclusions

The analysing system proved to be accurate enough. It also fulfils the demand of the standard EC 91/414. It is easy to use and the whole system proved to be very easy to use also in the field conditions, even in forestry.

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Use of previously constructed exposure models of physical workload and upper extremity musculoskeletal symptoms in women and men

Smith KF [1,2], Flowers L [2]

[1.] *Innovative Clinical and Consulting Services, Atlanta, Georgia, USA, email: ksmith@bellsouth.net*
[2.] *Emory University, Atlanta, Georgia, USA, email: lmflowe@hotmail.com*

Introduction

Exposure modeling of risk factors for musculoskeletal disorders of the upper extremities allows for possibility of defining the multifactorial dimensions of exposure, or the inclusion of multiple variables into an index. Modeling can be based upon *a priori* definitions (1), pathomechanisms (2, 3), or statistical methods (4, 5). Factor analysis is a technique used to understand the relationship of the structure of variables (6).

It is the aim of this study to use previously defined exposure models and to assess the association of musculoskeletal symptoms of the upper extremities. The two exposure models were defined using factor analysis. The first index is labeled 'physical work load' and was constructed by Torgén using this same data set (7). The second index was constructed by Ostlin to assess physical strain at work (8).

Materials and Methods

Subjects. The study group consisted of 225 females and 211 males below the age of 59 years in 1993 (4). Exposure. The PWL (physical work load) index was divided into three exposure levels, separately by gender. The PSAW (physical strain at work) index was divided into four exposure levels. Both indices were based on the subject's work in 1993. Outcome. Data concerning regional musculoskeletal symptoms in the upper extremities using the Nordic Musculoskeletal Questionnaire (NMQ) were collected and included the elbow and hand/wrist. The reports of symptoms at twelve months and in the last seven days were used (9). Three upper extremity diagnoses were constructed based on the report of symptoms by interview and physical examination. The three diagnoses were Carpal Tunnel Syndrome, Epicondylitis and Tendinitis. Statistical Analysis. All data were analyzed using SAS v.6.12. The prevalence of musculoskeletal symptoms in the upper extremities were studied and prevalence rate ratios (PR) and 95% confidence intervals (c.i.) were calculated.

Results

The one-year prevalence of symptoms was higher than the one-week prevalence for both body regions (elbow: 22.5% vs. 10.8%, hand/wrist: 24.3% vs. 10.3%, respectively). Symptoms were generally higher in women than in men. The highest prevalence among the diagnoses was Epicondylitis (10.3%), followed by Tendinitis (4.8%) and Carpal Tunnel Syndrome (4.5%). All diagnoses were more prevalent in women than in men. Table 1 presents PR and c.i. for each exposure model and regional musculoskeletal symptom. Table 2 presents PR and c.i. for each exposure model and diagnosis.

Table 1. Prevalence ratios and 95% confidence intervals for regional musculoskeletal symptoms based on exposure modeling.

	Elbow		Hand/Wrist	
PSAW	12 months	7 days	12 months	7 days
Low	1.00	1.00	1.00	1.00
Low-Medium	1.29(0.83-1.98)	1.09(0.56-2.15)	1.26(0.84-1.89)	2.22(1.04-4.71)
High-Medium	1.42(0.86-2.34)	1.90(0.97-3.70)	1.02(0.61-1.72)	2.73(1.24-6.01)
High	1.38(0.80-2.39)	0.78(0.28-2.20)	1.19(0.70-2.03)	3.41(1.56-7.45)
PWL	12 months	7 days	12 months	7 days
Low	1.00	1.00	1.00	1.00
Intermediate	1.06(0.65-1.73)	0.99(0.46-2.13)	1.05(0.66-1.67)	1.59(0.64-3.96)
High	1.76(1.16-2.67)	1.80(0.94-3.43)	1.60(1.07-2.39)	3.64(1.74-7.61)

Table 2. Prevalence ratios and 95% confidence intervals for musculoskeletal diagnoses based on exposure modeling.

PSAW	Carpal Tunnel Syndrome	Tendinitis	Epicondylitis
Low	1.00	1.00	1.00
Low-Medium	2.68(0.90-7.99)	0.85(0.21-3.41)	1.06(0.49-2.30)
High-Medium	1.76(0.44-7.11)	2.14(0.72-6.40)	1.69(0.78-3.65)
High	2.25(0.57-8.92)	3.33(1.19-9.29)	2.36(1.14-4.89)
PWL	Carpal Tunnel Syndrome	Tendinitis	Epicondylitis
Low	1.00	1.00	1.00
Intermediate	6.52(1.13-37.55)	1.71(0.40-7.27)	1.20(0.56-2.57)
High	9.93(2.04-48.32)	4.32(1.39-13.42)	1.80(0.91-3.55)

Discussion

Both exposure indices were associated with symptoms and diagnoses of musculoskeletal symptoms of the upper extremities. The PSAW index was more consistently associated with both types of outcomes. In many cases, the results suggested a dose-effect relationship. In a previous study by Ostlin, musculoskeletal disorders were studied as a group and there was a greater prevalence of these disorders in the higher exposed group (10). The PWL consistently demonstrated an association at a higher exposure level. The associations were stronger than in the PSAW index, and greater when based on diagnosis rather than symptoms.

The use of factor analysis as an exposure modeling method is well established. Two exposure indices previously constructed using factor analysis were used in this study. These indices have not previously been applied in studying regional musculoskeletal symptoms and disorders of the upper extremities. In many epidemiologic studies of musculoskeletal disorders, the researcher is confronted with the issue of modeling physical exposure. Often, these exposure models are not reapplied in subsequent studies or in different settings. This study demonstrates the potential for utilizing findings of other researchers in similar or new settings.

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Force as an agent: exposure analysis in ergonomic epidemiology

Wells R [(1)] and Van Eerd D. [(1)]

[1.] *Department of Kinesiology, Faculty of Applied Health Sciences, University of Waterloo, Waterloo, ON, Canada, e-mail: wells@healthy.uwaterloo.ca*

Introduction

The term "exposure" has suffered from inconsistent and confusing usage in many fields including environmental and occupational health sciences (6). The concept of ergonomic exposure has also been difficult to define. There have, however been a number of ergonomic or physical exposure models presented (1, 2, 5). The aim of this paper is to present a model that addresses current concerns about exposure, unifies a variety of physical/ergonomic exposures and includes the concept of human behaviour.

Ergonomic Exposure Terminology

To avoid adding to the confusion about exposure terminology we will explicitly define our terms prior to describing our model. When possible we will use terms and definitions from the exposure analysis literature (6). The concept of *exposure*, in the most direct sense, involves the contact between an agent and a target. In our proposed model, (see Figure 1) we consider the target to be biological or human tissue(s) and the agent to be force. *Environmental source* we define as any physical entity (including gravity) that a worker comes in contact with. *Human contact* therefore is any and all contact between the worker and the environmental source(s). The behavioural concept of *work strategies* is defined as the 'way' a worker chooses to perform tasks that involve contact with environmental sources. We can refer to *potential dose* as the amount of agent potentially available to interact with the target. *Transmission and transformation* refers to the transfer of the agent (force) through various tissues to the target and any changes that may occur during this transfer. The concept of dose involves the quantifying the interaction of the agent and the target, which we will call *internal dose*. *Injury mechanisms* are any processes that result in tissue damage as a result of the agent's interaction with the target tissue. *Effect/biomarker* refers to any observable outcome of the injury mechanism(s). *The natural history of the disorder* represents any and all processes that perpetuate the disorder to a point where it is recognisable and *early expressions of injury* can be observed. *Health outcomes* are the actual diagnoses of the injuries.

Ergonomic Exposure Model

The proposed model is described in a manner that is consistent with inhalation, dermal and ingestion exposure models, (3, 6). The model focuses on a single agent: force. While force may not be the only agent in ergonomic epidemiology we suggest it is key (4). Therefore by definition there can be exposure if there is human contact with something in the environment which results in force(s) on the target(s). That something could be a weight to be lifted, a chair to sit in, a computer mouse to manipulate, or a vibration from a hand held tool or simply gravity. It may even be that the majority of force is produced solely from within the target when contact is made with a computer mouse or keyboard, Table 1.

The proposed model allows discussion of a wide range of physical exposures including hand arm and whole body vibration, manual and office work scenarios.

Table 1. Two Examples of Ergonomic Exposure Processes and Indicators

Environmental Source*	**Job /task description**	**Work strategies**	**Human contact(s)**	**Transmission/ Translation +**	**Injury mechanism(s) N=1…, n**	**Natural History of Disorder**	**Health outcome**
Boxes (masses)	Lift *x* masses within environment	Work steadily, no gloves, squat, not stooped, posture	Hand applies forces to box handles	Forces acting on articulations estimated using a dynamic biomechanical link segment model.	Trabecula e buckling and failure of endplate	Breakdown of tissues, inflammato ry response, repair processes	Dx of chronic LBP
Mouse in VDT Office	Use VDT to perform specified tasks with a graphical interface	No arm rests or wrist rest present	Grasp mouse	Forces (moments) at major articulations and resulting internal muscle pressures	Reduced perfusion of muscle	Breakdown of tissues, inflammato ry response, repair processes	Dx of Trapezius myalgia

Potential contact	***Behaviour (Observed work style)***	***Potential dose#***	***Internal dose on target#***	***Effect / biomarker***	***Early expression of injury***
Weight and repetition	Weights lifted frequency of lifting , postures used …	Force applied to hand	Force acting on L4/L5 *Target*= L4/L5 motion unit.	Breakdown of endplate inferred from imaging of disc	LBP
Mouse use for *x* hours day	Posture, mouse position (reach), use of supports...	Force applied to hand	Intramuscula r pressure *Target*= Trapezius	Moth -eaten and Ragged Red Fibres in Trapezius	Neck/ shoulder pain

*Work occurs in a gravitational field.
+Includes the modifying effect of posture.
Including time variation pattern.

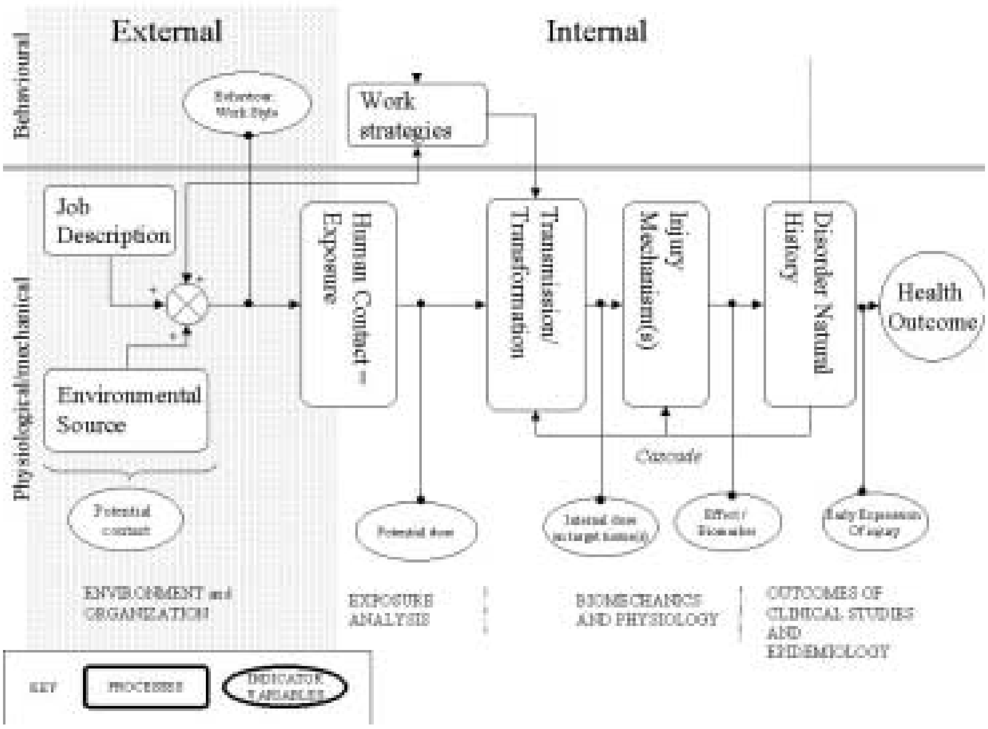

Figure 1. An ergonomic exposure model, details explained in the text.

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Levels of job routinization and implications for exposure assessment

Park J-S [(1)], Punnett L [(1)], Wegman DH [(1)]

[1.] *Department of Work Environment, University of Massachusetts Lowell, MA, U.S.A; e-mail:buddha@enteract.com*

Introduction

The estimation of occupational exposures requires valid estimation of both task duration and task-specific exposures. Exposure assessment becomes more complicated as the number of tasks increases and as the exposures within each task fluctuate more over time. We propose that these two features of a job determine the "job routinization level." To characterize a job in these terms, the analyst needs to determine, first, whether a worker performs one or multiple tasks; and second, whether the tasks involved are routine or non-routine. A task is here referred as "routine" when it is performed regularly and has no or few variable work elements, so that the frequency of occurrence, total work cycle (task duration), and type and intensity of stressors (task exposure) are all relatively constant. "Non-routine" tasks may entail variability in either task frequency, duration, or task exposure; there may even be a significant proportion of time in-between tasks. The aim of this paper is to present a classification system of the continuum of routinization in modern work that can guide the development of exposure assessment strategies.

Methods and Study Population

A fixed cohort of about 1200 automobile manufacturing workers has been under follow-up since 1992 (1) to study upper extremity musculoskeletal disorders and ergonomic exposures. At baseline, occupational exposure to ergonomic stressors was assessed both by interview (psychophysical items used to construct a primary exposure index) and by direct observation with a standardized checklist. The checklist was designed for analysis of tasks with relatively fixed frequency and duration, and with the assumption that the work cycle could be observed multiple times as needed to capture each exposure dimension. Jobs with multiple routine tasks were handled by computing time-weighted average exposures. About 10% of the study subjects were not observed because their work was highly variable (table 1). At the one-year follow-up, psychosocial strain was assessed with the Karasek-Theorell Job Content Questionnaire (JCQ).

At the six-year follow-up, preliminary observations and discussions with plant personnel showed that substantial changes in production technology had occurred, with attendant work re-organization. Previously most of the cohort members had held highly routinized jobs, which were relatively easy to analyze using the checklist for assessment of (each) short-cycle task. However, a large number of subjects were now employed in jobs with more varied tasks and content. It became clear that the previous checklist would no longer serve for the entire range of jobs from classically routine (short cyclic) to extremely non-routine, such as the tending of automated processes.

Using the criteria of task frequency and duration and task-specific exposures, we developed a set of five categories of routinization that cover the possible combinations of routine and non-routine tasks within any given job (table 1). A second checklist and sampling strategy were developed for non-routine tasks, involving the analyst's integration of multiple elements of a long task (2) so that all observations could be made during a single performance of the task.

Table 1. Automotive workers observed at baseline and six years, by routinization level

Routinization Category	1992: # workers (%)	1998: # workers (%)
1: single routine task	318 (50%)	142 (19%)
2: multiple routine tasks	251 (40%)	142 (19%)
3: mix of routine and non-routine tasks	-	150 (20%)
4: single non-routine task	-	148 (19%)
5: multiple non-routine tasks	-	185 (23%)

The routinization categories were developed to guide job analysis, not necessarily as indicators of exposure. However, there was a trend of increasing job control, as defined by the JCQ scale, with increasing level of routinization (table 2).

Table 2. Change in ergonomic exposure index (psychophysical data, range 0-25) from baseline to 6-year follow-up, and psychosocial characteristics (mean ± standard deviation), for automotive manufacturing workers surveyed in 1992 and 1998.

Routinization category	Number of subjects	Change in ergonomic exposure index	Psychological demands	Job control
1	92	- 0.4 ± 6.3	51.6 ± 4.3	58.7 ± 8.5
2	81	- 2.5 ± 4.9	51.9 ± 4.4	59.6 ± 9.6
3	117	- 1.3 ± 5.3	50.5 ± 4.4	64.4 ± 8.7
4	87	- 2.4 ± 6.4	50.2 ± 4.0	65.5 ± 7.6
5	101	- 3.8 ± 5.9	49.2 ± 4.6	67.2 ± 10.0

Discussion and Conclusions

The data obtained have some important limitations. Ergonomic analysis of non-routinized jobs was time-intensive and not all jobs were fully observed, especially where there were occasional (but high-exposure) tasks. In particular, non-routine tasks, because they vary from one occurrence to another, must be observed more than once. However, since their occurrence is not always predictable, this can require the analyst to spend a substantial amount of time on the shop floor waiting for these tasks to be performed. Thus it was logistically difficult to observe infrequent and unpredictable tasks. Although the goal was to generate comparable data for these jobs, calculation of a UE ergonomic exposure score for jobs with non-routine tasks (categories 3, 4, and 5) still requires extensive data management. If the historical developments in production technology could have been predicted in advance, we could have utilized at baseline a checklist and a sampling strategy with broader applicability that were less dependent on short-cycle work organization.

Increasingly, job rotation and tending of automated equipment produce complex work organizations, in industry and service sectors. For estimation of occupational exposures, it is important to employ a methodology and sampling strategy appropriate to the job routinization characteristics of a study population. This requires advance evaluation of both the number of component task(s) and the routineness of the task(s) in each job. It is recommended that researchers explicitly characterize their study population in terms of job routinization level in order to design an appropriate ergonomic exposure assessment effort.

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Past and present vibrating tools use at work and the association with symptoms of hand-arm vibration syndrome in women and men

Flowers L (1), Smith KF (1,2).

[1] *Emory University, Atlanta, Georgia, USA, email: lmflowe@hotmail.com*
[2] *Innovative Clinical and Consulting Services, Atlanta, Georgia, USA, email: ksmith@bellsouth.net*

Introduction

Hand-arm vibration syndrome (HAVS) is clinically defined as episodes of vasospasms producing blanching, feeling of numbness and cold in the distal extremities (1). This syndrome can produce changes in the vascular, neurologic, and osteoarticular systems and has been associated with workplace exposure to prolonged use of vibratory tools and repetitive hand trauma (1-3). The National Institute of Occupational Safety and Health estimated that 1.2 million Americans have vibration exposure, and that in selected populations symptoms of HAVS may be highly prevalent (3).

In epidemiologic studies of workplace associated musculoskeletal disorders, exposure assessments usually assume the exposure closely precedes the onset of the musculoskeletal disorder. In the case of HAVS, it has been suggested that the exposure has occurred over a long time period (4). Little is known about the association of cumulative years of risk factor exposure and HAVS, particularly in the general population (5).

The aim of this study is to assess the prevalence and association between cumulative exposure to vibration and associated symptoms of HAVS among the general working population of Stockholm County, Sweden.

Materials and Methods

Subjects. The study group consisted of 224 females and 211 males below the age of 59 years in 1993 (6). Exposure. Data include the present time, 5 and 10 years ago, and were based on reports of “work with hand-held vibrating tools” using a continuous visual analog scale. The cut-off point for potential high risk was set at 40% or more of the time. Outcome. Data concerning present symptoms of HAVS during the last 12 months for at least 7 days in a row (unusual weakness or fatigue; hands falling asleep, loss of feeling or tingling; finger(s) turning white when exposed to cold or moisture) were collected by interviewing the subjects. Confounders. Age and the psychosocial variable work engagements were examined as potential confounders. Statistical Analysis. All data were analyzed using SAS v.6.12. The prevalence of HAVS symptoms were studied and logistic regression was performed in order to simultaneously adjust for age and work engagements. Resulting odds ratios were converted to adjusted prevalence ratios (aPR) using a binomial model with a logarithmic link (PROC GENMOD, error=binomial link=log) with corresponding 95% confidence intervals (c.i.) (7).

Results

The prevalence of 'unusual weakness or fatigue' was 11.49% (15.63% among females and 7.11% among males). The prevalence of 'hands falling asleep, loss of feeling or tingling' was 18.16% (23.21% among females and 12.80% among males). The prevalence of 'finger(s) turning white when exposed to moisture or cold' was 12.18% (14.29% among females and

9.95% among males). Adjusted prevalence ratios and 95% confidence intervals are reported in Table 1.

Table 1. Adjusted prevalence ratios and 95% confidence intervals for HAVS symptoms based on present, 5 and 10 years cumulative exposure.

	No. Exposed	Hand(s) Weak(ness)	Hand(s) Asleep, Tingling/Numbness	Finger(s) Blanching
Males				
1993 exposure	18	1.60(0.78-3.27)	0.93(0.46-1.87)	2.69(1.63-4.46)
5-yr exposure	17	3.10(1.76-5.47)	1.68(0.96-2.92)	3.68(2.35-5.78)
10-yr exposure	16	3.99(2.33-6.84)	unknown	3.71(2.31-5.95)
Females				
1993 exposure	3	2.16(0.93-5.02)	1.77(0.77-4.09)	2.39(1.02-5.56)
5-yr exposure	3	2.62(1.12-6.13)	1.85(0.80-4.28)	2.52(1.08-5.89)
10-yr exposure	3	2.68(1.14-6.28)	1.86(0.81-4.31)	unknown
Overall (adjusted for gender)				
1993 exposure	21	1.85(1.06-3.22)	1.22(0.70-2.11)	2.66(1.73-4.07)
5-yr exposure	20	2.70(1.69-4.31)	1.67(1.05-2.65)	3.44(2.35-5.03)
10-yr exposure	19	2.82(1.78-4.46)	1.79(1.13-2.84)	3.47(2.40-5.01)

Discussion

In this study, symptoms of HAVS are associated with workplace exposure to hand-held vibrating tools. The overall prevalence of tingling or numbness and blanching was similar to that reported by Palmer, et al. in Great Britain for symptoms in the last 7 days (20.2% and 10.9%, respectively) (8). An association exists between vibration exposure and HAVS symptoms among the general population, which exhibits a dose-response; the association is stronger as the time of cumulative exposure increases. A previous study demonstrated vibration exposure was a dominant factor in developing vibratory white finger, similar to HAVS (5). The influence of vibration exposure increased over forty years. In our study, a similar trend was seen and involved all three symptoms of HAVS. While the strength of the association appears to differ among males and females, further research is needed in this area.

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Music teachers at municipality music schools - musculoskeletal discomfort, psychosocial work factors and physical work place factors

Fjellman-Wiklund A [1, 2], Sundelin G [1]

[1] *Department of Community Medicine and Rehabilitation, Physiotherapy, Umeå University, Umeå, Sweden,*
[2] *Kommunhälsan Health Care Center, Skellefteå, Sweden, e-mail: anncristine.fjellman-wiklund@kommun.skelleftea.se*

Introduction

Musicians at all levels of performance may experience health problems from the physical and mental demands of their work (1). The most common complaints among musicians are musculoskeletal symptoms. Few studies have investigated the work environment, including the physical and psychosocial factors, affecting music teachers (2). Music teachers working at municipality music schools are exposed to a special work environment as they teach many individuals ranging from compulsory school to secondary high school. Their work places are often spread out at different locations throughout a large region, which means that they travel many miles every day. Work also includes a lot of lifting and handling of instruments. Since music teachers educate and provide skills to future musicians, it is important to explore their work environment. By acting as good role models, they may help their students stay healthy and prevent musculoskeletal disorders. The aim of the present study was to investigate work place factors as well as musculoskeletal discomfort and psychosocial work factors among music teachers.

Methods

A questionnaire consisting of items from the standardised Nordic Questionnaire on muskuloskeletal pain and discomfort and the Karasek-Theorell Questionnaire on psychosocial work factors was mailed to all 23 municipality music schools in the northern region of Sweden. The questionnaire also included additional items on playing habits, weekly amount of performing and practice time, and perceived causes of symptoms and workload.

Results

Out of the 287 music teachers, 208 (72.5%) (88 women and 120 men) participated in the study. An analysis of the dropouts showed that gender, age, length of employment, and major instrument played did not differ for the respondents.

Of the total participants, 82% of the music teachers reported that they experienced discomfort during the preceding 12 months. The highest prevalence was found in the neck (59%), the shoulders (54%), and the low back (45%). Female teachers reported significant more symptoms than male in the neck (p=0.019), the shoulders (p=0.02), the thoracic back (p=0.000) and the feet (p=0.012). Results of musculoskeletal discomfort according to instrument are shown in table 1. Factors that were believed to cause the symptoms were work and playing postures (41%), practice time, stress (31%), hearing problems, (9%) and environmental causes such as temperature and ventilation (5%). The rest claimed other causes or had no opinion.

Table 1. 12-month prevalence of musculoskeletal discomfort in music teachers, according to instrument.

Instrument	Neck (%)	Shoulders (%)	Low back (%)
Brass and woodwind (n=69)	59	55	41
Guitar (n=34)	59	71	50
Piano (n=43)	58	44	51
Violin (n=31)	58	58	45
Voice (n=18)	50	50	29

Table 2. Major instrument played by the 208 music teachers.

Instrument	Women (n)	Men (n)	Total (n)
Brass and woodwind	22	47	69
Guitar	6	28	34
Piano	26	17	43
Percussion	-	10	10
Violin	17	14	31
Voice	15	3	18
Other	2	1	3
Total	88	120	208

Table 3. Characteristics of the population of 208 music teachers at municipality music schools.

	Women (n=88)		Men (n=120)	
Age, mean (SD)	40.3 years (8.2)		43.9 years (10.1)	
Job experience mean, (SD)	15.2 years (8.3)		16.7 years (9.5)	
Full time/part time work > 50 % (n)	44		54	
Part time work < 50 % (n)	44		63	
Playing, work time, mean, (SD)	12.6	(7.8)	11.3	(6.8)
Playing, leisure time, mean, (SD)	4.3	(4.6)	5.6	(5.1)
Schools per week, mean, (SD)	4.4	(2.4)	4.7	(2.6)

The psychosocial work was characterised by high demands, sufficient control, and good social support. There were no gender differences. The teachers reported that they had to work hard (76%), with high intensity (80%) and under time pressure (40%). The job required skills and creativity (99.5%) but was repetitive (87%). The teachers felt that they had influence over what and how the work tasks had to be done (99%). They also stated that the social support from superiors (95%) and colleagues (95%) was good.

Half of the participants worked less than 20 hours per week as music teacher at a municipality music school (table 3). The job was often combined with other jobs such as church musician, musician in a symphony orchestra, or music teacher at the Music University. Most of the teachers had four to five work places per week. The practice and playing time was 16.9 hours per week including work and leisure time.

Discussion

Musculoskeletal pain and discomfort in the neck, shoulders, and back are common among music teachers. The prevalence was higher among female teachers than male and also high compared to the general population. The results of this study are in agreement with other studies on professional musicians (3). The psychosocial work environment was fairly good and the teachers themselves believed that their discomfort was due to the work and playing postures as well as time pressure. This finding may indicate that further investigation of the work environment is necessary. While the response rate of this study was somewhat low, it is similar to an other study among Canadian musicians (4). Another factor influencing the results may be that pain and discomfort among musicians may be seen as a weakness, and therefore, the teachers may not have wanted to reveal their health status. Individual structured interviews may have been a better format for obtaining this information.

Conclusions

The work as music teacher was perceived as positive but with a high extent of musculoskeletal pain and discomfort. Further investigations should be targeted at exposure assessments of ergonomic and physical factors such as work and playing posture. Different approaches may be needed to measure exposure among various instrumental groups.

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Company Economic Position: Associations with Employee-Reported MSD Risk Factors and Indicators

Warren, ND [1]

[1] *Dept. of Work Environment, UMass Lowell, Lowell MA & Ergonomic Technology Center, UConn Health Center, Farmington CT, USA, email: warren@nso.uchc.edu*

Introduction

The last decade has seen substantial advances in linking outcomes of MSD (musculoskeletal disorders) with the combined contributions of biomechanical and psychosocial risk factors and the work organization that underlies these levels of risk. It is of great interest for prevention strategies to identify easily identifiable economic characteristics of companies that might indicate increased "shop floor" MSD risk. The aim of this study was to explore several categories of economic variable that might fulfill this function.

Methods

The study analyzed data from the 1993 Dutch Monitor Study, consisting of interviews with employers in 528 companies and questionnaires collected from random samples of their employees (n = 7717). From the employee questionnaires, 4 psychosocial risk scales (Demands, Autonomy, Skill Discretion and Social Support) and 4 biomechanical risk scales (Repetitive Bend/Twist, Static Bend/Twist, Reach/Prolonged Postures, and Physical Exertion) were constructed. A single item assessed employee perceptions of management action in health matters. 8 MSD indicators included scales of: exhaustion, physical strain, combined MSD symptoms, pain (3 measures: upper extremity, whole body, and low back), and 2 single items [extended sick leave (>3 mo.) and partial disability]. The employer interviews provided 19 measures of company economic position in the market economy (see Figure 1). After examining univariate relationships, multivariate linear models were explored at the company level, to determine associations between these economic independent variables and the 17 employee-reported measures or MSD risk and MSD indicators. SPSS "Enter" procedure was used. The number of significant ($p \leq 0.05$) and near-significant ($p \leq 0.10$) entries of the independent variables into these 17 models were summed separately for positive associations (increase in MSD risk or indicators) and negative associations (reduction in MSD risk or indicators). These models were also stratified by 6 economic sectors: Food & Entertainment, Wholesale, Banking & Insurance, Service, Industry I (Textile, Chemical, Electrical), Industry II (Graphics, Metalworking).

Results

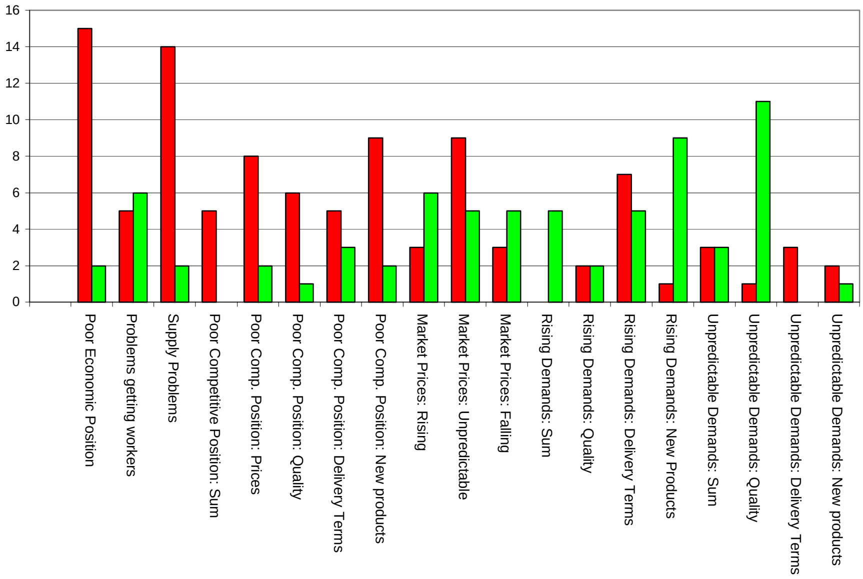

Figure 1. Associations between company economic variables and employee-reported MSD risk factors and MSD indicators. Y-axis = number of times the economic variable demonstrated a significant (p≤0.05) or near-significant (p≤0.10) entry in the 17 regression models. Dark bars = increase in MSD risk or indicators. Light bars = reduction in MSD risk or indicators.

The pooled sample of 528 companies showed both positive and negative associations for almost all of the 19 economic variables (Figure 1). However, the economic measures can be divided into 3 groups (Table 1): those that predominantly are associated with increased levels of MSD risk and indicators, those predominantly associated with decreased levels, and those with mixed associations that vary by sector (or demonstrated too few entries to generalize).

Table 1. Economic factors grouped by predominant effect.

Increase Risk/Indicators	**Decrease Risk/Indicators**	**Vary by Sector/too few**
Poor Economic Position Supply Problems Poor Competitive Position in: Summary measure Prices Quality New Products Prices: Unpredictable Unpredictable Demands for: Terms of Delivery	Prices: Rising or falling Rising Demands for: Summary measure New Products Unpredictable Demands for Quality	Problems getting workers Rising Demands for Quality Terms of Delivery Unpredictable Demands for: Summary measure New products

Stratification by sector revealed substantial sector-specific differences. For example:

1. "Problems getting workers" was protective in the Wholesale and both Industrial sectors, but it was detrimental in the Banking/Insurance and Service sectors.
2. In contrast to the other 4 sectors, any change in market prices (even if unpredictable) was protective in the Banking/Insurance and Service sectors.

Even within sectors, variation in association was also observed depending on the type of dependent variable. For example, in the Wholesale sector, employer reports of a poor competitive position with respect to prices were associated with increased psychosocial stressors but decreased body pain measures.

Discussion

The identification of company-level economic indicators of MSD risk factors and MSD indicators experienced by employees appears to be a very complex undertaking. Economic measures proposed in this study as potential indicators demonstrated mixed positive (detrimental) and negative (protective) associations. The strength and sign of associations between economic "exposures" and these outcomes depends on several variables: the sector of the company, the class of outcome explored (employee-reported MSD risk factor or MSD indicator), and even differences within these classes (e.g., biomechanical or psychosocial MSD risk factor). It seems likely that the meaning of the measures varies by sector and by context. For instance, we had hypothesized that unpredictability would show generally detrimental associations with the outcomes. This was generally true for unpredictable changes in market prices (with the exception of the striking reverse association in the Service sector). But unpredictable changes in market demands for quality were strongly associated with improvements in MSD risk and indicators. Likewise, rising demands showed generally protective associations with outcomes if they were demands for new products, but this association was reversed if the rising demands were for improved terms of delivery.

This research provides hypotheses for economic indicator measures and some of the covariates that must be measured to interpret their meaning. More research is required to make these meanings more precise and to generate measures that would be useful in directing prevention efforts towards particular companies.

Conclusion

The identification of company-level market position measures that would be useful in indicating companies at risk for higher MSD incidence is a complicated endeavor. Some measures showed fairly consistent associations with increased MSD risk and MSD indicators: poor economic position, supply problems, poor competitive position, and unpredictable market price changes. Another set of measures was generally associated with improved conditions, as reported by employees: rising or falling prices, rising demands for new products, and unpredictable demands for quality improvements. But other measures showed both detrimental and protective associations, depending on sector. Directions for further research are presented.

What is the evidence for an immune system measure of stress that can be used in the workplace?

Kelly S, Hertzman C

Department of Health Care & Epidemiology, University of British Columbia, Vancouver, BC, Canada, e-mail skelly@interchange.ubc.ca

Introduction

This project is a review of the existing literature on stress and immune system effects with the purpose of identifying biological measures of stress feasible for use in occupational or population health studies.

It was while reviewing the literature on immune system and hormonal measures that it first became apparent that a distinction must be made between acute and chronic stress. For example, lymphocyte stimulation assays are consistently decreased with exposure to chronic stress but there is no such consistency with exposure to brief, acute stressors. It is important to consider the relationship between acute and chronic stress. Does the acute stress response become chronic under the influence of repeated acute stressors, factors such as long-term loss of personal control, or "inappropriate" responses to acute stressors (i.e. 'biological embedding')? Or, do chronically-stressed persons become adapted to their life stressors in such a way that the stressors themselves stop having a biologic effect or do they stop perceiving their stressors to be stressful? We hypothesize that biological embedding leads to subtle, long-term changes in endocrine, hemostatic, and immune system function even if individuals have seemingly accepted the conditions of their lives. This review was restricted to studies examining immune system changes in persons exposed to chronic stressors.

Methods

We have previously proposed criteria for an ideal chronic stress marker (1, 2): it should be associated with stress, should have a half-life of months to years, and should have a well-defined distribution in the general population. In addition, when reviewing the literature for potential candidates the following criteria were used for evaluation: 1) consistency - has it been associated with stress in more than one study by different researchers studying different groups, 2) is there a dose-response relationship between the measure and stress, 3) is the odds ratio or risk ratio greater than 2.0 and statistically significant, 4) the stress occurs first, followed by a change in the parameter, 5) biological plausibility of the measured change, 6) is the analytic method sufficiently sensitive to measure the substance in all subjects, 7) is the distribution of cofactors such as gender and age understood?

In addition to the above criteria immune system measures provide some unusual conceptual and analytical issues. First is the problem that the most accessible portion of the immune system, the blood, probably does not represent what is happening in the remainder, and considerably larger portion, of the immune system: areas such as lymph, spleen, thymus, bone marrow, tonsils, etc. And, in addition isolating cells for analysis and this may alter their membranes, activity or cell status because of the change from their native *milieu*.

Sample collection and analysis issues are slightly different for some immune measures than the usual workplace or population measures. Assays such as cell stimulation assays that require live, unstressed cells have severe restrictions on the amount of time that can elapse before analysis can begin. Many analyses are also very labour intensive, time consuming and expensive; which will limit the population size that can be studied. Of even more concern is that, for most of the immune measures reviewed here, there is no gold standard method or *any* alternative.

Interpretation of the findings from immune assays is the third area of concern. Typically findings of a statistically significant change in immune system parameters are interpreted as if the physiological system is not functioning appropriately. But, the immune system is still largely a ‘black box’ and the clinical/health importance of statistically significant changes found in some research studies is not clear. Nor is it clear what illness condition might occur as a result of the measured change in an immune parameter. It is possible that a given change is normal fluctuation or that the failure to find a significant change in a parameter may occur because the change occurred in a compartment of the system that is not reflected in the blood. The added complexity of psychoneuroendocrine interactions makes interpretation difficult and subject to dispute. Lastly, the ill effects we are trying to describe may be caused by numerous small changes that 'sum up' to produce disease.

Results

Comparing studies for this review was difficult because studies differed in techniques used,. parameters measured, or had missing parameters or incomplete parameter description.

<u>Ennumeration Assays</u> This was a difficult section to review because the cell surface markers used to label the cells are not always clearly described and, as knowledge has grown, markers have changed. The methodology is now automated and analysis must begin within 3 hours of sample collection. Population studies are all based on pre-marker technology and the findings are not transferable to marker-based analytic methods. There does not seem to be any consistent association between any specific cell type/marker and chronic stress (3).

<u>Cell Activity Measures</u> The analytic methodology is very labour intensive and time from sample collection to the start of analysis is critical. When studies are restricted to chronic stress, lymphocyte stimulation assays show a consistent decrease in those who are stressed or an increase with stress-relieving techniques (3). Studies measuring natural killer cell activity do not show the same consistency in findings (3).

<u>Immuoglobulins and Complements</u> Analytic methods are well established and automated medical laboratory procedures, and population distributions are well understood. There is no support in the literature for an association between the complements and stress (3). There are very few studies that examined an association with immunoglobulins and results are mixed (3). One of the few to find an association (4) may show why other studies have failed to find an effect; the difference in the mean IgG level between the top and bottom stress categories is extremely small and only analyses with a low technical error can detect differences.

<u>Cytokines</u> Of all the molecules that have been identified as immune system signals only interleukins, interferons, and tumour necrosis factor have been examined in the context of chronic stress. Results are mixed (3), possibly because at least some have circadian rhythms (5) and the cytokines are present at such low concentrations that many subjects do not have detectable levels. Interleukin-6, currently being examined in work stress (6) and over-trained athletes (7) shows some promise as an immune measure of stress.

<u>Antibodies to Latent Viruses</u> It is hypothesized that chronic stress down-regulates the cellular immune response and the literature does show significantly increased levels of latent virus titres in subjects under chronic stress as compared to those who are not (3). An anti-stress intervention has also been shown to decrease levels (Esterling 1992).

<u>Response to Immunization</u> It was theorized that people undergoing chronic stress would be slower to respond to immunization. The most difficult problem in using this measure is to identify a novel antigen for the population being studied. And, testing requires repeated

samples which increases costs and may lead to sample attrition. There are only a few studies but most have showed a delayed response to immunization (e.g. (8, 9)) but further research on larger populations is needed (3).

Conclusions

Only three immune system measures have literature support: lymphocyte stimulation assays, antibodies to latent viruses, and response to immunization. Unfortunately the methodology for lymphocyte stimulation assays is not practicable for a large survey and it might be difficult to identify a novel antigen for an immunization response test.

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Questionnaire and interview collected information about psychosocial working conditions: An intervention study at a Swedish automobile plant

Bildt C. (1), Fröberg, J. (1), Fredriksson, K (1).

(1) National Institute for Working Life, S-112 79 Stockholm, Sweden. carina.bildt@niwl.se

Introduction

In the car body-sealing department at a large automobile plant in Sweden, a re-organisation of the work from lineout to line production was performed to meet the requirement to increase production capacity and quality (1, 2). A team organisation with short-cycle production targets was created to fulfil the goals, and in that process the company aimed at a broad-based participation. The new production system was planned to lead to rotation between work tasks, increased work contents and better ergonomic conditions.

The aim of the present study was to compare the results from the two data collection methods used in the study.

Methods

The study started in the spring 1997. During the summer holiday the same year the line production system was installed. The process of change was followed until the spring 1998, when the workers had got used to the new production system. Circa 90 operators, more than half of them females, were employed at the car body-sealing department at the time when the study started.

Information about the psychosocial working conditions were collected both by use of questionnaire and interview. The questionnaire-based information about the psychosocial working conditions was collected before the line production system was installed, in the spring 1997, and in the spring the next year, 1998. Seven questions were analysed in the present study, covering the areas of mental demands, control, stimulation, emotional climate at work and social support from colleagues and superiors. They were combined into indices and dichotomised at the 75th percentile. Differences between the answers before and after the implementation of change was calculated. The questionnaire also covered physical working conditions and health problems. That information have been analysed and presented elsewhere (2). The response rate was 87 percent at the first occasion (78 of 90 distributed questionnaires were returned). At the second occasion, 74 percent of those who answered the first questionnaire returned a second one. The responses from these 58 persons, 33 women and 25 men, were analysed. Structured group interviews, focused on psychosocial working conditions, the implementation of the changed production system (presented elsewhere (3), were performed by two psychologists at the same periods as the questionnaires were distributed. The psychosocial themes in the interviews the same as in the questionnaire. In these interviews, 25 randomly selected operators from 4 teams of operators participated. The interviews were taped.

Table 1. Prevalence of different psychosocial exposures before and after the change

	(N=58) 1997	1998
Low occupational pride	42	56
High demands	27	26
Low stimulance	37	55*
Poor emotional climate	31	43
Low control	29	90*
Poor social support from superiors	13	42*
Poor social support from colleagues	16	16

*=statistically significant difference between 1997 och 1998

Results

When comparing the operators' view of the psychosocial working conditions before and after the implementation of the new production system, many had experienced deterioration. The increase of operators who experienced low possibilities to control their work was threefold, from nearly thirty percent to ninety percent. Low stimulation at work was reported by circa thirty-five percent before the implementation of the line production system, and by fifty-five after the implementation. The proportion of subjects reporting poor social support from superiors was more than three times higher in 1998 than 1997.

In the interviews it was obvious that the experience of demands in work had increased after the implementation of the new work organisation. The operators were also more bound to their work place than before, and it was hard to get replacements when they needed to go to the bathroom and such things. In case of emergency, an operator had to stop the whole line, causing everyone working at the line an involuntary break in the work. Several workers expressed experiences of being "robotised". Earlier, it had been possible for a pair of operators to decide when to start with a new car body, to work hard for a while to be able to take a break later in the day. In the new work organisation this was not possible, which increased the feelings of having less control over the work. The possibility to influence work was much smaller after the implementation of the new work organisation, both because of the line and because of the fragmentation of the job tasks. Before the change, each operator sealed a half car body that took circa 30 minutes. After the change, the sealing tasks had been divided in several, causing the work cycle to be a minute, or less than a minute, to be compared with the former 30 minutes. The occupational pride had been reduced because the work had been a hard one to learn before the change. The training period had been as long as six months. After the change, it was possible to learn just a small part of the former job task in only a couple of hours, something that many operators experienced as degrading. The teams were in general satisfied with the support they gave each other, but because many operators had been employed lately, the job rotation had not been implemented as planned (no time for training the new), something that many operators was disappointed with and that caused hard feelings between "old" and "new" operators. The new work organisation did interrupt old work pairs of operators, something that many operators had dreaded beforehand, and even if they did appreciate the new work teams, many still miss the relation they had with their old partner. In general, there was a feeling that the emotional climate had deteriorated. In the teams, there was a common feeling that there was no support from the superiors. They did not listen to the operators, did not listen to their suggestions of improvements, did not give information about decisions taken by the management that had impact on the operators work and so on. This may partly be explained by the new work organisation, where the superiors can't be present to the same degree as before the change, but also by the fact that the operator can't leave her/his place at the line to search for the supervisor. In the new system, the operators shall indicate that they want to have contact with a supervisor by a signal system, that indicates on a display where and which problem that has occurred.

Conclusions

The information collected by questionnaire and interview was partly the same, but partly complementary. Some of the results from the questionnaire were easier to interpret when adding the information from the interview, where it had been possible to ask subsequent questions. In the interviews, the operators were very explicit with why they were experiencing for example feelings of reduced occupational pride or lack of control over their work situation. Another thing that came up in the interviews was that the more experienced operators, with long employment time, had had previous negative experiences of implementations of changes within the company. Their view of the company's general way of implementing changes was that, regardless of what has been planned, changes are implements in a hectic and unstructured way, that makes is very hard for the operators to participate with their knowledge and experience. Such information is hard to receive by use of questionnaire, and our conclusion is that we gained a lot by using both questionnaire and interview as data collection methods, even thus the interview method is much more time consuming, both for the researchers and the study participants.

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Comparison of task-based and full-shift strategies for noise exposure assessment in the construction industry

Seixas N(1), Sheppard L(2), Neitzel R(1)

[1] *Department of Environmental Health, University of Washington, Seattle, WA 98195 USA, e-mail: nseixas@u.washington.edu.*
[2] *Department of Biostatistics, University of Washington, Seattle, WA 98195 USA*

Introduction

Efficiencies for the accurate assessment of occupational exposure have been suggested for task-based (TB) in comparison to full-shift (FS) methodologies, especially in cases of high variability in time-at-task (TAT) and in FS exposures[1]. TB methodologies have been proposed as particularly relevant in industries such as construction, in which workers may conduct numerous tasks, with a high degree of variability between workers, and workdays[2]. We have compared TB with FS exposure assessment for a group of construction workers from five trades in order to describe the potential errors associated with a TB approach, and to demonstrate how the method of deriving the TB estimates affect this relationship,

Methods

502 noise dosimetry readings were collected among 5 trades (Carpenters, Laborers, Ironworkers, Operating Engineers and Electricians) working on 9 construction sites using data-logging noise dosimeters, programmed to record the exposure level each minute of the work-shift. In addition to obtaining the one-minute exposure levels, TAT cards were filled out by each subject on each day of testing, allowing for the one-minute sound levels to be coded according to the task and other potential determinants were taking place during each time interval. We derived estimates using several linear models using both specific tasks, and combinations of simplified exposure determinants. Linear models were developed regressing the one-minute L_{Avg} on various combinations of potential determinants, including Grouped Task (6 levels), Grouped Tool (9 levels), Site Type (4 levels), Trade (5 levels), and specific Task (53 levels). Variables that would not usually be available, such as individual subject, were not included in these models.

Full shift (FS) average exposure levels ($L_{Avg,k}$) were calculated using the one-minute levels observed on minute $i=1$ to n on shift k (L_{ki}), using:

$$L_{Avg,k} = ER\left[Log_2 \sum_{i=1}^{n} 2^{L_{ki}/ER} - Log_2(n) \right]$$

where ER is the exchange rate (5 dB), as specified by the US Occupational Safety and Health Administration (OSHA) exposure standard. Task-based (TB) estimates of $L_{Avg,k}$ ($TBLevel_k$) were similarly calculated using the model-predicted one minute exposure levels (note these predictions are constant over the duration of a ‘task’). To correct for the bias introduced by the reduced variability in the predicted values in conjunction with the non-linear relationship between L_{ik} and $L_{Avg,k}$, the TB $L_{Avg,k}$ were recalculated using the functional form of $L_{Avg,k}$ and assuming an underlying normal distribution for the one-minute model residuals. That is, the corrected TB estimates of $L_{Avg,k}$ are of the form,

$$[TB\ L_{Avg,k}] = [TB\ Level_k] + f_1[Residual\ Mean_k] + f_2[Residual\ Variance_k]$$

where (TB $Level_k$) is the estimate defined above, and the last two terms are functions of the shift-specific mean and variance, respectively, of the model residuals. FS measurements and TB estimates of the exposure levels were compared by regression analysis. Sources of error between the FS measurements and TB estimates were explored by comparing models with and without corrections for the Residual Mean and Variance.

Results

197 subjects were monitored for a total of 502 shifts comprising 248,677 minutes of exposure measurement. The one-minute noise levels had an average of 75.7 ±12.8 dBA. Results of the 5 models for task-associated exposure levels are shown in Table 1. The model r^2s are low, explaining a maximum of 12% of the minute to minute variability. Shift-specific model residuals were described in terms of their mean (between shift variability) and variance (within shift variability). For all five models, the between-shift means had a mean of about 0 and SD of 6, and the within shift variances had a mean of about 107 ± 47. The calculated FS exposure for the 502 observations was 82.6 ±6.2 dBA. In comparison, the simple TB exposure (using only the model-predicted means) was about 76 with SD ranging from 2.1 to 3.5, indicating a large bias in the TB exposure estimates (Table 2). This bias is due to the importance of within shift variability in the non-linear calculation of the shift-long exposure level. If the exposure levels are adjusted for within-shift variability, the exposure levels are about 83.5 (SD range, 3.9-4.5), much closer to the calculated FS level (Table 2). Even with the correction for within-shift variability, only a marginal improvement of the relationship between the FS measurements and TB estimates is obtained (r^2 up to about 0.3). Further adjustment for the between shift variability in exposure means produces little change in the exposure levels, but a very substantial increase in the relationship between FS measurements and TB estimates – with r^2 up to 0.9. Unfortunately, the between-shift variability is typically unavailable when using a TB exposure assessment procedure, so this adjustment may not be generally possible.

Table 1. Models predicting average noise exposure levels (dBA) for combinations of task, tool, site and trade (n=248,677)

Model	Variables	# 'Tasks'	r^2
1	Grouped Task	6	0.053
2	1 + Grouped Tool	15	0.073
3	2 + Site Type	19	0.108
4	3+ Trade	23	0.111
5	Task	53	0.120

Table 2. TB estimates of exposure, and relationships (r^2) between FS and TB noise exposure levels (dBA) (n=502)

TB Estimate	Model 1	Model 2	Model 3	Model 4	Model 5
TB L_{OSHA} (Predicted)					
Mean	76.0	76.1	76.1	76.1	76.2
(SD)	(2.1)	(2.6)	(3.5)	(3.5)	(3.5)
r^2	0.083	0.17	0.26	0.27	0.30
TB L_{OSHA} (Predicted + Variance)					
Mean	83.4	83.5	83.5	83.5	83.6
(SD)	(3.9)	(3.9)	(4.5)	(4.4)	(4.5)
r^2	0.11	0.20	0.30	0.32	0.31
TB L_{OSHA} (Predicted + Mean + Variance)					
Mean	83.5	83.6	83.5	83.5	83.6
(SD)	(6.9)	(6.9)	(6.9)	(6.9)	(6.9)
r^2	0.89	0.90	0.90	0.90	0.89

Conclusions

Task-based exposure estimation may have significant advantages to full shift measurement, especially in industries such as construction in which workers have highly variable work tasks and conditions, and therefore, exposures. However, between subject and between shift variability remains a very large source of error in TB exposure estimation. In our study, only about 30% of the variability in daily exposures could be accounted for with a TB methodology. Even this may be somewhat optimistic, as our estimates were derived from the same data on which the FS exposures were measured. For noise exposure measured in dB, which accumulate in a non-linear fashion, within-shift (or within task) variability is a very important source of bias in exposure estimates. Use of task-associated simple averages, which artificially compress exposure variability, to estimate the FS exposure results in a very substantial negative bias. Additional work is needed to identify methods of accounting for between-shift variability through, modeling or additional exposure measurement.

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Traditional analysis, evaluation, and rating of noise exposures – a critical review from an ergonomics point of view

Strasser H(1), Irle H(1)

1. Ergonomics Division, University of Siegen, Paul-Bonatz-Str. 9-11, Siegen, Germany, e-mail: h.strasser@aws.mb.uni-siegen.de, h.irle@aws.mb.uni-siegen.de

Introduction

Both ergonomists and practitioners responsible for occupational health and safety in a company normally use and appreciate indices of workload and environmental exposures presented in the simplest possible figures and numbers. Therefore, in traditional standards, rules, and safety regulations, the physical environment is normally rated in 8-hour-based mean values via connecting intensity and duration of stress by means of a multiplication, i.e., a mutual settlement of high load within a short exposure time and a low stress height within a longer lasting exposure. This principle is well-based on the experience that a low workload can be tolerated for a longer duration than a high workload. But does this confirm the hypothesis that equal energy or dose, or equal demanded output, also involves equal short or long-term human responses? Unfortunately, standards and conventional guidelines for occupational health and safety are more closely related to physics than to physiology. Yet, in order to really protect man at work, ergonomics must be more concerned with physiological costs of work and environmental stress than with physical principles of equal energetic dose.

Traditional assessment of intensity, frequency, and exposure time of sound exposures

The intensity of sound events has always been quantified in decibels by the sound pressure level in a logarithmic scale. Of course, that is a pragmatic scale because a tremendous span of, e.g., 12 decimal powers of sound intensity can be condensed into easily manageable values of only 3 digits (e.g., 0 to 120 dB). However, scientists and practitioners nowadays still have to work with this scale, despite the somewhat paradoxical fact that the psychophysical basic law of Weber-Fechner has meanwhile proven to be incorrect for acoustic stimuli. Although the formula for the sound pressure level is due to Weber-Fechner's law, the resulting logarithmic scale is not in accordance with human sensation. Therefore, instead of the incompatible logarithmic scale, a scale of loudness with linear units in Sone due to sensation derived from Stevens's law of power should be used.

With the intention of specifying sound immission with regard to intensity and frequency in one single value frequency-dependent filters A, B, C, or D should take into account the physiological characteristics of hearing. The filters A, B, C, and D, however, as a reciprocal approximation of the phone curves in different volume ranges, are based on the subjective comparison of sequentially presented tones and, therefore, cannot lead to an adequate assessment of noise, which normally is a mixture of inharmonious sounds. Furthermore, in most cases today, only the A-weighting network is used for all volume ranges, although doing so conflicts with scientific knowledge. This discrepancy sometimes leads to the fact that, to the disadvantage of man, sound pressure levels of some noise sources do not represent the real sensations of man.

Sound pressure levels mentioned in ergonomics and in all legal regulations, standards, and prevention instructions (cp., e.g., NN 1990, NN 1996, NN 1998, ISO DIS 1999) do not refer to a momentary sound event; they normally refer to the rating level L_r as an average value for the noise exposure associated with an 8-h working day. The energy equivalent calculation of the mean value is, of course, applicable to a great many working situations. However, situations also exist where a purely formal calculation yields peculiar results which lead to a serious misinterpretation.

When applying energy equivalence, (cp. Fig. 1) 85 dB for 8 h are equivalent to 88 dB for 4 h, 91 dB / 2 h, or 94 dB / 1 h. This mutual settlement of noise level and exposure time is correct as far as sound dose and sound energy are concerned. However, with regard to physiological and psychological aspects of work, inevitably some discrepancies result.

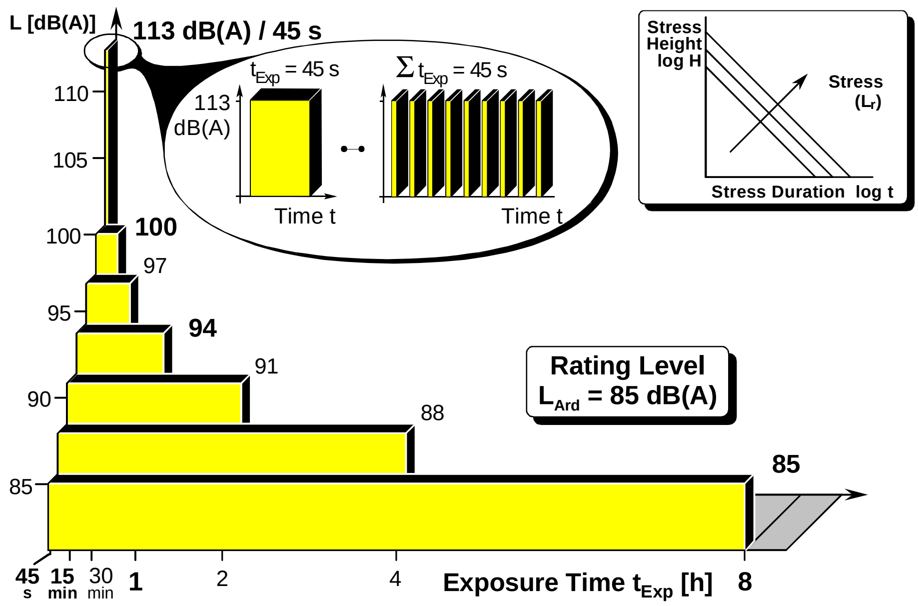

Figure 1. Sound pressure levels of different durations leading to an equal rating level (in this case 85 dB(A)) when applying the ”3-dB-exchange rate”

Ninety-four dB / 1 h (cp. right part of Fig. 2) – as previously described are energetically equivalent to 85 dB / 8 h, i.e., they correspond to an L_r of 85 dB. If only the energy, i.e., the sound dose, is considered, what is shown in the left part of Fig. 2 also holds true. In this case, 94 dB for 1 h and an additional 75 dB for the remaining 7 h also result in an L_r of only 85 dB. Physically seen, this is correct, but it is comparable to the situation of filling up quiet periods with noise, and from a psychological point of view it is likely that nobody would prefer a situation as described in the left part of Fig. 2. Provided that the noise distribution shown here would stem from 2 machines, strange effects would also result with respect to technical approaches of noise control. If an engineer in this case would decide to completely insulate the machine which emits the lower level, the rating level would not be influenced at all. The application of the measure ”rating level” consequently allows these strange ratings, as long as the lower value of noise remains a certain amount below the peak levels. For an equal exposure time, a difference of only 10 dB between the two levels is already enough to neglect the lower level, which absolutely agrees with legal regulations, standards, and national or international guidelines.

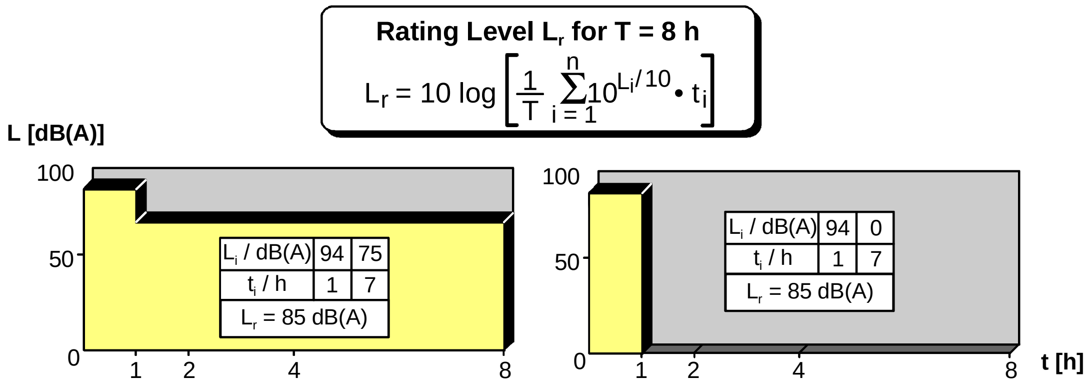

Figure 2. Elucidation of discrepancies in rating noise via the 3-dB-exchange rate

When continuing to halve the exposure time and when applying the ”3-dB-exchange rate” as shown in Fig. 1 – from a purely arithmetical point of view – even a quarter of an hour of techno music in a discotheque at 100 dB would correspond to an 8-h working day at 85 dB, which is still tolerated in the production sector according to almost all international standards (cp. NN 1997). Nevertheless, physiologically seen, high sound levels for a short period of time, e.g., 100 dB over 15 min or consequently 113 dB for 45 s have to be assessed much more advantageously than continuous noise. This can be demonstrated, e.g., by temporary threshold shifts (TTS) resulting from different noise levels with corresponding exposure times in an energy equivalent arrangement (see Irle et al. 2000).

The equal energy principle and the conventional rating of continuous and impulse noise

But may the mutual compensation of stress height and exposure time to the advantage of man be applied without limit? Can 120 dB, 130 dB, 140 dB, 150 dB, or even 160 dB at an adequately reduced exposure time (of 10 s, 1 s, 0.1 s, 10 ms, or 1 ms) be assessed to be identical to or even more advantageous than, e.g., the above-mentioned 113 dB / 45 s? From a physiological point of view the answer must be ”no,” even though TTS may level off completely. Nevertheless, in the past, the energy equivalent compensation of a halving of the duration with a level increase by 3 dB and vice versa (or the factor 10 in duration versus level) has become the basis for cut-off level diagrams to avoid hearing impairment which are applied in civil as well as in military sectors (cp. NN 1987).

In the case of impulse noise, exposure times even reach down into the range of ms. When establishing a logarithmic scale for the exposure time in addition to the already existing one for the noise level in dB, the straight line in Fig. 3 illustrates the energy equivalence for the rating level of 85 dB, e.g.,

- 1 x 1-ms impulse of 160 dB,
- 10 x 1-ms impulses of 150 dB,
- 100 x 1-ms impulses of 140 dB,
- 1000 x 1-ms impulses of 130 dB,
- 9000 x 5-ms impulses of 113 dB, and
- 85 dB for 8 hours (28 800 s), respectively.

Although the unevaluated noise level in industry may not exceed 140 dB according to revised noise regulations (e.g., NN 1990, NN 1997) due to the limit line in Fig. 3, the varying time structures of the sound exposures are not considered.

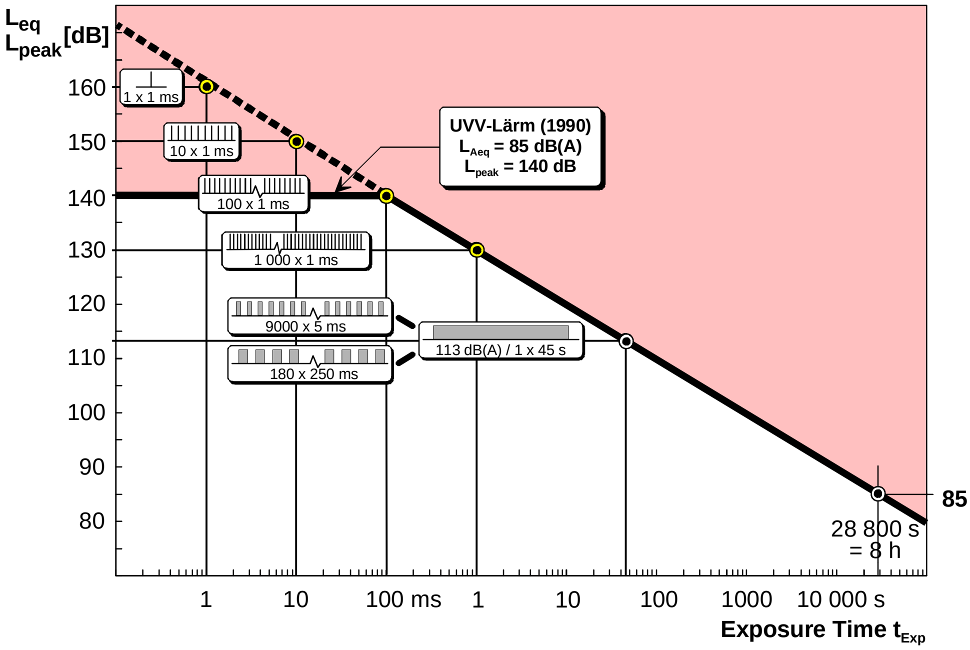

Figure 3. Conventional noise rating according to the principle of equal energy with a tolerable rating level L_{Ard} of 85 dB(A)

Equal work or energy, a principle beyond ergonomics limits

But can these procedures of traditional occupational health and safety, really guarantee a safe degree of hearing protection? The answer is no, because they are based solely on the principle of equal energy, and this is a principle beyond ergonomics limits. Traditional cut-off level diagrams as well as the determination of the rating level can only represent an aid for the evaluation of the sound energy acting on man. But when stress is quantified only with regard to physical aspects, man and his physiological characteristics are principally not included in the approach of the assessment.

The calculation of the total stress by a multiplication of intensity and duration indeed is a common procedure for the assessment of other kinds of the physical environment, too. However, if man is involved in work, which is, of course, unalterable in ergonomics, plausible limiting conditions may never be neglected in the domain of stress.

A performed output (physical work) can be calculated by the height and duration of work, e.g., the performance on a bicycle ergometer. However, this is only reasonable within physiological limits of the endurance level. A male worker may be able to perform about 50 Watts for extended periods of time. For instance, the product from 50 Watts and 60 min working time (e.g., $B_3 = H_3 \times T_3$ as seen in the front part of Fig. 4) is identical to the work resulting from 100 Watts and a working time of 30 min or also 200 Watts performed for 15 min (analogous to $B_1 = H_1 \times T_1$). Yet, can the strategy of mutual compensation be continued arbitrarily ad libitum? The answer must be no. At least in the limiting ranges, human nature does not play along. Nobody will be able to comply with a demand of 500 Watts for 6 min or 1000 Watts for 3 min. The principle of equal work, i.e., the mutual compensation of intensity and time, cannot meet physiological laws.

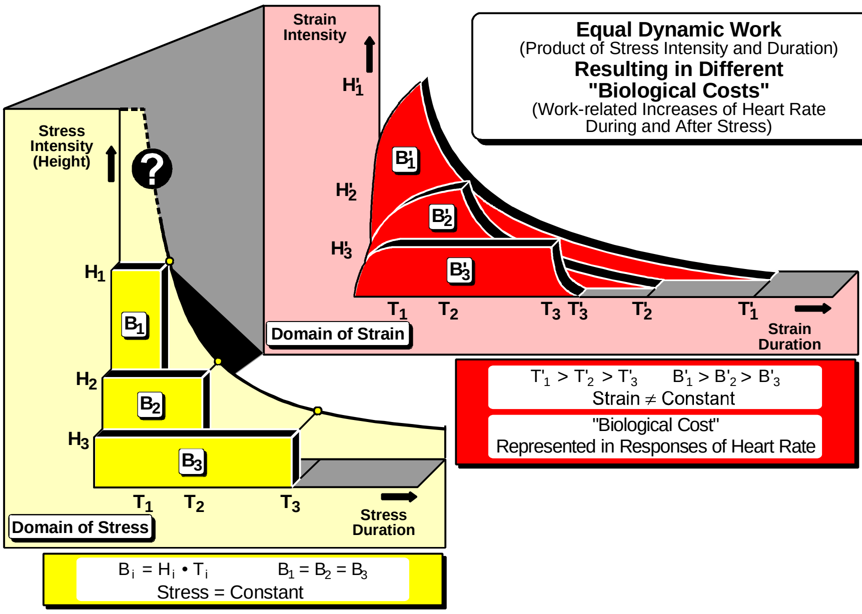

Figure 4. Equal dynamic work, i.e., product of stress intensity and duration (lower frontal part) resulting in varying ”biological cost”, i.e., work-related increases of heart rate during and after stress (upper part behind)

This can be shown via the general responses of the heart rate to the above-described workload constellations (see upper part of Fig. 4).

For physiological reasons, occupational situations must not occur which, e.g., result in critical heart rates of about 180 beats/min, even if this occurs for only a short time. In this case, the mutual settlement of high workload and short duration must reach an upper limit. But it is exactly this procedure – a procedure which is based solely on physics rather than ergonomics – which is practiced when applying the equal energy principle, i.e., the 3-dB-exchange rate, to assess short duration continuous and impulse noise.

Risks in occupational safety and health by the application of the equal energy hypothesis

Drawing inferences about the reported theoretical considerations on the one hand (which are presented by Strasser and Hesse (1993) and Strasser (1995) in much more detail), and regarding the results of several experimental investigations into the physiological costs of noise on the other hand (see Hesse el al. 1994; Irle et al. 2000), it should become evident that real risks exist in occupational safety and health rules which are based on the equal energy hypothesis or the principle of equal work.

When, e.g., thinking about the fact that the prick of a needle into a finger, always is one and only one singular event of a mechanical irritation which causes pain, which cannot be converted into the caressing of this very point over a longer period, the inevitable issue raises whether our sensory organ ”ear” may represent an exception in the case of impulse noise. Can the ear actually be expected to tolerate 160 dB for 1 ms or 100 noise events of 140 dB / 1 ms in the same way as it tolerates continuous noise of 85 dB for 8 hours, which is what the principle of equal energy suggests? When considering the density of energy acting on the ear, impulse noise simply cannot be compared with continuous noise. Equalizing 160 dB / 1 ms or 1000 noise impulses with a level of 130 dB and a duration of 1 ms, each, with, e.g., 85 dB for 8 hours according to the 3-dB-exchange rate is in accordance with energy equivalence. However, this does not mean that the term ”dose” as a datum level is in fact acceptable in this case. During continuous noise, the sound energy acting on the ear is distributed over the 28 800 s of an 8-h-working day. However, in the case of impulse noise, the total sound energy is forced on the human sensory organ in extremely high doses within a fraction of a second. Just as a drug which in a small dosage over a longer period of time can induce healing and one single ”overdose” of that drug can be lethal, the impacts of impulse and continuous noise simply are not identical. An impulse noise event is comparable, for example, with a hurricane in the inner ear which can hardly pass the carpet of hair cells without any adverse effect, just as a short-time gust blowing over a cornfield or being caught in a sail cannot have the same effect as a light wind over a longer period of time.

Conclusions

In the context of the energy equivalence principle in rating the physical environment (cp., e.g., Martin 1976; Strasser and Irle 2000), one must not forget a mechanical analogue where deformations of materials are the intended aim of an energy concentration. Fast, energetic manufacturing operations, such as, e.g., beating, bumping, or punching, are the essential presuppositions for deformations of materials. Therefore, it is only a stringent consequence that short but intensive events of environmental stress must involve a greater potentiality of health hazards for man. So, the validity of acceptable equivalences of environmental stress to guarantee health protection must be called into question. There should be no doubts that the effect of a dose which is dispensed within two different time intervals is more striking within the shorter one. Also, unquestionably, in the case of increasing density of energy or concentrations of harmful agents, the exceeding of physiological barriers with simultaneous intensifications of the effects becomes much more probable. This is especially true when the organism does not possess effective potentialities of temporal and/or spatial buffers. Therefore, the well-known endeavor for simplification and standardization which drives attempts to squeeze the rating of complex environmental situations into simple models or integrated measures as is done, e.g., also for ultra-violet radiation, mechanical vibrations, and carbon monoxide, cannot be adopted by ergonomics. Via this procedure, multidimensional connections get lost. In this context, a simple but slightly meditative comparison may be convincing for skeptics: The leveling of short lasting high intensity stress, based on physical rudiments, indeed seems to be as trustworthy as the statement that nobody can drown in a river with a statistical average depth of 50 cm.

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Validity of a questionnaire method for estimating noise exposure in sawmill workers

Davies HW [1], Ostry AS [2], Teschke K[1,2], Hertzman C[2], Demers PA[1,2]

[1] *School of Occupational and Environmental Hygiene, University of British Columbia, Vancouver, BC, Canada (email: hugh.davies@ubc.ca)*
[2] *Department of Health Care and Epidemiology, University of British Columbia, Vancouver, BC, Canada.*

Introduction

UBC researchers have assembled a cohort of 28,000 British Columbia sawmill workers who worked in one of 14 participating sawmills between 1950 and 1998 (1, 2). In studies of psychosocial job strain in this cohort (3,4) noise exposure was assessed because of its high levels in sawmills, and its recognized potential as an external stressor. The assessment was based on a single question added to a modified job content questionnaire (5). Noise dosimetry data collected from cohort mills as part of a separate study on the cardiovascular effects of noise enabled us to examine the validity of the questionnaire instrument, and to compare results of different expert-rater groups.

Methods

Questionnaires were completed for a set of approximately 50 standardized sawmill job titles (as they existed in 1997) by two different groups of expert evaluators. The first expert group comprised 4 union/management "Job Evaluators", each with over 30 years industry experience. The second expert group comprised 30 randomly selected, senior (> 20 years experience), sawmill workers ("Worker-Experts"), 10 each from 3 cohort sawmills. These mills were selected to represent a cross-section of 1997 industry technology. The questionnaire delivered the statement "The job is noisy". For each job title, experts were asked whether they strongly disagreed, disagreed, agreed, or strongly agreed with this statement. Answers were coded numerically as 1, 2, 3, and 4, respectively, and within each of the two groups, averaged for each job title.

Also in 1997, full-shift noise dosimetry was performed at 4 randomly selected cohort mills. The sites were stratified by region and were representative of the range of technology found in cohort sawmills. During two site visits, conducted in summer and winter seasons, measurements were obtained for every production and maintenance job title. Our goal was a minimum of 2 observations per job. Instruments were calibrated on a daily basis. One mill ("Mill Y") was coincidentally selected for dosimetry and for recruiting of Worker-Experts, which enabled us to create a third group for analysis, and test the validity of Mill Y Worker-Expert ratings of noise exposure against dosimetry measurements taken at Mill Y.

Results

The three analysis groups contained different subsets of job titles (Table 1) because we required a minimum number of questionnaire responses (5 for Job Evaluators), and a minimum number of dosimetry observations (2, except for Mill Y group, where single observations per job title were allowed). Following exclusions, between 2 and 21 dosimetry observations were averaged for each job title. Dosimetry results illustrate the very high noise levels found in sawmills, averaging over 91 dBA.

Table 1: Measurement Data Summary

Group	Number of Experts	Number of Jobs Analyzed	Noise Exposure (Mean, Range)	
			Questionnaire	Dosimetry (dBA)
Job Evaluators	4	37	2.8 (1.8-4.0)	91.4 (84.1-102.2)
Worker-Experts	30	32	3.1 (2.2-3.7)	91.7 (84.1-102.2)
Mill Y Worker-Experts	10	23	3.2 (2.6-3.7)	91.4 (83.2-105.0)

Associations between questionnaire and dosimetry were moderate to high, with Pearson r ranging from 0.61 to 0.80 for the three evaluation groups (Table 2). The lowest correlation was found with the Job Evaluators, and the highest with the group of Mill Y Worker-Experts when dosimetry measurements were limited to those taken at Mill Y. Unexplained variation in measured noise levels is likely due to determinants of noise exposure (worker enclosures, distance from noise sources etc.) not accounted for in the generalized rating of the expert evaluators.

Table 2: Pearson Correlation between expert groups and Dosimetry

Group	Pearson r
Job Evaluators	0.61
30 Worker-Experts	0.70
10 Mill Y Worker-Experts	0.80

Regression equations were generated for each analysis group and the noise level associated with the "pivotal" rating value (2.5, midway between "disagree" and "agree") was predicted. Job Evaluators and Worker-Experts rated "noisy jobs" as being above 87 to 90 dBA.

Table 3: Expert rating Vs. Dosimetry

	$L_{ex} \geq 90$ dBA	$L_{ex} < 90$ dBA
Expert rating of 3 or 4	21	9
Expert rating of 1 or 2	1	6

For the Job Evaluators only, sensitivity and specificity of the expert rating was evaluated using a dosimetry level of 90 dBA as the criterion for "exposed"(Table 3). This gave results of 95% and 40% respectively. The level of agreement between questionnaire and dosimetry methods was "fair" (kappa statistic = 0. 39).

Conclusion

Semi-quantitative estimation of noise exposure by industry experts is a useful tool where noise measurements are not available, as may be the case in retrospective exposure assessment. We have shown that a relatively crude assessment technique using a simple question and ordinal answer, when pooled, gave a valid and useful quantitative estimate of noise exposure in this cohort of sawmill workers. Evaluators with direct work experience in the mills were able to give better evaluations than those with more remote knowledge of mill jobs. Expert evaluators assessed as "noisy" jobs whose measured exposure levels were above 87 dBA. This is a useful breakpoint only slightly higher than common regulatory limits, and the point at which initial health effects are observed.

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Self and expert assessment of styrene exposure – A comparison in six reinforced plastics factories

Liljelind I (1), Rappaport S (2), Levin J (1,3), Pettersson-Strömbäck A (4), Sunesson A-L (3), Sundgren M (3), Bergdahl I A (1), Järvholm B (1)

[1.] *Occupational Medicine, Department of Public Health and Clinical Medicine, Umeå, Sweden, e-mail: ingrid.liljelind@envmed.umu.se*
[2.] *School of Public Health, University of North Carolina, Chapel Hill, NC, USA*
[3.] *National Institute for Working Life, Programme for Chemical Exposure Assessment, Umeå, Sweden*
[4.] *Work and Organisational Psychology Unit, Umeå, Sweden.*

Introduction

In order to seize the inherent variability in occupational exposure, the sampling strategy should provide sufficient numbers of samples and include repeated measurements from the same workers (1,2). Because traditional sampling methods rarely allow a sufficient number of measurements, it has been suggested that the sampling design should include self-monitoring by the workers. We employed the self-assessment of exposure method (SAE) in six reinforced plastics factories in Sweden, where the workers performed full-shift personal measurements with user-friendly diffusive samplers (3). In order to find out if self-assessment caused any bias, we compared those results with expert measurements.

Methods

The SAE method was introduced to six factories and 42 styrene workers performed after oral and written information full-shift personal monitoring with diffusive samplers (Perkin-Elmer tube with Tenax TA), distributed by mail (4). After laboratory analysis of the monitors by thermal desorption and GC, results were sent to the workers as well as to the supervisory staff for evaluation and interpretation. Expert measurements, with the same type of sampler, were accomplished to evaluate the self-assessments. Comparing self and expert assessments with mixed-effects linear models statistically evaluated the potential bias of SAE (5).

Results

A total of 216 styrene exposure measurements collected from 42 factory workers were included in the data analysis. Most of the data (73.6%) were collected by SAE. The number of repeated measurements was, 1 – 9 per worker, median 6. The range of the results was large, between 0.4 and 245 mg/m^3. Only one or two expert measurements were generally obtained for each worker and in a few cases no expert measurements were available for practical reasons. Likewise, in a few cases only expert measurements were available.

A statistical analysis indicated no significant difference in the measurements between self and expert-assessment in 5 out of 6 factories. The estimated effects of self-assessment, shown in Table 1, were not statistically significant (anti-logged 95% CI includes 1) for any of the factories except factory 4.

Factory	Mean (mg/m3)	Effect of SAE	95% CI [b]
F 1 [a]	2.82	0.998	0.833-1.19
F 2	41.0	1.08	0.603-1.93
F 3 [a]	53.6	0.998	0.833-1.19
F 4	5.81	3.60	1.30-9.94
F 5 [a]	21.4	0.998	0.833-1.19
F 6	51.1	1.09	0.403-2.93

Table 1. The estimated multiplicative effect of SAE and the mean exposure in the styrene factories. (All data shown is anti-logged). F 1 – factory 1, F 2 - factory 2 …..etc

[a] Pooled with regard to distinct between-worker and common within-worker variance components.
[b] Confidence interval, includes 1 if non-significant.

Discussion

We are not aware of any prior studies having compared self and expert assessment with the aim of determining possible bias associated with SAE. In this investigation, an occupational hygienist conducted measurements during the same time period (15 months) but not at the same days as those obtained by the workers independently. No statistically significant effect of SAE was observed in 5 of the 6 factories investigated. In factory 4 much of the discrepancy between self and expert measurements involved workers who were no longer employed when the expert measurements were collected and the company had made large alterations within personal tasks and the individual structure. Excluding the non-representative workers, based on statements from the workers and the company, the effect of SAE was at the border of statistical significance (data not shown). Simple passive monitors are available for personal monitoring of several gaseous air contaminants. Applied to working populations over several years, SAE would be a possible way to achieve sufficient sample sizes to eliminate many of the problems currently plaguing epidemiological studies, which invariably suffer from the lack of exposure data. Finally, we believe that SAE serves another important function, namely, involving the workers directly in the process of exposure assessment and control. In order to facilitate effective involvement of workers in the process, it will be important to ensure timely feedback of results so that they can relate the results to recent experience.

Conclusions

The results indicate that untrained, unsupervised workers are able to collect consistently unbiased exposure data by employing currently available passive monitors.

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The role of feedback in self assessment

Pettersson-Strömbäck A [(1)]

[(1)]. *Work and Organisational Psychology Unit, Umeå University, Umeå, Sweden,*
e-mail: anita.stromback@aop.umu.se

Introduction

Self-Assessment of Exposure (SAE) requires participation and co-operation by the workers (1). The workers themselves perform the measurements and they also receive the measurement results for interpretation. Participation in exposure assessment and feedback of measurement results could be a tool to enhance the workers own control in their working situation by taking preventive actions on behalf of the measurement results.

The variation in exposure levels is quite large which implies that the information of exposure levels is afflicted with uncertainty. The consequence of this uncertainty is that a sufficient number of measurements has to be done in order to estimate expected value and confidence intervals. Earlier studies in the SAE-project indicated that the workers stop measuring after performing two to three measurements (Liljelind et al., 2000). A possible explanation for this is that the workers had an inadequate understanding of the concept of variation and neglected it in order to reach a plain decision whether the value was above or below the occupational exposure level (OEL). Also, this reasoning raises questions about whether uncertainty and risk are crucial concepts in taking preventive measures.

The effect of feedback of uncertain information is theoretically interesting. How is the worker's risk perception established, when he/she receives repeated knowledge of results? How does the risk perception influence the worker's intention to take preventive actions?

Method

A study was conducted in reinforced plastic industry in Sweden. In the reinforced plastic industry the workers are exposed to styrene, a solvent that can cause neurological lesions. A multiple case study was conducted, seven reinforced plastic factories were invited and six accepted. The study was longitudinal, started in December –98 and data are still being collected. The workers performed between four to seven self-assessments each. Repeated feedback of measurement results where given to the workers, presented in the form of a diagram where the OEL for styrene was marked. After each self-assessment, the workers were interviewed. Before receiving feedback on their own measurement result, they were asked to predict their measurement value and also to estimate a confidence interval. When receiving the result they were asked to comment upon it. They were also asked whether they would take any preventive measures on behalf of a particular value, and to rate the degree of perceived control of the exposure levels.

Results

The results indicate that the workers' judgements tended to be stabilised rather early in the process. Even if the variation in exposure levels was large, the representation of uncertainty was probably not essential in their diagnosis and risk perception. The workers adjusted their estimations to anchorage points, such as the OEL, extremely deviating values, and to perceived trends in measurement results.

The rather fast adjustment of judgements is also found in the workers' action repertoire. The workers tended to restrict themselves to a few options of actions (such as wearing mask when working) insensitive to variation of exposure. In some instances, when the workers judged the exposure levels as high, the judgements did not result in any actions.

Also, individual attitudes to the phenomena of exposure influence the diagnosis and decision to act, – for example, some workers had a kind of fatalistic view of an unavoidable nature of exposure.

Discussion

These results indicate that other factors than specific measurement data influence the workers' diagnosis and intended actions. For example, workers judged exposure as high and yet took not any preventive actions. Socio-economic factors such as recession and the availability of a work can influence the workers behaviour more than the exposure data.

Conclusions

Risk perception did not prove to be a sufficient condition for the workers' intention to take preventive actions. The explanation for this may be difficulties in cognitive handling of numerical data as well as biased attitudes towards preventive actions.

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(Semi) self-assessment of long-term exposure to solvents and welding fumes in a shipyard

Hilhorst SKM[(1)], Vermeulen R[(1)], Kromhout H[(1)]

[1.] *Environmental and Occupational Health Group, Institute for Risk Assessment Sciences, Utrecht University, Netherlands, e-mail: s.hilhorst@vet.uu.nl*

Introduction

A hazard inventory and evaluation of exposure to chemicals was executed in 1998 in a shipyard. The highest exposures were expected to occur in Shipyard I (S1) for welding fumes and in Shipyard II (S2) for organic solvents. A quantitative survey concerning the long-term exposure of solvents and welding fumes was started in 1999. The measurements were taken in four periods between April and December of that year. The aim of the study was to assess long-term exposure to welding fumes and solvents and to implement a routine monitoring program. During the first measurement period a contact person of the shipyard was trained to perform and assist the employees with the measurements during the subsequent periods.

Methods

Measurement strategy

For the assessment of long-term exposure we used a measurement strategy that was first described by Rappaport *et al.*(2). This approach takes into account that occupational exposures varies both within and between workers even in so-called 'homogenous exposure groups'. The approach requires as a starting point repeated measurements on a random sample of workers from an observational group.

The long-term exposure was examined following measurement schemes like figure 1. S1 comprised two a-priori defined job functions: welders (n=20) and shipbuilders (n=24). In S2 the subjects were grouped in six a-priori defined job functions based both on the location of the activities (ventilation) and the activity itself (exposed solvents): dockyard (paint, n=26), wharf (paint, n=18), screen printing/painting signs (paint, n=6), spray painting (paint, n=8), sail making/isolation (glue, n=16) and wood/polyester (glue, n=42).

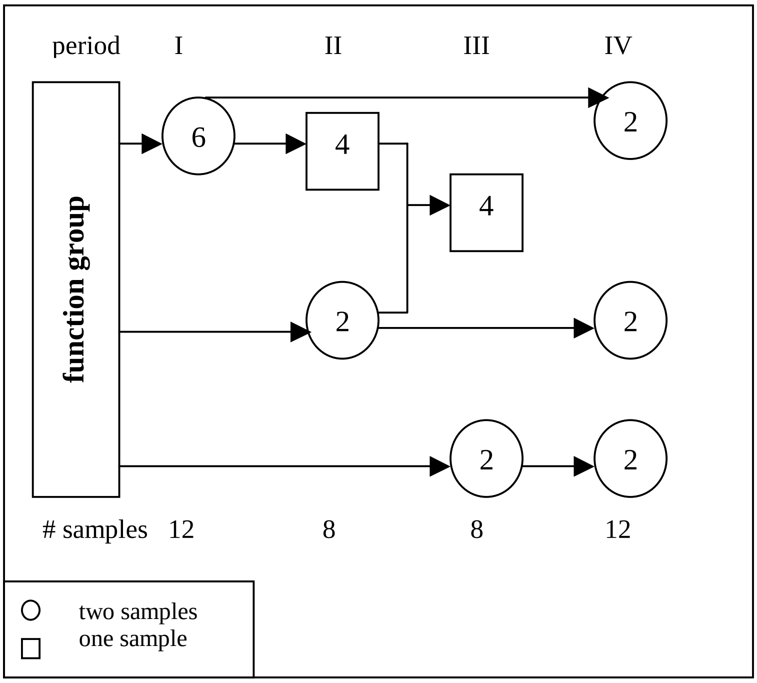

Figure 1: Measurement scheme with the number of persons sampled and number of samples in each period

Each period the contact person of the shipyard received a new random measurement scheme with the names of workers and dates to be monitored. The sample was rejected when a subject was sick, on holiday, did not show up or practised fraud with the sampling equipment. In such case, a worker was re-scheduled for a new measurement.

The exposure to welding fumes was assessed by using a portable pump with a PAS-6 inhalable dust sampler. Organic solvents were measured using a passive organic vapour monitor (diffuse sampler).

For exposure to organic solvents, the exposure index was calculated.

The evaluation of the data was performed with SPEED. SPEED is a Statistical Program for the Evaluation of Exposure Data that is based on the procedures described by Rappaport *et al.* (2) and Lyles *et al.* (1).

Results

Exposure measurements

129 inhalable dust samples of 32 employees of S1 were taken. The exposure ranged from 0,03 to 9,55 mg/m^3. The mean exposure was 0,72 mg/m^3. The long-term exposure on welding fumes was considered to be acceptable (OEL=3,5 mg/m^3). The employees appeared to be uniformly exposed.

The geometric mean exposure index for organic solvents for the 217 samples from 53 workers was 0.01. There was a large variation in exposure values (range: 0.001-2.58), mostly day-to-day variation. The long-term exposure to organic solvents was acceptable (OEL exposure index = 1). The employees were exposed uniformly with the exception of a small group of spray painters. However even for them the long-term exposure proved to be acceptable. Only on three occasions, the OEL was exceeded.

Effectiveness of sampling scheme

In table 1 the effectiveness of the sampling scheme is shown.

Table 1. Effectiveness of sampling scheme in shipyard I and shipyard II

	N	OK	Failed	No show	Sick	Holiday	Fraud[1]
S1	213	129 (61%)	84 (39%)	10%	8%	7%	15%
S2	279	217 (78%)	62 (22%)	4%	9%	9%	0%

N measurement attempts
[1] including pump failure

In shipyard I more failures occurred, mostly because employees did not show up on the given day and due to fraud with pumps and inhalable dust samplers. The percentage of employees that were sick or on holiday was equally distributed between the two departments.

Routine Monitoring program

Based on the results of the exposure survey the optimum routine monitoring program was calculated. For S1 this routine monitoring program consist of three repeated measurements on six subjects distributed equally over a period of a year. The monitoring program of S2 consists of two repeated measurements on nine subjects.

Discussion

This study shows that the used protocol makes up a good framework for a systematic evaluation of chronic exposures based on a-priori criteria.

This study also shows that self-assessment with a random measurement strategy can be implemented. Still remote control will be necessary, as well as a well-trained contact person and quality assurance scheme. Also a positive attitude towards the assessment of workers and management is essential for a successful realisation of the measurement program. In spite of this, increased measurement failure should be taken into account, especially with dust measurements using pumps.

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Self assessment of exposure as a tool in Systematic Work Environment Management

Trägårdh, C

Swedish Work Environment Authority (SWEA), Chemistry and Microbiology Division, Solna. Sweden, e-mail: claes.tragardh@av.se

Introduction

"Systematic Work Environment Management" means in Swedish legislation the work done by the employer to investigate, carry out and follow-up activities in such a way that ill-health and accidents at work are prevented and a satisfactory work environment is achieved. It is described in the ordinance "Systematic Work Environment Management", AFS 2001:1, which also implements the Council Directive 89/391/EEC on the introduction of measures to encourage improvements of the safety and health of workers at work.

Discussion and conclusions

Self assessment of exposure of air contaminants has been tested by researchers in Umeå as a method in systematic work environment management. According to section 8 of the ordinance the employer shall regularly investigate the working conditions and assess the risk of any person being affected by ill-health. The risk assessment shall be documented in writing. The survey methods can include occupational hygiene measurements and other measurements as part of the risk assessment process. The employer shall see too it that the employees knowledge of risks is sufficient. Self assessment of exposure is one way to contribute to that..

Advantages with self assessment

- easy-to-use equipment
- fairly cheap
- the employees can after instructions/education assist the occupational hygienist with sampling
- better participation

This can lead to

- more measurement results
- the results can influence the employee in how to perform his/her work to avoid air contaminants

Disadvantages/risks with self assessment

- measurement results without or with too little documentation can not be understood
- the employees finish to measure when the results are well below the limit value
- partly in conflict with the regulation on how to perform measurements
- misunderstandings can arise when measuring at work-sites where use of PPE is necessary

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Exposure related mutagens in urine of rubber workers associated with inhalable particulate and dermal exposure; influence of skin quality

R. Vermeulen [(1, 2,3)], R.P. Bos [(2)], J. Pertijs [(2)], H. Kromhout [(1)]

(1) Environmental and Occupational Health Group, Utrecht University, Utrecht, The Netherlands, E-mail: VermeulR@mail.nih.gov
(2) Department of Pharmacology & Toxicology, UMC St. Radboud, University of Nijmegen, Nijmegen, The Netherlands
(3) Present: Occupational Epidemiology Branch, National Cancer Institute, Bethesda, Maryland, US

Introduction

Employment in the rubber industry has long been recognized as being associated with excess cancer risks. Mutagenic activity has been found in chemicals used as raw materials, in airborne rubber dust and fume samples taken from the workplace and in the urine of exposed rubber workers (1-5). Although elevated urinary mutagenicity levels have been detected in these workers, direct relationships with exposure levels seldom have been identified. Only in a study of workers in an aircraft tire retreading company was a direct relationship between urinary mutagenicity and dermal exposure to cyclohexane soluble matter (CSM) found (5). The suggestion that dermal exposure could be an important exposure route in the rubber industry also is supported by the observation that the amount of a contaminant available for uptake through the skin could be up to ten times higher than through inhalation, depending on the specific situation in the work place and use of personal protective devices (6).

Methods

This study was conducted to determine the relationship of the inhalation and dermal exposure routes and mutagenic activity in the urine of rubber workers (n=105). Mutagenic activity of ambient total suspended particulate matter (TSPM), surface contamination and Sunday and weekday urine samples was assessed with S. *typhimurium* YG1041 in the presence of a metabolic activation system. Each subject was grouped into one of two exposure categories for dermal exposure (high (≥25 rev/cm^2), low (<25 rev/cm^2)) based on the mutagenic activity detected on likely skin contact surfaces. Subjects were also grouped into two airborne mutagenic exposure categories (high (≥210 rev/m^3), low (<210 rev/m^3)). The potential influence of skin aberrations and biotransformation polymorphisms (NAT2) on urinary mutagenicity levels also was evaluated.

Results

An elevated increase of 1605 rev./g. creat. in urinary mutagenicity during the workweek relative to levels observed on Sunday was observed for the total population (*t*-test, p=0.08). The increase was most pronounced among technical engineers (+4196 rev./g. creat.; t-test, p=0.08) and subjects who were exposed to high levels of airborne mutagenicity levels and had a high potential for dermal contact with surfaces contaminated with substances exhibiting mutagenic activity (+3206 rev./g. creat. ;*t*-test, p=0.12). Subsequent multivariate regression analyses, with the subjects' weekday urinary mutagenicity levels as the dependent variable, revealed significant associations with the level of mutagenic contamination on surfaces with which the subjects had potential contact, with subjects' inhalable particulate exposure level, with observed skin aberrations, and when the subjects had a slow acetylation phenotype. Similar associations were observed with Sunday urinary mutagenicity levels, except for the association with the slow-acetylation phenotype. High potential for exposure to surface contamination with mutagenic activity was estimated to increase weekday urinary mutagenicity by about 67% when compared to low exposed workers, while high inhalable particulate exposure levels increased weekday urinary mutagenicity levels by about 23%. Subjects with skin aberrations revealed an additional increase in weekday urinary mutagenic activity of about 40% compared to subjects without skin aberrations.

Discussion

These results suggest that the dermal exposure route may contribute more to the level of urinary mutagens of rubber workers than the inhalation route, especially since subjects with skin aberrations revealed an additional increase in weekday urinary mutagenicity levels compared to subjects without skin aberrations. In addition, the levels of mutagens in urine were modulated by NAT2-dependent enzyme activity, with slow acetylators having higher levels of mutagens in their urine than fast acetylators. Prevalence rates of these unfavorable skin and biotransformation conditions in this population were 40% and 60%, respectively, and therefore were important for a significant proportion of the studied workforce.

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Dermal exposure assessment to benzene and toluene using charcoal cloth pads

Van Wendel de Joode BN [1,2], Tielemans E [1], Wegh H [2], Vermeulen R [2,3], Kromhout H [2]

[1] *Department of Chemical Exposure Assessment, TNO Chemistry, Zeist, The Netherlands, e-mail: vanwendel@chemie.tno.nl*
[2] *Environmental and Occupational Health Group, Institute for Risk Assessment Sciences (IRAS), Utrecht University, Utrecht, e-mail: b.vanwendel@vet.uu.nl*
[3] *Occupational Epidemiology Branch, National Cancer Institute, Bethesda, Maryland, USA.*

Introduction

Cohen and Popendorf reported already in 1989 on the use of charcoal cloth to assess volatile toxic materials on skin based on laboratory test results. However, few studies actually used this method to measure dermal exposure in working situations. Consequently, its applicability in field situations remains largely unknown. Especially when control measures are being evaluated dermal exposure assessment may provide useful information that cannot be obtained by biological monitoring.

The aims of this study were to evaluate whether: (1) charcoal pads are useful for dermal exposure assessment to benzene and toluene; and (2) dermal exposure to droplets/aerosols occurred in addition to gases or vapours.

Methods

Full-shift personal inhalation (passive diffusion dosimeter, 3M 3500) and dermal exposure levels were measured for 42 workers of a petrochemical plant performing activities related to shutting down the plant, maintenance, and starting up the plant. Activated charcoal cloth pads (Carbopad$^{tm)}$ (4 x 3cm) were worn on the wrist of the hand of preference to assess dermal exposure.

Samples were stored at –20ºC. Prior to analysis a sample was taken out of each charcoal pad by a punch (30mm). Subsequently, benzene and toluene concentrations of inhalation and dermal samples were determined by CS2-extraction and gas chromatography analyses. Recoveries of charcoal pads for toluene and benzene ranged from 85-108%. In addition, 33 subjects were asked to deliver a urine sample at the end of working day. In order to estimate benzene uptake S-phenylmercapturic acid, a urinary excretion benzene metabolite, was measured according to a method proposed by Boogaard and Sittert (1993). Creatinine levels of urine samples were determined by the Jaffé method.

Results

Since exposure values were log-normally distributed, all statistical analysis were performed with log-transformed values. Dermal benzene and toluene exposure levels (µg/cm^2.8 h) were for 47.4% and 74.2%, respectively, explained by inhalation levels for benzene and toluene (mg/m3) (linear regression analysis, both p-values=0.0001). Therefore, further analyses were performed with adjusted dermal exposure levels using the residues of these two linear regression equations.

Table 1 shows measured inhalation (mg/m3) and adjusted dermal (µg/cm^2.8 h) exposure levels to benzene and toluene per job title. Inhalation levels to benzene and toluene were highest for operators, followed by mechanics performing pitching activities [pitching consists of the placement of partition components into the plant's pipes]. Mechanics who pitched had highest dermal benzene exposure levels, where operators and mechanics performing miscellaneous activities had highest dermal exposure levels to toluene.

Table 1. Geometric means (GM) with 95% confidence intervals (CI) of inhalation (mg/m3) and adjusted dermal (µg/cm^2.8 h) exposure levels to benzene and toluene per job title.

		Inhalation (mg/m3)		Dermal (µg/cm^2.8 h)[*]	
Job title	N	Benzene GM (95% CI)	Toluene GM (95% CI)	Benzene GM (95% CI)	Toluene GM (95% CI)
Operators	13	0.40 (0.23-0.70)	1.12 (0.37-3.42)[†]	1.28 (0.65-2.52)	1.52 (0.78-2.98)[§]
Mechanics pitching	9	0.38 (0.28-0.51)	0.53 (0.27-1.03)[‡]	1.71 (0.72-4.03)[§]	0.92 (0.38-2.23)
Mechanics miscellaneous	7	0.22 (0.10-0.48)	0.11 (0.05-0.27)	0.97 (0.34-2.72)	1.56 (0.54-4.54)
Cleaners, safety personnel	13	0.23 (0.14-0.37)	0.27 (0.11-0.68)	0.55 (0.28-1.08)	0.55 (0.27-1.10)

[*] Residues of linear regression equations.
[†] Statistically significant higher than GM of mechanics performing miscellaneous tasks, and cleaners and safety personnel (p=0.002 and 0.02, respectively).
[‡] Statistically significant higher GM than mechanics performing miscellaneous tasks (p=0.04).
[§] Statistically significant higher GM than cleaners and safety personnel (p=0.03).

The median internal exposure of S-phenylmercapturic acid was 2 mmol/mol creatinine (range 1 – 15). S-phenylmercapturic acid levels (mmol/mol creatinine) were for 13% explained by inhalation exposure levels (exp(β)=1.66, p=0.04). Adjusted dermal exposure values did not explain internal exposure levels (p=0.73), neither did smoking status (yes/no) (p=0.41).

Discussion and conclusion

In general, measured exposure levels were low: inhalation exposures were well below occupational exposure limits and internal values were just above limit of quantification. Inhalation and dermal exposure levels varied when considering different job titles. For job titles with high inhalation exposure levels only partly corresponded with high dermal exposure levels, charcoal pads seemed to measure additional dermal exposure different from exposure due to vapours, possibly caused by small droplets or contact with contaminated surfaces. However, the biological relevance of the dermal exposure measured by the charcoal pads remains unclear and should be studied into more detail, preferably in workplace environments with higher potential for exposure. Nevertheless, the charcoal pads are likely to provide useful information with regard to the evaluation of control measures.

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Occupational exposure to azinphos-methyl during tree fruit thinning: dose modeling and hygienic behavior assessment

Fenske R[(1)], Doran E[(1)], Kissel[(1)], Simcox N[(1)]

[1.] *School of Public Health and Community Medicine, University of Washington, Seattle, WA, 98195, e-mail: rfenske@u.washington.edu*

Introduction

Tree fruit thinning in Washington state apple orchards requires continuous contact with fruit and foliage. Most orchards are sprayed periodically with organophosphorous pesticides to control the coddling moth. Azinphos-methyl (CAS 86-50-0) is the most commonly used compound in the region. Workers are allowed to enter orchards at the expiration of the federal restricted entry interval. Dermal contact represents the primary route of exposure under these work conditions. Workers have access to hygienic facilities, and make use of them, to varying degrees. Studies to date have measured exposure for relatively short periods (e.g., 1-3 days), and have not evaluated the ability of hygienic behavior to reduce body burden. The aim of this study was to estimate azinphos-methyl exposure and dose in 20 workers across an entire thinning season, and to determine the effect of hygienic behaviors on dose.

Methods

Workers were recruited from three different Washington state orchards, and followed over a four to six week period, for a total of 272 person-days of observation. Dislodgeable foliar residues were measured in each orchard across the study period, and residue decay was modeled for each site. Spot urine samples were collected from workers on a daily basis, and analyzed for the dialkylphosphate metabolites of azinphosmethyl: dimethyl phopshate, dimethyl thiophosphate, and dimethyl dithiophosphate. Two models were used to estimate dose from the foliar residue data: one treated dermal absorption as a constant or fixed fraction of dermal exposure, while the other considered absorption to be sensitive to the length of time the residues resided on the skin (1). Model results were compared to dose estimates based on the urinary metabolite data. Access to and use of washing facilities were recorded for each observation. A frequency distribution of hygienic parameters was created for each worker, and multiple linear regressions were performed.

Results

Foliar residue decay was characterized by plotting the log of residue levels vs. days post application to yield a decay constant and half life specific to each work site. R-squared values were .73, .73 and .99 for the three sites. The fixed fraction model over-estimated absorbed daily doses when dermal absorption was treated as a total daily fraction of exposure, and under-estimated doses when absorption was treated as an hourly rate. The time sensitive model, which considered exposure as cumulative, and allowed exposure to continue after the end of the work shift, produced estimates that fell between the two fixed fraction estimates, and these were more consistent with the dose estimates derived from the biologic data (Table 1).

Table 1. Univariate regression analysis of fixed and time sensitive dermal absorption models when compared to dose estimates based on biologic data (n=272).

Dose Model	Adjusted R^2	Coefficient	95% Confidence Interval	
Fixed fraction – daily total	.61	1.83	1.66	2.01
Fixed fraction – hourly rate	.90	0.68	0.65	0.71
Time sensitive	.87	0.93	0.89	0.97

In terms of hygienic behavior all eight workers at one orchard ate lunch off-site, and all but one worker reported washing before lunch 100% of the time. Only this site provide washing facilities on location. This site also provided workers with at least one hour for lunch. In contrast, none of the workers at the other sites ate lunch off-site, and all reported a low frequency of lunch hand washing. These other sites did not provide a well-defined lunch period. The frequency of end-of-shift washing was high across all worksites, with about two-thirds of the workers reporting washing at the end of each day. The effect of these hygienic behaviors was determined by linear regression, with adjustment for dermal exposure. Washing after work reduced estimated dose substantially (Table 2), as did eating lunch off-site. When these two hygienic behaviors were combined, dose was reduced about 75% as compared to a worker who practiced neither behavior.

Table 2. Estimated relative reduction in seasonal absorbed dose of azinphos-methyl in field workers due to hygienic behaviors. Seasonal absorbed dose calculated from urinary pesticide equivalents following dermal exposure to 440 mg of azinphos-methyl.

Hygienic behavior	Seasonal absorbed dose (mg)	Percent of seasonal dermal exposure absorbed	Percent of "No hygiene" exposure absorbed
No hygiene	53	12	100
Wash after work	19	4	35
Consume lunch off-site	37	8	70
Wash after work and consume lunch off-site	13	3	25

Discussion

These results indicate that the length of time pesticide residues reside on the skin can have a significant effect on the amount of pesticide dermally absorbed, and that regular use of on-site washing facilities can significantly reduce total absorbed dose. Two federal standards in the United States – the Field Sanitation Standard (OSHA) and the Worker Protection Standard (EPA) – require that washing facilities be made available to field workers in agriculture who are likely to have contact with pesticide residues. However, no empirical studies that demonstrate the efficacy of such facilities are cited in these standards. The data presented here support the public health relevance of these standards, and demonstrate that access to and use of washing facilities can reduce a worker's seasonal pesticide body burden.

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Dermal exposure to nickel and chromium in electroplating

Mäkinen M [(1)], Linnainmaa M [(1)], Kalliokoski P [(2)] and Kangas J [(1)]

[1.] *Kuopio Regional Institute of Occupational Health, Kuopio, Finland, e-mail: milja.makinen@occuphealth.fi*
[2.] *University of Kuopio, Department of Environmental Sciences, Kuopio, Finland (current address University of Michigan, Environmental Health Sciences, Ann Arbor, MI, USA)*

Introduction

Nickel and chromium compounds have been the most common causes of occupational allergic contact dermatitis in Finland during the 1990's. Some of these compounds are also known as carcinogens. It has been noticed, that skin can be significant route of exposure in electroplating due to inadequate personal hygiene or absorption (1,2,3). Dermal exposure assessment is an essential part of chemical risk assessment according to the European Union legislation, and it is also needed for designing effective exposure control measures. The aims of this study were to develop valid sampling methods, and to assess dermal exposure of electroplaters.

Methods

Potential dermal exposure of the five workers (10 measurements) in two electroplating shops was studied according to the OECD guidance document on pesticide studies. Exposure of the body was measured by sampling with alpha-cellulose patches attached on the top of the work clothing. Hand exposure was measured with the CEN-standardized hand wash method. The total number of the measurements was 16. Biomonitoring and personal air sampling were also included. Dermal exposure was calculated according to the OECD guidance document.

Results

The results of the patch and hand wash sampling are presented in table 1. In figures 1 and 2, the distribution of the metals in different body parts is shown. About 85 % of the total dermal exposure to nickel and chromium was found in legs and thighs.

Table 1. Dermal exposure of electroplaters to nickel and chromium in two Finnish electroplating shops (mg/h).

		Nickel		Chromium	
Exposure	n*	Mean	Range	Mean	Range
Body	10	22.04	0.69-148	1.27	0.23-3.28
Hand	10	0.32	0.11-0.95	0.04	0.01-0.06
Total	10	22.35	0.88-148	1.30	0.33-3.31

* n = number of measurements

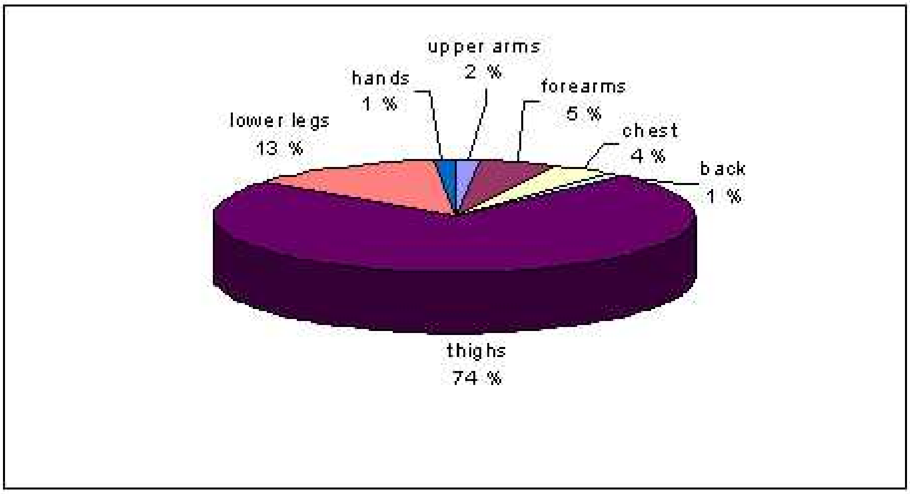

Figure 1. Distribution of dermal exposure to nickel in electroplating.

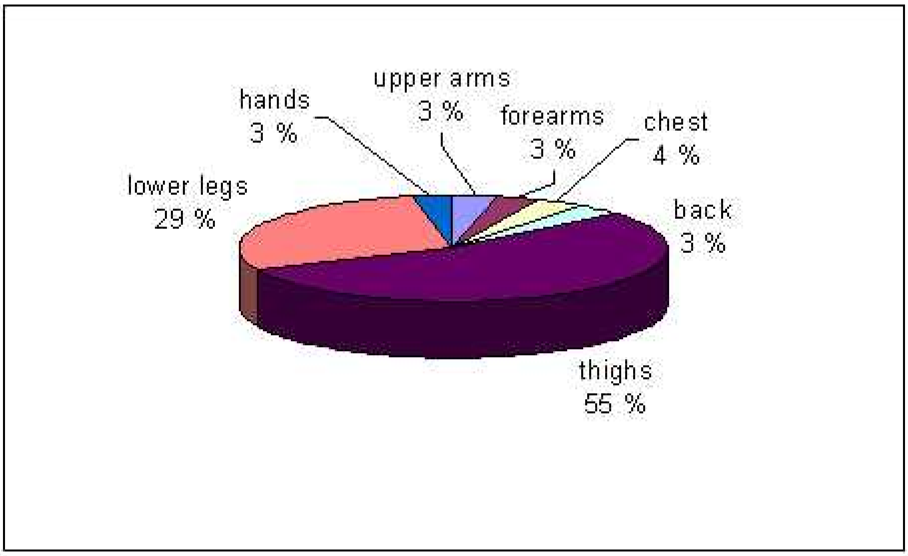

Figure 2. Distribution of dermal exposure to chromium in electroplating.

Discussion

The variation in the dermal exposure between workers was high. The results of the hand wash samples were lower than expected, especially in the cases where the workers did not use protective gloves. The efficiency of the method was tested with tape stripping after washing, but no measurable traces of metals could be found.

Lower parts of the body dominated the exposure. This is quite logical, as the workers must often lean close to the pools. Therefore they may touch contaminated surfaces, and the electrolyte liquid may splash on them. An apron made e.g. of PVC could give quite effective protection.

Conclusions

It is important to compare the results presented here with the biomonitoring and air sampling results. This may give more information about the relevance of the dermal route in occupational exposure of electroplaters. Even though the hand exposure seemed low, it is most important to take care of personal hygiene by washing hands before eating, smoking etc. to avoid hand-to-mouth exposure.

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Assessment of psychosocial work factors among computer users – Tools developed at the University of Wisconsin-Madison

Pascale Carayon, Adsada Sae-Ngow, Leah Newman and William Schmitz

Department of Industrial Engineering, University of Wisconsin-Madison, Madison, WI, USA, email: carayon@engr.wisc.edu

Introduction

The rapid increase in the use of advanced technology in offices has raised concern for the health and well-being of office workers. Numerous research studies have shown that computer users experience musculoskeletal discomfort (1,13,17,18,20,23) and psychological stress (11,18). The focus of the proposed project is to assess a methodology to evaluate work factors that contribute to both musculoskeletal discomfort and psychological stress in computer users.

Different terms have been used to describe CTD's, such as work-related musculoskeletal disorders (WRMD's), repetitive strain injuries, overuse injuries and repetitive motion injury. Putz-Anderson (16) has defined cumulative trauma disorders as well as collection of health problems that have three characteristics. First, they are cumulative, that is injuries develop over a long period of time as a result of repeated, continuous exposure of a particular body part to stressors. Second, the repeated, continuous exposure to stressors leads to trauma of tissues and joints. Third, CTD's are physical ailments or abnormal conditions. Putz-Anderson (16) identifies three types of upper extremity CTD's: tendon disorders (e.g., tendonitis), nerve disorders (e.g., carpal tunnel syndrome) and neurovascular disorders (e.g., thoracic outlet syndrome). This project focuses on musculoskeletal disorders of the upper extremity; that is, in the neck, shoulder, arms and hands regions. Upper extremity CTD's are increasingly becoming more prevalent in the American workforce. The introduction of computer-based technology seems to have been accompanied by an increase in upper extremity CTD's. Computer-based technology seems to intensify work so much as to create stressful and unhealthy working conditions.

There are theoretical reasons to believe that work organization and psychosocial work factors can play a role in the report and development of CTD's (6,7,10,14,19). Several models have been proposed for this theoretical relationship (7,19). One model stipulates that work organization factors, which can cause psychological stress, may influence or be related to ergonomic stressors, such as force, posture and repetitiveness, which can influence CTD's. Another model highlights the physiological, psychological and behavioral stress reactions to psychosocial work stressors that can affect CTD's directly and indirectly. These models are discussed by Smith and Carayon (19), Carayon et al. (7) and Moon and Sauter (14) to show the theoretical relationship between CTD's, on one hand, and work organization and psychosocial work factors on the other hand. There is insufficient research that evaluates tools for assessing the psychosocial work environment of computer users in order to better develop and monitor work redesign interventions aimed at reducing CTD's. This project examines the appropriateness of a questionnaire survey in relation to other methodologies as a means for capturing the work factors that may contribute to musculoskeletal discomfort among computer users.

There is some empirical evidence of the relationship between work organization, psychosocial work factors and CTD's among computer users (12,15,18,20). Studies have shown that the following work factors are potential contributors to musculoskeletal discomfort among computer users: work content (12,15,20), social environment (12,15,20), job demands such as workload, work pressure and cognitive demands (3,15,20), lack of job control (15,20), and job future uncertainty (15,20).

In summary, there are multiple psychosocial work factors that can be related to CTD's among VDT users. Therefore, any methodology aimed at capturing the psychosocial work environment of computer users should examine the multiple facets of that environment. In our project, we examine the following psychosocial work factors (see Table 1).

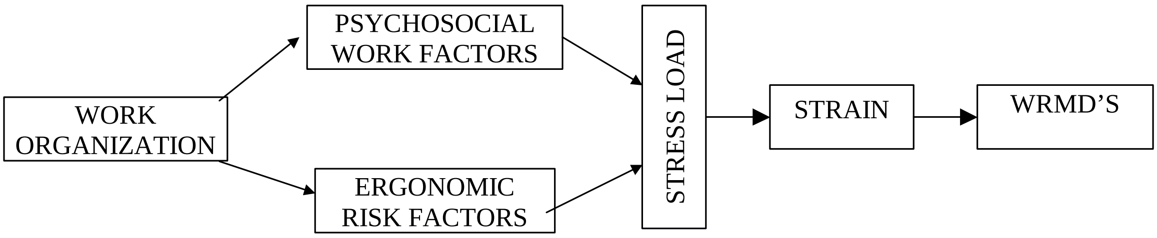
Table 1 – Psychosocial work factors

Job Demands:	quantitative workload
	work pressure
	cognitive demands
	emotional demands
Job Control:	task control
	decision control
	resource control
	control over work pace
	participation
Social Interactions and Relationships:	interaction with clients
	social support from supervisor
	social support from co-workers
Organizational Stressors:	role ambiguity
	job future or career concerns
Job Content:	boredom
	challenge
	task uncertainty
	required skill
Computer-Related Problems:	frequency of computer-related problems

Conceptual model

The conceptual model used for this study is similar to models proposed by various researchers (2,6,10,19). Briefly, work organization can lead to musculoskeletal discomfort and CTD's in computer users. Mediating this relationship are (1) ergonomic risk factors (e.g., postures, force), (2) psychosocial work factors and (3) stress load, as well as the interactions among these factors. Work organization is defined as "*the way in which work is structured, supervised and processed.... It is the objective nature of the work process. Work organization factors are seen as the objective aspects of how work is organized, supervised and carried out.*" (9, pp.393-394). Psychosocial work factors are *the individual subjective perceptions of the work organization factors* (9, p.395). Organizational, ergonomic and psychosocial factors can produce a "*stress load*" on the individual: this stress load can have both physiological and psychological consequences in terms of strain, as well as work-related musculoskeletal disorders (9,21). Figure 1 displays our conceptual model.

Figure 1 – Conceptual model



Study overview

In a research study funded by the Center for VDT and Health Research of the Johns Hopkins University (contract #95-0004), we evaluated the appropriateness of questionnaire-based methods in relation to other methodologies as a means for capturing the psychosocial work factors that may contribute to musculoskeletal discomfort among computer users. In a previous paper, we have reported on the validity and reliability of the University of Wisconsin Office Worker Survey (5). In this paper, we report data on the diary study data.

Diary studies

Diary studies can examine the rapid changes (i.e. daily) in stress and musculoskeletal discomfort over time. The diary study by Carayon and Hajnal (4) examined the cumulative effects of computer use on worker stress in a four-week diary study. The results showed that computer-related problems can be considered as "daily hassles" that affected work stress over time. In the weekly analyses, the results showed that computer slowdown and breakdown and frequency of problems affected the mood of workers. In the monthly analyses, the cumulative of number of computer-related problems was related to worker stress.

Lundberg *et al.* (1999) conducted a diary study among 72 supermarket cashiers in which they investigated psychological and physiological stress responses. Each participant was asked to record symptoms of musculoskeletal pain in the evening for one week. Results showed that older women reported more pain than younger women. In addition, older women had higher blood pressure, more work stress, and psychosomatic symptoms. The cashiers with trapezius problems reported shoulder pain increase successively during consecutive weekdays, and the peak in shoulder pain was on Friday. The researchers concluded that stress levels may be important in explaining neck and shoulder symptoms among cashiers.

Other diary studies have explored the relationship between stress, health, and mood. DeLongis, Folkman, and Lazarus (8) performed a study to scrutinize daily stress among 75 married couples. Data was collected via questionnaires and monthly interviews and included information on social support, self-esteem, beliefs, values and commitment, life stress, health, and psychological well-being. Participants completed the Hassles and Uplifts Scale and the Daily Health record at the end of each day during 4-day period for 6 months. Results showed a significant relationship between daily stress and health problems. The negative effects of stress on mood were limited to a single day. Study participants with low supportive social relationships and self-esteem had more opportunity to report psychological and somatic problems both on and following a stressful day than were participants with high social support and self-esteem. This study also suggested that when stress levels increased, study participants with low psychosocial resources were vulnerable to illness and mood disturbances, even though they had little stress in their lives.

Teuchmann, Totterdell, and Parker (1999) studied how work demands influence acute and chronic stress in a group of 7 accountants. Each accountant recorded data on pocket computers three times a day for four weeks. The measures included negative mood, time pressure, perceived control, and emotional exhaustion. In the aggregated analysis, the data for each day was averaged. Results showed that mood and emotional exhaustion oscillated in parallel to time pressure. The results in the segregated analysis confirmed that work demand had a direct impact on perception of control, time pressure, mood, and an indirect impact on emotional exhaustion. The results suggested that the negative effect of time pressure might be alleviated with enhanced perceived control.

Diary studies have also examined the fluctuation of psychosocial work factors, stress and musculoskeletal discomforts. Fujigaki (1992) investigated the relationship between job pressure and stress in a group of software engineers. She conducted a longitudinal study to observe individual job content and stress for six months. The daily work content was recorded in a diary style. The results of the study showed that stressors, such as time pressure and quantitative workload, were fluctuated over time, and affect on stress of engineers. In this paper, we present results of a diary study that examines psychosocial work factors, stress and musculoskeletal discomfort in a group of computer users. In our diary study, data was collected daily for a total of four weeks.

Methodology

Sample

The sample chosen for our study includes computer users. One division of a large state agency in the Midwest of the USA agreed to participate in the study. In this division, one can find many types of office jobs with a variety of computer usage. In addition, this division and the Department of Industrial Engineering at the University of Wisconsin-Madison have formed a partnership to study the relationship between work organization, well-being and musculoskeletal health. Therefore, we had good cooperation from the employees to participate in the diary study. A total of 20 employees voluntarily participated in this project. See Table 2 for the demographic and job information.

Table 2 - Demographic and job information

Gender:	
Female	86%
Male	14%
Education:	
Completed college with bachelor's degree	40%
Completed some college	33%
Completed high school with other non-college training	6%
Completed high school	21%
Age: (years) [mean, SD]	43.0 (7.1)
Full time employees:	90%
Experience with employer: (years) [mean, SD]	14.2 (9.4)
Tenure of current position: (years) [mean, SD]	9.5 (6.8)
Work hours:	
Per week (hours) [mean, SD]	39.7 (5.9)
Per day (hours) [mean, SD]	8.3 (0.7)
Computer Usage:	
Computer usage per day (hours) [mean, SD]	5.4 (2.0)
Experience with computer (years) [mean, SD]	13.4 (5.2)

Diary study questionnaire

The diary survey questionnaire is comprised of two main sections. First, an introduction part includes a consent form for invitation and agreement for participating in study, a letter to participants, and instructions. The second section contains the questions on psychosocial work factors, stress and musculoskeletal discomfort. Each participant assessed their health at the beginning and at the end of the study to measure starting and ending health conditions by using health information forms. The Profile of Mood States (POMS) scale was used at the beginning of the first week and at the end of each week. Also, participants daily answered the questions on psychosocial work factors, stress, and musculoskeletal discomfort. This latter part of the questionnaire was separated into four one-week sections assessing the participants' health, mood, daily psychosocial work factors, daily stress, and daily musculoskeletal discomfort. See a copy of the daily questionnaire at the end of the paper. In this paper, we present the daily data on psychosocial work factors, stress and musculoskeletal discomfort. Complete data sets for the daily data were obtained for 16 of the 20 employees participating in the overall study.

The measures of psychosocial work factors were developed from the University of Wisconsin Office Worker Survey (Carayon, 1991). The University of Wisconsin Office Worker Survey (UW OWS) is specifically developed for office workers, particularly VDT and computer users. The reliability and validity of this UW OWS have been examined in another part of the research project (5). The diary study questionnaire includes 16 questions that ask about several psychosocial work factors: job demands, job content, job control, social interactions, and computer-related problems. The measures of stress were developed from the Profile of Mood States (McNair *et al*., 1971) and Swanson (1997). The questions ask participants to rate their feelings today. The response scale ranges from 1 to 5 (not at all, a little, moderately, quite a bit, extremely). The questions, scales, and the body part diagram are adapted from the standardized Nordic questionnaires (Kuorinka *et al.*, 1987). These questions ask the participants to assess the level of discomfort, which is defined as pain, aching, stiffness, burning, tingling or numbness, for different body parts. The response scale of discomfort ranges from 1 to 5 (none at all, a little, moderate, quite a bit, extreme). The descriptive statistics for the different scales are presented in Table 3.

Table 3 - Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Job demands	272	1.0	4.0	2.946	.692
Job control	272	1.0	4.0	2.519	.769
Negative social interactions	272	1.0	4.0	1.531	.797
Computer-related problems	271	1.0	4.0	1.454	.759
Social support	255	1.0	4.0	1.900	.900
Fatigue	272	1.0	5.0	2.152	1.251
Tension	272	1.0	5.0	1.564	.941
Upper body discomfort	272	1.0	5.0	1.813	.958
Hand-arm discomfort	270	1.0	3.5	1.281	.556

Further data will be presented and discussed later.

Acknowledgments

Funding for this research project was provided by the Center for VDT and Health Research of the Johns Hopkins University (contract # 95-0004).

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Appendix – Daily questionnaire

Last Four Digits of Social Security Number __________

Date Monday March 3, 1997

Please indicate how much you were exposed to the following working conditions today.

	None	A Little	Some	A Lot
1. How much workload did you have today?	1	2	3	4
2. How much did your job require you to work very fast today?	1	2	3	4
3. To what extent did your work require you to pay extremely close attention today?	1	2	3	4
4. How much did you face hostility or abuse from customers or clients today?	1	2	3	4
5. How much challenge was there in your job today?	1	2	3	4
6. How much influence did you have over the pace of your work, that is how fast or slow you work today?	1	2	3	4
7. How much influence did you have over the order in which you performed tasks at work today?	1	2	3	4
8. To what extent were you able to do your work ahead and take a short rest break during work hours today?	1	2	3	4
9. How much were you able to rely on your immediate supervisor when things got tough at work today?	1	2	3	4
10. How much were you able to rely on other people at work when things got tough at work today?	1	2	3	4

To what extent did you face the following conditions in doing your own work today:

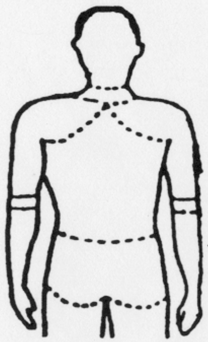
	None	A Little	Some	A Lot
11. Work deadlines	1	2	3	4
12. Backlog of work	1	2	3	4
13. Understaffing	1	2	3	4
14. Contact with people who were upset or emotional	1	2	3	4
15. Computer breakdown	1	2	3	4
16. Slow response of computer	1	2	3	4

Please read each item and circle one number for each word which describes how you have been feeling today.

	Not at All	A Little	Moderately	Quite a Bit	Extremely
17. Fatigued	1	2	3	4	5
18. Exhausted	1	2	3	4	5
19. Bushed	1	2	3	4	5
20. Nervous	1	2	3	4	5
21. Tense	1	2	3	4	5
22. Shaky	1	2	3	4	5

Rate the level of discomfort (pain, aching, stiffness, burning, tingling, or numbness) in each area of the body using the scale below.

Discomfort Scale: 1 = None at all 2 = A little 3 = Moderate 4 = Quite a Bit 5 = Extreme



Please list any Critical/Unusual Events (ie, training, conflicts, meetings, or emergencies) that occurred during your work day today (Please describe)?

____

____

____

The validation of QPSNordic - a questionnaire for psychological and social factors at work

Skogstad, A[1], Dallner, M, Elo, A.L, Gamberale, F, Hottinen, V, Knardal, S, Lindström, K, Øhrhede, E

1. Department of Psychosocial Science, University of Bergen, Norway, e-mail: Anders.Skogstad@psych.uib.no

Introduction

Psychological and social factors at work have been frequently been measured with different measures in the Nordic countries. However, the reliability and validity of such measures have been questionable. The Nordic Council of Ministers established a research group with the aim to develop and validate a questionnaire instrument covering essential psychological and social factors at work, to be used in organizational development and research. The following research questions will be addressed: 1) to what degree do the items in the QPSNordic represent separate dimensions which may be included in separate scales?, and 2) what is the criterion validity of the relationships between QPSNordic scales to measures of well-being?

Methods

This study is based on two questionnaire studies resulting in a database consisting of totally 2010 respondents. During the autumn of 1997 1015 respondents of 16 organisations participated in the first data collection. The second data collection was carried out between May and November 1998 with 995 respondents representing five organisations. Respondents were from Denmark, Finland, Norway and Sweden representing the following sectors: public services, health sector, private services and manufacturing.

Results

The first research question was investigated by analysing the factor structure of the items in the questionnaire. However, items representing background variables, group work, work centrality, and interaction between work and private life were not included in the analysis. Factor analyses of three different subsets of items belonging to three different conceptual levels (task, individual, and social and organisational level), resulted in 26 scales with totally eighty items (table 1). The factor analyses of the task level items (31 items) was forced to 9 factors which explained 51% of the total variance. The factor analysis of individual level items (25 items) produced 6 factors explaining 52% of the total variance. The factor analysis of the social and organisational level items (31 items) were forced to 9 factors explaining 60% of the variance.

Most constructed scales were relatively independent of each other. However, 24 correlation coefficients in the three analyses exceeded .40. Quantitative job demands correlated with decision demands and role conflict, and group work ($r > .40$). Support by superiors correlated with several organisation level scales, other leadership scales, and support from co-workers ($r > .40$). In addition, some other scales measuring the properties of the work organisation correlated with each other.

Table 1. The organization and content of scales in the QPSNordic questionnaire

Content area and scale	Levels of the scale	N of items
Job demands		
Quantitative demands	Task	4
Decision demands	Task	3
Learning demands	Task	3
Role expectations		
Role clarity	Task	3
Role conflict	Task	3
Control at work		
Positive challenge at work	Task	3
Control of decision	Task	5
Control of work pacing	Task	4
Predictability at work		
Predictability during the next month	Organization	3
Predictability of next two years	Individual	2
Preference for challenge	Individual	3
Mastery of work		
Perception of mastery	Individual	4
Social interactions		
Support from superior	Organization	3
Support from coworkers	Organization	2
Support from friends and relatives	Organization	3
Leadership		
Empowering leadership	Organization	3
Fair leadership	Organization	3
Organizational culture and climate		
Social climate	Organization	3
Innovative climate	Organization	3
Inequality	Organization	2
Human resource primacy	Organization	3
Commitment to organization	Individual	3
Work motives		
Intrinsic motivation to work	Individual	3
Extrinsic motivation to work	Individual	3

The second research question was investigated by analysing relationships between the scales and the outcomes job involvement, job satisfaction, emotional exhaustion, distress symptoms and headache. Results in Table 2 show that most and the highest correlations were between scales, and Job involvement and Job satisfaction. Job involvement correlated most highly with Work centrality, Commitment to the organisation, and Positive challenge at work. Job satisfaction correlated strongly with Commitment to the organisation, and also highly with Positive challenge at work, Support from superior, social climate, and low role conflict.

Table 2. Average correlation of samples of the QPS scales to selected outcomes in 2d stage of data collection (n=995)

Scale name	**Job involvement**	**Job satisfaction**	**Emotional exhaustion**	**Distress symptoms**	**Headache**
Quantitative demands	0.05	-0.18	**0.36**	**0.34**	0.18
Decisional demands	0.08	-0.12	0.17	0.13	0.10
Learning demands	0.14	-0.03	0.18	0.15	0.05
Role clarity	0.12	*0.23*	-0.08	-0.15	-0.08
Role conflict	-0.12	**-0.41**	**0.35**	**0.36**	0.17
Positive challenge at work	**0.39**	**0.45**	-0.21	-0.14	-0.04
Control of decision	0.24	0.27	-0.23	-0.10	-0.09
Control of work pacing	0.13	0.19	-0.22	-0.14	-0.10
Predictability during the next month	0.05	0.17	-0.05	-0.03	-0.11
Predictability of next two years	0.18	0.13	-0.05	-0.02	-0.05
Preference for challenge	0.10	-0.04	-0.21	0.01	-0.04
Perception of mastery	0.10	**0.32**	-0.28	**-0.31**	-0.06
Support from superior	0.22	**0.45**	-0.24	-0.22	-0.13
Support from coworkers	0.06	0.25	-0.12	-0.11	-0.05
Support from friends and relatives	-0.01	0.16	-0.17	-0.16	-0.01
Empowering leadership	**0.30**	**0.37**	-0.15	-0.13	-0.09
Fair leadership	0.07	**0.36**	-0.25	-0.27	-0.18
Social climate	0.21	**0.42**	-0.29	-0.28	-0.16
Innovative climate	0.18	**0.33**	-0.19	-0.12	-0.05
Inequality	-0.03	-0.16	0.15	0.13	0.13
Human resource primacy	0.26	**0.39**	-0.24	-0.16	-0.07
Commitment to organization	**0.47**	**0.58**	**-0.37**	-0.21	-0.14
Intrinsic motivation to work	0.16	0.00	0.07	0.16	0.09
Extrinsic motivation to work	0.02	0.01	0.20	0.00	0.07

Any correlation coefficient $r > 0.07$ is significant at 0.05 level (2-tailed).

Discussion

The analysis support the assumption that the items in the QPSNordic may be organized in separate scales were a majority of items show low or moderate correlations.

The findings indicate that the scales in the QPSNordic show adequate predictive validity with respect to job satisfaction, job involvement and subjective health .

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Assessment of work system risk factors among home care workers

Dellve L, Lagerström M, and Hagberg M

Institute of Internal Medicine, Section of Occupational Medicine, Göteborg University, Sweden and National Institute of Working Life, Sweden
email: lotta.dellve@ymk.gu.se

Introduction
The aim of this presentation is to show a methodology to define, register, analyse and assess “the exposures” of the work system for nursing personnel, especially home care workers. There is little information about how exposure factors for nursing personnel should be modelled. The exposure for nursing personnel is complex. It’s argued that assessment of exposure factors should consider the possibilities of prevention in professional and non-professional contexts.

The home care service has grown fast during the last decade, due to health care reforms and this growth is assumed to continue due to the increasing proportion of elderly persons in western societies. The dilemma between organisational circumstances, physical and psychological demands in human service and especially home care work is recognised and discussed (1-3). The demand-control model has been used but has also been criticised for lack of fit within human service occupation (1) and underspecification error (4). The emotional demands, such as the home care workers relation to the client, seem to be especially important (1-3). Qualitative studies also describe the importance of the working climate, such as the relation to and support from the working group and the supervisors (2, 5), insufficient resources and medical problems among care takers (5). There is a further need to theoretically systemise risk factors related to work organisation and at the same time, identify situation-specific risk factors to gain knowledge with practical impact on interventions of the work-place (6). It is important to explore factors that have practical relevance for the organisation of a health promotive working situation.

Home care workers show high levels of indicators related to ill health, such as long-term sick leave, disability pension and occupational disorders. The assessment of exposure must be considered in relation to conditions related to the age of the subjects (main part over 55 years) and gender (95% female). The interference of home-life strain has been highlighted in earlier studies. Dimensions of controllability differ from work in one’s own home compared to work in a caretaker’s home. Among women in this age group, the combination of unpaid domestic labour and formal paid employment seems to be more crucial for health than domestic labour in it’s own. Earlier studies also suggest that it is the specific balance of formal and domestic labour that is related to woman’s health.

The theory of the work system forms a conceptual framework of how job design can improve exposure factors that can produce stress and ill health on the worker. A balance within and among the five job elements: organisation, task, technology, environment and person are desired for a good health (7). According to Carayon & Smith (1999), the accumulated negative aspects can lead to stress reactions and ill health if not balanced by positive factors (8). The work system model has not earlier been used in jobs related to the home care or health care sector. This model of work system can offer a theoretical contribution while concretising risk factors and explore the system of interactions that contribute to work-related health.

Method and study-group
A study was initiated to investigate on how the work system factors contribute to the development of disability pension among home care workers. We used a retrospective case-control design to examine the magnitude of exposure five and 15 year before disability pension, the relative importance of home-life factors and the accumulative effect of a number of risk factors. The study-group was 454 cases (disability pensioned home care workers in Sweden, 1997 and 1998) and 580 controls (home care workers still working) matched by age.

Development of a questionnaire
A questionnaire was developed to assess exposures retrospectively (The questionnaire is available at request by the author). The questions covered aspect of working-life, home-life, life style and employment factors representing dimensions of the model of the work system. The variable specification within the theoretical framework was guided by results from earlier quantitative and qualitative studies of working conditions in home health care work (2, 6). The validity was checked qualitatively through interviews with 20 home care workers; 15 of them were working and five had disability pension. The implications from the results of the interviews were related to defining the time-period, used vocabulary, variable specification and the exclusion of frequency scales. There were no memory difficulties related to the general questions and the items indicated if the problems existed or not. The subjects found it easy to separate the time-period of the previous 5 and 15 years. Since there were non-parametric data, the items were constructed to permit dichotomising and classifications of the answers. Items were theoretically sorted into subgroups representing an exposure variable. Answers of the underlying items in each subgroup were theoretically grouped into exposed or unexposed. Cronbach's alpha coefficient, of cases and controls, were used to indicate degree of internal consistency within each subscale. Correlation within each work system element was also controlled.

Modelling procedures
The magnitudes of variables within each element of the work system were estimated by using logistic regression. Those variables that were significant (logOR $p<0,05$) were included in the overall model. In the overall model interactions between the selected variables were tested using the systematic of hierarchically principle by Kleinbaum (9). The possible influence on the model from factors related to person's lifestyle/life-satisfaction, home-life, employment and age were estimated by effect likelihood ratio test (9).

Results and discussion
Variables of exposures in home care work did easily fit the model of work system. We modified the model to suit working conditions among female nursing personnel, especially home care workers (Table 1). We also included the home-life factors. Home-life factors were related to influence and controllability (own time at home, influence on decisions), demands (possibilities to rest from work, workload, caring needs), support in work related issues, quality in leisure-time and violence. The modelling procedure worked well like the classification procedure of exposures. However, the use of Cronbach alpha statistics for originally qualitative data can be questioned. The results of the present study show that risk factors in working-life here systemised within elements of the work system were strongly related to the magnitude of risk for disability pension. Work-system risk factors were robust to the inclusion of factors of home-life, lifestyle/ life-satisfaction and employment-profession in the models. Being exposed to the more risk factors within the same work system element increased the magnitude of risk for disability pension.

Table 1 Work system variables included in analysis

Work system variables	Cronbach's alpha 15 / 5 year previous
ORGANISATION	
Formal properties – regularly routines	0.87 / 0.70
(regular supervision, competence dialogue and general workers meeting)	
Controllability	0.87 / 0.73
(own/work-groups influence in decisions, participation in planning work and schedule)	
Organisational support	0.79 / 0.70
(availability of medical expertise, time to grief clients death, organising substitute in absences)	
Leadership	0.86 / 0.81
(competent leadership, available leader, support, conflicts solving abilities)	
Competence development	0.81 / 0.69
(possibilities for developing one's competence, use of competence, possibilities to learn)	
TASK	
Task demands	*
(workload, time-pressure)	
Ergonomics / lifting	0.86 / 0.76
(heavy lifting, lifting in uncomfortable postures, lifting by one's own)	
Quality in caring performance	*
TECHNIQUE	
Lifting technique	*
(lifting aides, co-working)	
Caring technique	*
ENVIRONMENT	
Organisational distrust	0.84 / 0.82
(distrust in organisations ethical decisions, prioritising and/or "general orderliness")	
Working climate	0.81 / 0.71
(work-group support, perceived climate in work-group)	
Relational problems	0.92 / 0.76
(unjust treatment by superior, mobbing)	
Violence	0.93 / 0.84
(threats, sexual violation)	

*Single items

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The effect of hearing protectors to exposure in cold environment

Toppila E [(1)], Starck J [(2)], Pyykkö I [(3)]

[1.] *Finnish Institute of Occupational Health, Esko.Toppila@occuphealth.fi, Finland*
[2.] *Finnish Institute of Occupational Health, Finland*
[3.] *Karolinska Institute, Sweden*

Introduction

A hearing protector (HPD) can reduce the exposure significantly. The nominal attenuation, recommended by the manufacturers, varies from 11 dB to 35 dB, depending on the HPD and the frequency contents of the noise (1). This nominal attenuation is obtained if the usage rate is more than 99% of the exposure time (2). However, the use of manufacturers' data for the evaluation of attenuation has been questioned in several studies suggesting that the field attenuation may be 3-10 dB smaller then the given attenuation.

Very little is published on the attenuation of HPDs in extreme conditions like cold. In cold environmemt the workers wear helmet liners with the helmet. In this situation the earmuffs are placed on the liner which may reduce the attenuation of the HPD.

The purpose of this study is to evaluate the effect of cold to attenuation of HPDs.

Methods

In the first part the effect of liners which are often used to The study comprised of three earmuffs commonly used by Finnish forest workers. The attenuation of the hearing protectors was measured with subjective method at room temperature. A total of 14 subjects were used. The attenuation was measured with no liners, with cloth liners, with fur liners and with slip fur liners. In the slip fur liner the cup of the HPD could be placed inside the liner via the slip.

To measure the effect of cold to the HPDs attenuation was conducted in a cold chamber (-10 C) were the HPDs were kept for several hours. Then the test person installed the HPD and the change in the sound level was recorded in 10 s interval. When no change was obtained the measurement was stopped.

Thirdly the usage rate of HPDs was evaluated among 100 forest workers during a time period of 1960-1995 by a questionnaire.

Results

The subjective measurements show the helmet-liner decreases the attenuation of the earmuffs. When using a helmet cloth liner at frequencies below 1 kHz the performance decreased about 6 dB and at frequencies over 1 kHz about 3 dB. The fur helmet-liner decreased the attenuation below 1.5 kHz to almost zero. Above that the attenuation increased about 15 dB/octave, but it still remained far less than without the liners. When using a slip fur liner the attenuation increased by about 2 dB at all frequencies.

The temperature of the HPDs increased to normal in some minutes. The effect of cold depends a lot of frequency. Attenuation stabilized in some minutes (fig 1). When applied to forest the measured attenuation changes and taking into account the pauses during which the HPDs are taken off in cold, the effect to the total daily exposure was at highest 3 dB.

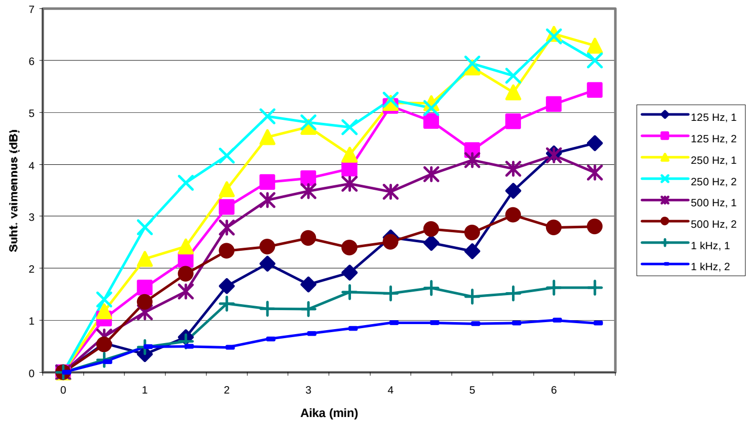

Figure 1. Change in attenuation at different frequencies of a HPD after they are mounted

According to the questionnaire the use of HPDs started in early 1970ies and ten years later 95 % of the forest workers used always HPDs (fig 2).

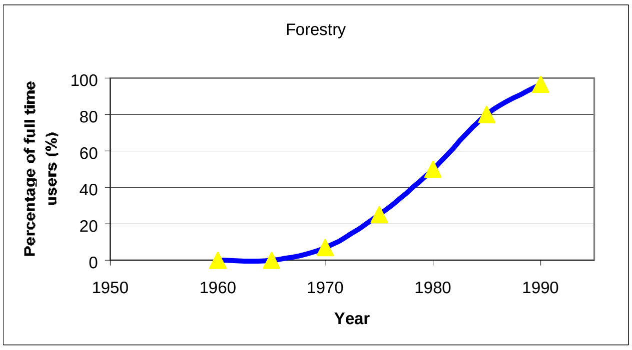

Figure 2. The development of usage rate of HPDs with time

Discussion

A liner increases the leakage when placed between the cushion and the skin, which is the explanation for the results. As the maximum of the power spectrum of the chain saw is between 500 and 2000 Hz. Using the EN 458 methods it can be evaluated that performance of the protectors is about sufficient when no liners are used or when the slip fur liners are used. In other cases the performance is not sufficient. Specially the fur liner should be avoided, because of it's effect to the attenuation.

The effect of cold to attenuation was small. We may expect the highest effect among forest workers who have to refill the chain saw during each hour of operation. When the chain saw is not running, the HPDs are in stand-by position and are cooled by the ambient temperature.

The use of HPDs was polarised. Workers either used the HPDs regularly or they did not use them or used them only a couple for very short periods, since only a couple of workers reported usage rate of HPDs from 30 to 95 %. The high usage rates are more unreliable than the low ones, since even a short time without HPDs is sufficient to decrease considerably the performance of the HPD. Thus the mean attenuation of HPDs and the mean levels are probably too optimistic by a few dB since the mid-eighties.

Conclusions

The exposure evaluation in cold work is affected by the use of liners and the number of times the HPDs are taken away. Although HPDs are nowadays used with 95 % usage rate in life time exposure evaluation the usage rates are still the highest source of error.

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The role of free-time and military exposure in total life noise exposure

Starck J [(1)], Toppila E [(2)], Pyykkö I [(3)]

[1.] *Finnish Institute of Occupational Health, Finland, e-mail: Jukka.Starck@occuphealth.fi,*
[2.] *Finnish Institute of Occupational Health, Finland, e-mail: Esko.Toppila@occuphealth.fi*
[3.] *Karolinska Institute, Sweden, e-mail: iipo@ent.ks.se*

Introduction

Most hearing conservation programs (HCP) focus on occupational noise exposure. People in modern society are exposed additionally to wide range of environmental noise that has mostly been neglected. The standard ISO-1999 (1) intended to the risk assessment of noise- induced hearing loss (NIHL) does not provide any rules to combine the various noise exposures, when the total noise exposure is composed of free-time noise, military service noise and occupational noise. The exposure of the inner ear to noise is also dependent on the use of hearing protectors.

Shooting and hunting increase the risk of hearing loss. Forest workers who were exposed to gunfire noise had an additional 10 dB hearing loss than those who had only occupational exposure to chain saw noise (2). NIHL occurs at a younger age in the military than in other groups of workers exposed to excessive noise (3). In branches of the military where large caliber weapons are used, the risk is especially high, as is the development of NIHL. Hearing protection has proved to be less effective here, due to the non-linearity of the attenuation against very high peak levels and the low frequency components of large caliber weapons (4).

Exposure to gunfire noise is difficult to assess, since there is no standard method available to evaluate its effect on the inner ear. The existing measurement methods can be divided into two categories; the peak level methods and energy attenuation methods.

The most frequent exposure in free time is exposure to music. The highest music exposure rates are from rock music. Noise levels in a concert or a disco may be around 100 dB. Thus, only one attendance a week causes an exposure exceeding the occupational action limit. Similar levels are reported in the users of portable cassette recorders (5). In classical music the levels are lower but the musicians still have a risk of hearing loss. Among musicians the use of HPDs are low, but use is increasing, notably during rehearsals. Music exposure is frequent among young people. Among middle aged or older people it is very tends to decrease. No studies about the free-time exposure of the adult population is available.

The aim of the present study is to evaluate the exposure of adult people in free-time and propose a model for the cumulative life time exposure

Methods

The subjects consisted of three different groups of workers: forest workers (N=100), papermill workers (N=406) and shipyard workers (N=176). The data for the forest workers were obtained during a follow-up study 1972-1995 (Pyykkö et al 1989). The data for the papermill workers and shipyard workers were obtained from the local occupational health care centres. The noise exposure was measured as A-weighted energy equivalent level by qualified industrial hygienists. The accuracy of the noise level measurement was estimated to be 3 dB. The noise exposure level inside the HPD was calculated. The usage rate of HPDs was collected using a questionnaire. The workers were asked to evaluate whether they use HPDs always, often, half of the time, occasionally, never. These evaluations were rated to correspond to 100 %, 75 %, 50 %, 25 % and 0 % usage rates, respectively.

Results

In the papermill, the mean noise level was 93 dB(A), in the shipyard 93-95 dB(A), and in forest work 95-97 dB(A). The mean attenuation of the HPDs was 15 dB in forest work, 17 dB in the papermill, and 20 dB in the shipyard.

Unlike youngsters our subjects did not report exposure to music. However powertools and snow scooters were regularly used by 16% of the subjects. During this time only 13 % used HPDs. Totally 361 (53%) subjects reported shooting during their free-time. The total number of shots was small, 92% of subjects had shot less than 1000 shots in all and 8% reported over 1000 shots. HPDs were used by 47% of subjects all the time, and 29% reported that they never used HPDs. 25% of subjects were estimated to have been exposed to several hundreds shots while not wearing HPDs.

Military service exposure to noise from handguns was reported by 468 (68%) subjects. The median value was 101-1000 shots. HPDs were worn 42% of subjects during shooting most of the time, 12% reported non-usage at all and 25% reported using them always. Military service exposure to large calibre weapon noise was reported by 266 (40%) subjects. 161 (25%) subjects had been exposed to less than 10 shots. 63% of the subjects used the HPD always, while 13% did not use HPDs at all.

The problems can be illustrated with the following example (Fig. 1). A shipyard worker starts working at the age of 20 years. He is exposed at work to 98 dB(A) impulsive noise. He uses HPDs with a nominal attenuation of 24 dB. He attends weekly discos and concerts with a mean sound pressure level of 98 dB(A) for 6 h. He starts visiting the discos at the age of 15 and stops at the age of 30. His hobby is hunting. Annually he shoots 30 shots on average in the forest without HPDs and 100 shots of target shooting with HPDs. Based on these figures the cumulative exposure is calculated from concerts and discos, the true work exposure with its accuracy, and the estimated work exposure without use of HPDs (Fig. 1). If the use of HPDs is omitted the considerable overestimate of exposure is obtained. Even with the poorest use of HPDs, the free-time exposure is the dominant exposure. The logarithm of the number of shots without HPDs is also given in figure 1. As stated earlier there is no generally accepted way to combine steady-state noise and shooting noise. Still the number of shots presented here is large enough to be a cause of notable hearing loss.

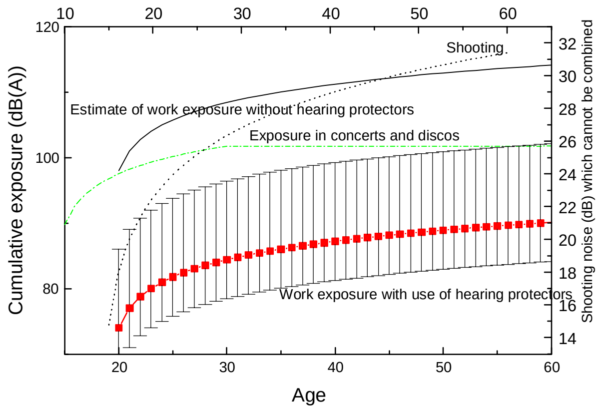

Figure 1. An example of the model of the role of free-time and occupational exposure when HPDs are used in total exposure evaluation

Conclusions

Free-time exposure may be more important than work exposure, especially when HPDs are used. Shooting noise also contributes significantly to the total noise exposure. However, there are no rules for combining these two exposures.

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Estimation of lifetime noise exposures based on audiograms and international noise and ageing standards

Franks JR

National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, Ohio 45226, USA, jfranks@cdc.gov

Introduction

Exposures to noise and the simple act of ageing have negative consequences for hearing sensitivity: both result in loss of hearing. When studies have been conducted to determine the effect of either ageing or noise exposure on hearing, the primary task has been sort out the hearing impairment due to each. There are two standards (3,2) that propose methods for predicting the impact of noise exposure on hearing. Each standard provides reference databases; ANSI S3.44 included the two databases contained in ISO 1999 plus one additional. Just as these standards allow prediction of hearing loss due to ageing and noise exposure, their equations may also be used in reverse to determine the amount of noise that would be responsible for an observed, age-corrected hearing loss. These noise levels may then be compared to observed noise exposures in order to determine the accuracy or error of the standards. As well, this procedure may suggest modifications to the standards= equations may be in order.

Methods

Audiometric databases from mining and manufacturing sector companies were analyzed to determine the prevalence of materials hearing impairment by worker age. These databases contained date of employment, birth date, hearing thresholds with test dates, as well as some indication of noise exposure level and the use of hearing protectors. Exposure ranges were as low as 75 to 80 dBA and as high as 110 dBA. For those workers exposed to greater than 85 dBA, hearing protector usage was ranked from seldom to more than 50% of the time.

In order to have estimates of the prevalence of hearing impairment from each data base as function of worker age, it was necessary to first Aclean@ the data by removing questionable audiograms. The NIOSH Expert System (4) was used to filter all of the audiograms in the databases. Audiograms were removed if the thresholds were not repeatable on subsequent audiograms, if there were large interaural differences suggesting poorer-ear shadow audiograms, if the audiogram appeared to be affected by excessive background noise levels in the test booth, and for other irregularities.

For each database, prevalence of hearing impairment (binaural average hearing levels for the 1000, 2000, 3000, and 4000-Hz pure-tone average equal to or greater than 25 dB HTL re ANSI S3.6-1996) was calculated for each database as a function of worker age and compared to prevalence of hearing impairment predicted by the standards due to age alone. Figure 1 shows such a comparison. By reversing the equations in the standards, the amount of noise that would be responsible for the magnitude of observed prevalence of hearing impairment in this example was calculated to be between 98 and 100 dBA (8-hour time weighted average based on a 5-dB exchange rate).

From the low-noise exposed databases an age-based prevalence of hearing impairment was established which was compared to the standards. The prevalence values from the other databases were compared to this as well.

Results

The results indicate that the standards provide a greater weight to age than to noise and the differential emphasis is particularly noticeable as the exposure levels increase. The results also indicate that the standards= assumption that age effects and noise effects are additive is probably too simplistic. While the data show most hearing loss occurring within the first few years of employment, the standards provide a linear growth with time. Finally, the standards do not accurately predict further accrual of hearing loss once and initial noise-induced hearing loss has been sustained, as occurs frequently according to the data.

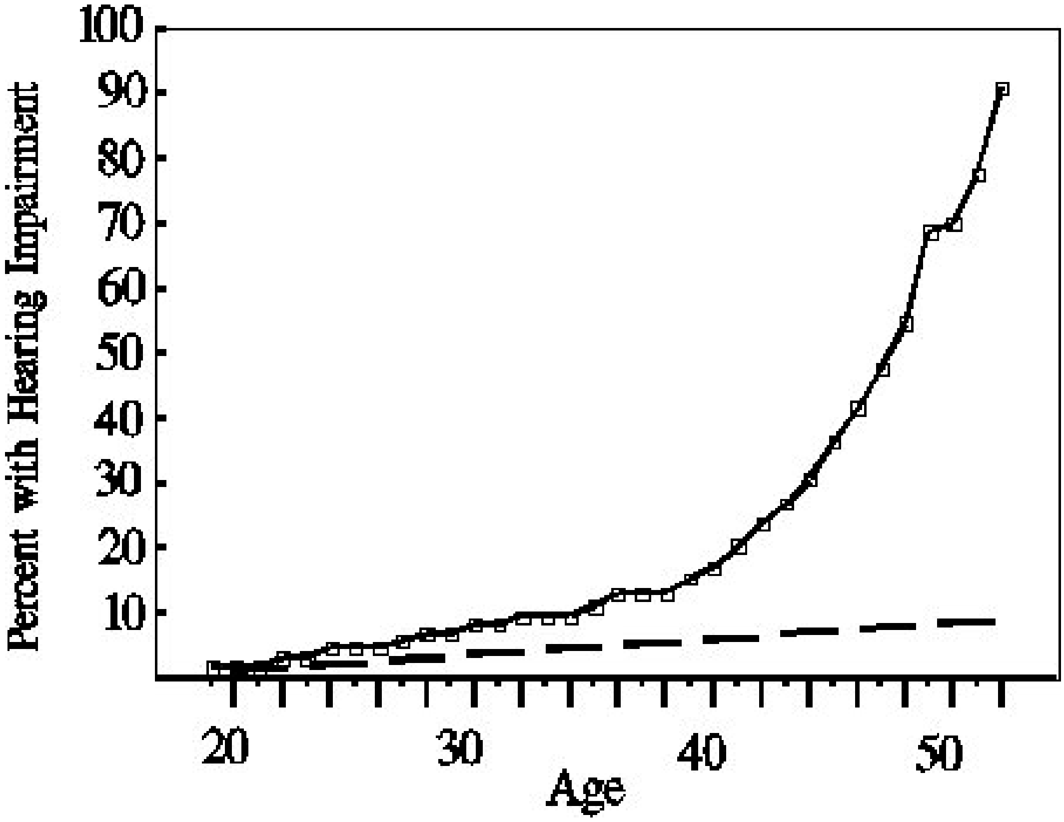

Figure 1. Percent of miners with NIOSH defined hearing impairment (average of 1000, 2000, 3000, and 4000 Hz => 25 dB) by age - solid line - compared to the percent of the non-occupationally exposed population having hearing impaired as calculated from ISO-1999- dashed line.

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Using employees' self-logged record to identify high-risk tasks of exposure to 1,3-butadiene in the petrochemical industry

Chang HY[(1)], Smith TJ[(2)], Shih TS[(3)], Cheng CJ[(3)], Lin WC[(4)], Guo YL[(1)]

[1.] *Graduate Institute of Environmental & Occupational Health, National Cheng Kung University Medical College, Tainan, Taiwan, ROC, e-mail: h7154@mail.ncku.edu.tw*
[2.] *Dept. of Environmental Science, Harvard School of Public Health, MA, USA*
[3.] *Institute of Occupational Safety and Health, Council of Labor Affairs, Taipei, Taiwan* [4.] *Dept. of Cosmetic Science, Chia Nan University of Pharmacy and Science, Tainan, Taiwan*

Introduction

Environmental monitoring by time-weighted sampling has long been applied to assess the personal exposure to the chemical hazards in the work place. For the same hazard, however, the inter-individual variability within the same day or the inter-day variability for the same person was found to be substantial in some industries. This study aimed to use employees' daily self-logging records to identify high-risk tasks of exposure to 1,3-butadiene in the petrochemical industry.

Methods

Full-shift timed-weighted sampling was performed to determine the exposure of 1,3-butadiene for four teams of total 35 workers in the refinery department of a petrochemical factory for 35 consecutive working days. Passive sampling badge and gas chromatography equipped with flame ionization detector was applied in personal sampling and instrumental analysis, respectively. A structured logbook was designated to each participant to record daily activities in details throughout the work shift. Because the workers stay in the control room for the most working time, the fixed-site sampling in control room for each working day as the baseline exposed levels of 1,3-butadiene for the most workers.

Results

The exposure levels of 1,3-butadiene were found to be largely diversified among individuals of the same team in the same day. It was also noted that the inter-day variability is significantly substantial for some identical workers. All the 1,3-butadiene concentrations monitored in the control room were under limit of detection (0.076 ppm). The detailed time-activity self-logbook for each workers were used to determine the high risk tasks by using the equation listed as follows. The valve-switching was found with the highest exposure levels and most significant contribution to the daily time-weighted average concentration of 1,3-butadiene.

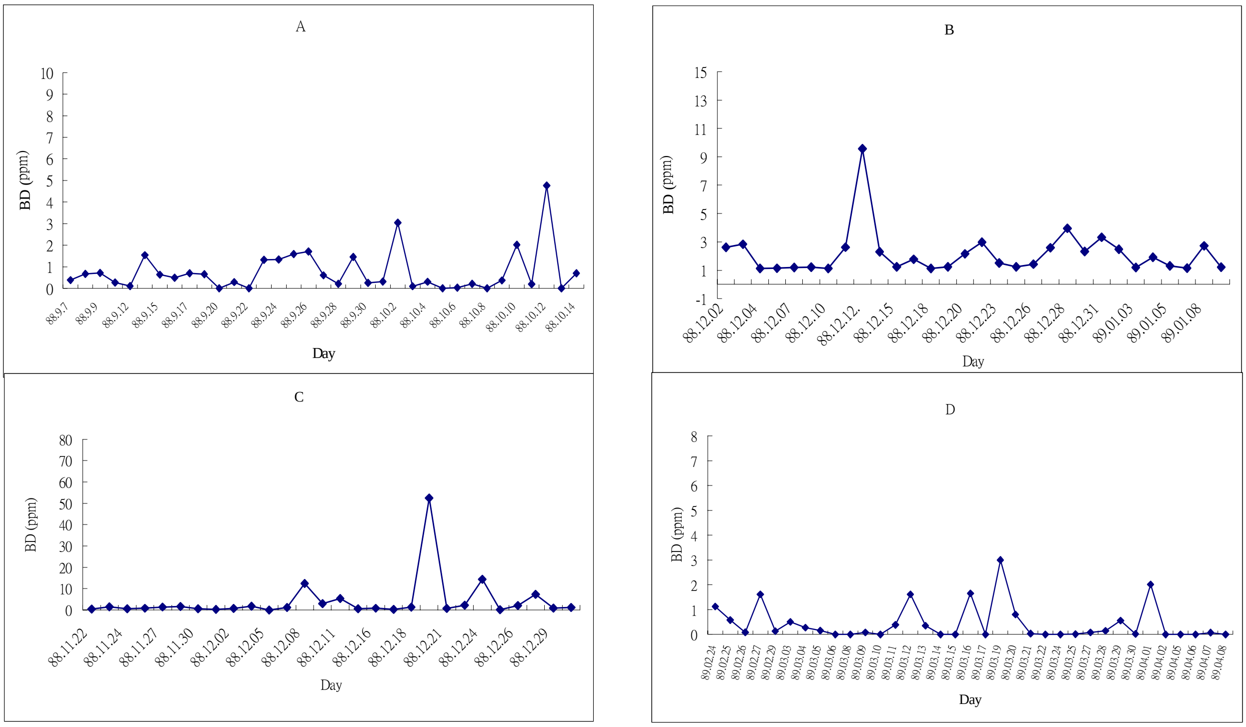

Figure 1. Inter-individual 1,3-butadiene concentration profiles among four teams over 35 consecutive working days.

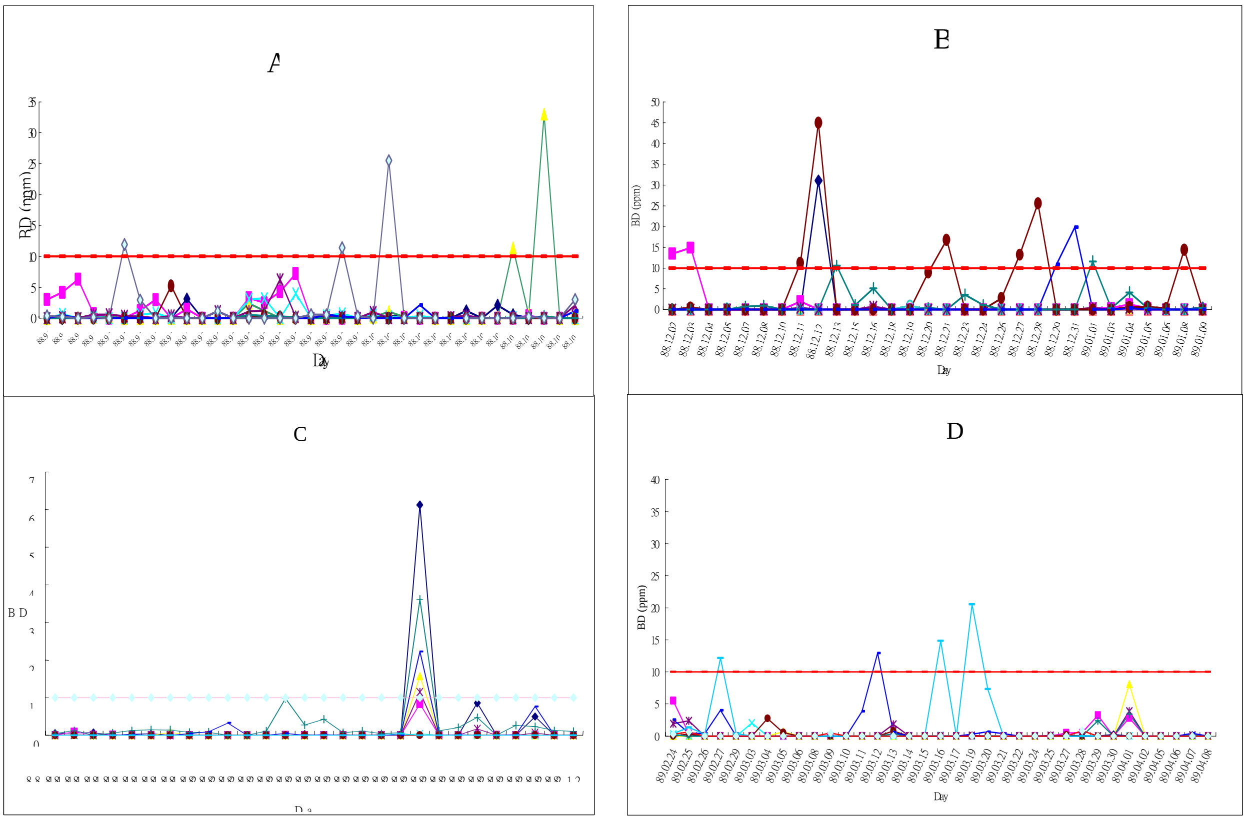

Figure 2. The inter-day concentration profile of 1,3-butadiene exposure among four teams over 35 consecutive working days.

$$C_i = \frac{\overline{C_{TWA}} * T_{TWA}}{\sum T_i}$$

TWA: Time-weighted adjustment in full-shift working time
C: 1,3-butadiene concentration (ppm)
T: sampling time
i: task happened other than in control room

Conclusions

This study demonstrated the potential applicability of a using daily employees' self-logging record to identify high-risk tasks of exposure to 1,3-butadiene in the occupational settings.

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Self-reported versus expert opinion on exposure to potentially hazardous substances: A comparison of its effect on risk-estimates in a case-control study of Aplastic Anaemia

Muir KR [(1)] Grainge M [(1)] Gardiner K [(2)], Van Tongeren M [(2)] Chilvers CED [(1)]

(1) Division of Public Health Medicine and Epidemiology, University of Nottingham. kenneth.muir@nottingham.ac.uk, UK
(2) Institute of Occupational Health, University of Birmingham.

Introduction

Aplastic Anaemia is a rare but serious condition in which the marrow of sufferers is suddenly lost and replaced with fatty deposits. There have been a number of epidemiological studies investigating the possible risk factors for the occurrence of this disease and several factors have been suggested but weakly characterised. These include occupational exposure to paints, dyes, solvents, pesticides and radiation. The previous informative studies have all been of the case-control design and have relied on participants' self-reported exposure.

The United Kingdom Aplastic Anaemia study was set up in 1993 to investigate the suggested factors above in a case-control study of cases occurring in the United Kingdom. For adults, a total of 146 cases and 284 controls were included in the study. A detailed questionnaire assessing occupational exposure, lifestyle, medications and other factors was employed. Computation of risk by exposure to specific chemicals has been calculated and is reported in detail elsewhere.

A further investigation centred on utilising expert opinion to classify likely exposure on the basis of occupational history and details on specific tasks and duties within jobs. This current paper reports the comparison of the levels of agreement seen and on the calculation of risk as scored by 1, self-reported data on exposure; 2, expert assessment of likely exposure from an occupational and duties history from participants' work histories.

Materials and methods

Exposure was classified on the basis of participants' self-reported exposure and expert opinion on their occupational history. These were both scored and the levels of agreement calculated. Odds ratios for each exposure were calculated (adjusted for manual and non-manual status) and a comparison made of the risk estimates derived using each of the two approaches to defining exposure.

Results

Table 1: Levels of agreement between the expert opinion and self reported exposure as recorded in the questionnaire

Solvents		Exposure according to expert (% of row total)		
		+ ve	- ve	Total
Exposure according to questionnaire	+ ve	112 (69.6)	49 (30.4)	161 (100)
	- ve	84 (31.2)	185 (68.8)	269 (100)
	Total	196 (45.6)	234 (54.4)	430 (-)

Petrol/diesel/hydrocarbons		Exposure according to expert		
		+ ve	- ve	Total
Exposure according to questionnaire	+ ve	89 (70.1)	38 (29.9)	127 (100)
	- ve	75 (24.8)	228 (75.2)	303 (100)
	Total	164 (38.1)	266 (61.9)	430 (-)

Dyes/pigments		Exposure according to expert		
		+ ve	- ve	Total
Exposure according to questionnaire	+ ve	26 (32.5)	54 (67.5)	80 (100)
	- ve	26 (7.4)	324 (92.6)	350 (100)
	Total	52 (12.1)	378 (87.9)	430 (-)

Cutting or lubricating oils		Exposure according to expert		
		+ ve	- ve	Total
Exposure according to questionnaire	+ ve	84 (74.3)	29 (25.7)	113 (100)
	- ve	67 (21.1)	250 (78.9)	317 (100)
	Total	151 (35.1)	279 (64.9)	430 (-)

Asbestos		Exposure according to expert		
		+ ve	- ve	Total
Exposure according to questionnaire	+ ve	33 (45.2)	40 (54.8)	73 (100)
	- ve	28 (7.8)	329 (92.2)	357 (100)
	Total	61 (13.9)	369 (86.1)	430 (-)

Pesticide		Exposure according to expert		
		+ ve	- ve	Total
Exposure according to questionnaire	+ ve	24 (55.8)	19 (44.2)	43 (100)
	- ve	27 (7.0)	360 (93.0)	387 (100)
	Total	51 (11.9)	379 (88.1)	430 (-)

Herbicides/weedkiller		Exposure according to expert		
		+ ve	- ve	Total
Exposure according to questionnaire	+ ve	17 (47.2)	19 (52.8)	36 (100)
	- ve	27 (6.9)	367 (93.1)	394 (100)
	Total	44 (10.2)	386 (89.8)	430 (-)

Wood preservatives		Exposure according to expert		
		+ ve	- ve	Total
Exposure according to questionnaire	+ ve	31 (57.4)	23 (42.6)	54 (100)
	- ve	28 (7.5)	348 (92.6)	376 (100)
	Total	59 (13.7)	371 (86.3)	430 (-)

Metal filings		Exposure according to expert		
		+ ve	- ve	Total
Exposure according to questionnaire	+ ve	21 (21.7)	76 (78.4)	97 (100)
	- ve	6 (1.8)	327 (98.2)	333 (100)
	Total	27 (6.3)	403 (93.7)	430 (-)

Soldering fumes		Exposure according to expert		
		+ ve	- ve	Total
Exposure according to questionnaire	+ ve	33 (41.3)	47 (58.8)	80 (100)
	- ve	29 (8.3)	321 (91.7)	350 (100)
	Total	62 (14.4)	368 (85.6)	430 (-)

Table 2: Odds ratios for exposure to occupational substances according to expert opinion and self-reported data.

Exposure	Matched Odds Ratio and 95% CI (adjusted for manual/non-manual status) Odds ratios estimated according to expert opinion	Odds ratios as calculated from self- reported data
Solvents	1.60 (0.99, 2.60)	1.66 (1.03, 2.69)
Petrol/diesel/hydrocarbons	1.09 (0.60, 1.98)	1.19 (0.73, 1.92)
Dyes/pigments	1.28 (0.67, 2.44)	1.22 (0.72, 2.06)
Cutting/lubricating oils	2.01 (1.15, 3.52)	2.10 (1.23, 3.57)
Asbestos	1.50 (0.77, 2.91)	2.03 (1.12, 3.68)
Pesticides	1.34 (0.68, 2.64)	2.08 (1.07, 4.03)
Herbicides/weedkillers	1.34 (0.67, 2.66)	1.73 (0.86, 3.47)
Wood preservatives	1.22 (0.63, 2.38)	1.45 (0.74, 2.85)
Metal filings	1.03 (0.45, 2.35)	2.18 (1.27, 3.75)
Soldering fumes	2.07 (1.08, 3.97)	2.23 (1.29, 3.85)

Conclusion

The levels of agreement between exposures as reported directly by participants and as estimated from occupational history by expert assessment, show that agreement was only moderate and for some exposures, such as dyes, was relatively poor.

The consequences for risk estimates of such differences in categorisation are that the odds ratios are generally higher when calculated using self-reported data. Indeed, for four exposures (solvents, asbestos, pesticides and metal filings) the risk was only statistically significant for self-reported data. For cutting/lubricating oils and soldering fumes the risk was significantly elevated for both approaches.

These results highlight the uncertainties in identifying occupational exposures.

Risk perception and self-assessment of exposure to antineoplastic agents among nurses: the preliminary data

Petrelli G [(1)], Vollono C [(2)], Badoni G [(1)], Papaleo B [(3)], Rocco G [(4)]

[1.] *Laboratorio di Epidemiologia e Biostatistica. Istituto Superiore di Sanità, Rome, Italy, e-mail: petrelli@iss.it*
[2.] *Laboratorio di Igiene Ambientale. Istituto Superiore di Sanità, Rome, Italy*
[3.] *Dipartimento di Medicina del Lavoro. ISPESL, Rome, Italy*
[4.] *Collegio IPASVI, Rome, Italy.*

Introduction

For many anticancer drugs a genotoxic, mutagenic, or carcinogenity activity has been proven in experimental systems (1). The first evidence of the potential health effects of exposure to antineoplastic agents on the health of healthcare workers was obtained from the examination of the mutagenity of urine from nurses who had handled cytostatic agents (2). For some antineoplastic drugs there is also sufficient evidence of a carcinogenic effect in humans (3). Furthermore, hospital work environments may be characterized by occupational hazards for reproduction due to a combination of chemical and biological agents, shift work, high physical work load, and psychological stress. All of these can potentially have adverse effects on reproduction, but limited data are available (4). The aim of the present study is to evaluate, by risk self-assessment data, occupational exposure to antineoplastic agents in nurses working in hospitals, considering that exposure levels can be influenced by misperception of risk and lack of information.

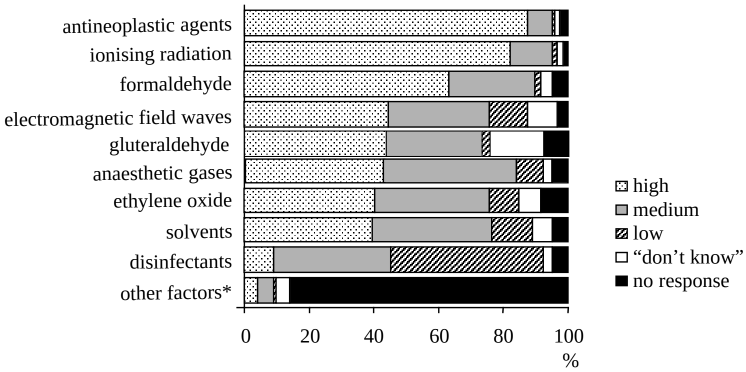
Methods

The study involved a random sample of 119 nurses of both sexes, aged 20-55, working in different hospital divisions and resident in the district of Rome. A short mail questionnaire was used to collect data from each subject. The questionnaire included information on age, sex, marital status, educational level, employment history, and job at the survey time. The questionnaire also collected information about the consciousness of possible harm to health caused by chemical and/or physical agents present in the hospital environment such as disinfectants, anaesthetic gases, solvents, electromagnetic field waves, ionizing radiation. Furthermore, the study investigated the perception of risk and knowledge about the effects of exposure to antineoplastic drugs on health and safety precautions to be adopted in handling these substances. In addiction, each worker was questioned about past and present occupational exposure to antineoplastic drugs. Lastly, data were collected about accidents that had occurred when handling these agents. We considered "exposed" the workers involved in the following jobs: preparation of antineoplastic drugs, their distribution in the hospital divisions and administration, change of contaminated linen, cleaning of rooms for reconstitution of antineoplastic agents, and removal of contaminated waste.

Results and Discussion

The nurses interviewed included 62 males (52.1%) and 57 females (47.9%); the mean age was 33.8 and 34.3 years, respectively. The majority of the workers were married (60,4%). Most had a high school educational level (84.9%), 10.9% had a secondary educational level, and only 4.2% were university graduates. Among the 119 nurses, 52.9% were exposed to antineoplastic agents; of these, 7 workers reported an accidental contamination and only one reported ocular damage. About 87% of the nurses considered antineoplastic agents more dangerous than the other chemical or physical agents considered in the questionnaire (figure 1). Moreover, 53.8% showed a medium-high level of consciousness of danger in handling these substances. The European Society of Clinical Pharmacy (1990) has recommended the use of laminar down flow safety hoods, latex surgical gloves of sufficient thickness, gowns, surgical masks, and hair covers for employees handling antineoplastic agents to prevent and reduce risk in professionally exposed personnel. Unlike the recommendations of the European Society of Clinical Pharmacy we found that the nurses considered surgical masks and glasses (respectively 96.7% and 95%) much safer than gloves (72.3%) and gowns (68.9%). Lastly, among all the protective measures, they considered the hoods the least safe (56%).

Figure 1. Degree of risk perception concerning health effects due to some chemical and/or physical agents.



* antibiotics, biological fluids, lead, infective agents

Of the 119 respondents, 66 (41 exposed and 25 unexposed workers) said they have received information on occupational risk and precautions to be adopted for handling antineoplastic drugs. Furthermore, most of these declared they had mainly informed by colleagues (table 1).

Table 1. Information sources on occupational risk and precautions to be adopted for handling antineoplastic drugs.

Variable	Exposed (n=41)		Unexposed (n=25)		All (n=66)	
	n	%	n	%	n	%
Medical Direction	3	7.3	3	12.0	6	9.1
Occupational Health Service	3	7.3	3	12.0	6	9.1
Pharmacy Service	2	4.9	1	4.0	3	4.5
Training	13	31.7	12	48.0	25	37.9
Colleagues	33	80.5	14	56.0	47	71.2
Other sources	11	26.8	8	38.1	19	16.0

With regard to the items analized, these data did not show a satisfactory level of knowledge of risk among workers exposed to antineoplastic agents.

Conclusions

As widely known, with regard to occupational exposure to chemical agents that are potentially harmful to health, the risk perception of exposed workers seems to play a major role (5). The specificity of damages related to antineoplastic agents and the general tendency to under-estimate occupational risk by the workers themselves can increase the exposure level. This study underlines a high perception of risk connected with antineoplastic agents among hospital workers involved in nursing practices. At the same time, data show that workers concerns are poorly supported by professional training. This result, if confirmed by further investigations, should be carefully evaluated by central and local health authorities in order to promote a wider disclosure of information on antineoplastic drugs, aiming for the adoption of safety measures among workers who are professionally exposed to them.

Acknowledgements

The present study was supported by the project: "Donna Salute Lavoro: nuovi orientamenti della ricerca"(Art. 12 Decreto Legislativo 502/92) ISPESL.

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Comparison of qualitative indices of exposure to acrylamide-containing grouting agents during tunnel work

Kjuus H [1], Goffeng LO[1], Skaug V[1], Heier M[2]

[1]National Institute of Occupational Health Oslo, Norway,
[2]Dept. of Clinical Neurophysiology, Ullevål Hospital, Oslo, Norway, e-mail: Helge.Kjuus@stami.no

Introduction

When quantitative exposure information is lacking, it is a challenge to identify relevant indices of qualitative exposure. We have studied alternative exposure indices in relation to acylamide exposure in tunnel work. To prevent water leakage during tunnel construction, chemical grouting agents may be injected. During construction of a railway tunnel to the new Oslo Airport, 340 tons of a grouting agent based upon N-methylol acrylamide (NMA) and sodium silicate was used, which contained 4-5% acrylamide as an impurity. The workers were exposed during mixing, pumping and injection of the grouting agent. They reported frequent spills on their clothes with the acrylamide-containing solution. They also reported «showers» with leaking water contaminated with acrylamide. Thus, the main route of exposure was believed to be related to skin contact and not to inhalation. No measurements of acrylamide in the working environment was performed during the injection work.

Acrylamide exposure may lead to reduced nerve conduction velocity (NCV), mainly in a reversible manner. We have examined exposure and possible effects on the nervous system among 25 tunnel workers with high exposure to the NMA grouting agents during a two-year period. The aim of the present study was to compare different indices for qualitative exposure assessment, partly obtained from adminstrative sources, related to time- and place-based cumulative use of NMA grouts and partly from self-reported questionnaires.

Methods

Two to four months after the injection work was stopped, the 25 workers judged to be the most heavily exposed were selected for further examinations, including a detailed questionnaire on work tasks and exposure to NMA grout. From the contracting company, we received detailed information on volumes of the grouting agent used in the different parts of the tunnel during specified periods. Combined with information on working time in the tunnel and estimated "injection" time, three administrative exposure indices were developed:

Tunnel time (TT): Total working time in the tunnel (in months)

Injection time (IT): Time with NMA grout injection (in days)

Exposure time index (ETI): Based upon the weighted cumulative exposure time (Low volume injection period (months) (LVP), High volume injection period (months) (HVP), Tunnel water exposure period (months) (TWP), where ETI was estimated as: (LVPx2) + (HVPx4) + (TWPx0.5).

From the questionnaires, we developed a self-reported exposure index (SEI) related to the frequency of injection, mixing, cleaning and spill on skin (often, seldom, never) during specified periods, together with information on reported skin contact with tunnel water and inhalation of NMA grouts. The sum score for the SEI ranged from 1-15. We also used a combined measure of total injection time and self-reported exposure index (IT x SEI).

Change (improvement) in neurographic measures between 4 and 16 months post exposure were used for the comparisons. Spearman correlation coefficients between the different exposure indices and improvement in neurographic measurements were calculated.

Results

The Spearman correlation coefficient between working time in the tunnel (TT) and the self-reported exposure index (SEI) was 0.29 (p=0.16). The correlation coefficient between the a priori most relevant administrative measure, injection time (IT) and the self-reported exposure index (SEI) was 0.44 (p=0.03). Substituting IT with the weighted, cumulative index (ETI) gave no stronger correlation. Significant correlations between improvements in nerve conduction velocities (NCV) and estimated tunnel time (TT) were observed. The use of Injection time (IT) gave slightly better correlations, but no further improvement was observed by use of the Exposure Time Index (ETI). The self-reported exposure index (SEI) was not significantly correlated with improvement in any of the neurographic measurements. Combining Injection Time (IT) with self-reported exposure (SEI) gave lower correlation coefficients than for the separate use of Injection time (IT) and the exposure time index (ETI).

Conclusion

When quantitative measures of exposure are missing, several sources for qualitative exposure assessment may be utilized. In the present study, the administratively based time-related exposure information seemed to be superior to self-reported information on exposure in predicting improvement in the outcome parameters.

Using a physiologically-based pharmacokinetic (PBPK) model to estimate the contribution of skin absorption resulting from exposure to 2-methoxy ethanol (ME) vapor in the occupational environment

Chang HY [1], Chia WC [1], Chou JS [2], Shih TS[2]

[1.] *Graduate Institute of Environmental & Occupational Health, National Cheng Kung University Medical College, Tainan, Taiwan, ROC, e-mail: h7154@mail.ncku.edu.tw*
[2.] *Institute of Occupational Safety and Health, Council of Labor Affairs, Taipei, Taiwan, ROC*

Introduction

Due to constraints relating to ethical concerns and measurement issues, PBPK modeling has been mainly applied to animal experiments and human volunteer studies. This study aimed to use PBPK techniques to examine the time-based skin absorption of ethylene glycol monomethyl ether based upon data obtained from the occupational environment. The contribution of vapor absorption via the skin as compared to absorption via the inhalation route has also been investigated.

Methods

The model validation was made using the PBPK model in this study to compare with human subject studies deriving from the literature. Airborne ME concentration and pre- and post-working shift urinary 2-methoxy acetic acid (U-MAA) concentration were monitored for, respectively, six, and seven consecutive days, for eighteen people working in a copper-laminate circuit board-manufacturing plant. A six-compartment PBPK model was used to depict the fate of ME in the body and time-series U-MAA concentration. A comparison of time-matched U-MAA concentration was made between those levels predicted by the model and actual measurements from the field study.

Results

When compared with the human subject studies in the literature, the estimates of mean urinary MAA excretion from this PBPK-modeling study were found to lie within the range specified by the experimental measurements (Table 1). The fact that both predictive total excretory MAA in urine from an inhalation exposure to ME and from skin exposure to ME vapor are compatible with the experimental results derived from this study, indicates that the PBPK model used for this study can be acceptably applied to human-volunteer studies in a well-controlled exposure situation.

Table 1. A comparison of PBPK-modeling estimates with literature-derived experimental results

Exposure conditions		Experimental results (mg)		PBPK estimate from this study (mg)
RV	Conc.: 13.5 ppm Time: 60 min Venti.: 440.2 l/hr	MAA in urine $_{48}$ [a]	1.2-3.7 [2.7][b]	2.0
DV	Conc.: 1,562 ppm Time: 45 min Area: lower arm	MAA in urine $_{48}$	10-30 [17]	20

Source: Kezic et al., 1997 (n = 5), ref = 1

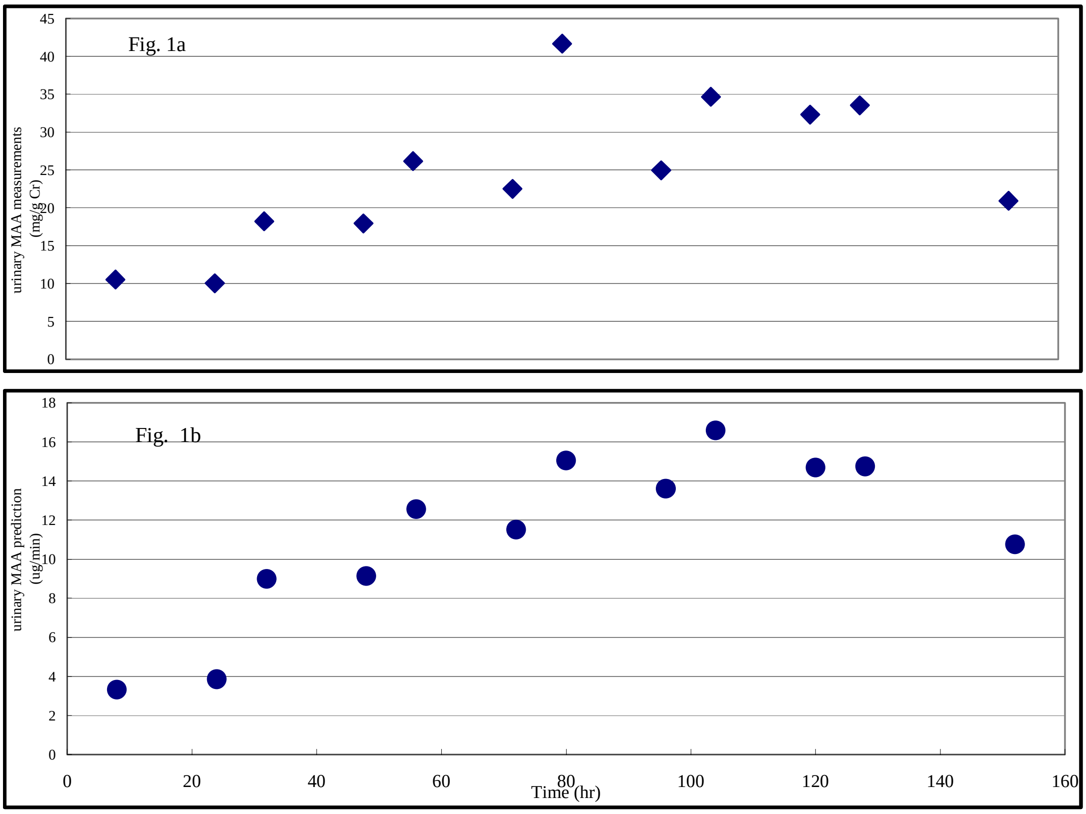
RV: Respiratory exposure to vapor; DV: Dermal exposure to vapor

a. The summary of urinary MAA throughout a 48-hour exposure period.

b. Mean values of the experimental data in parentheses

When airborne ME measurements in a semiconductor copper-laminate circuit board-manufacturing plant were applied to a PBPK model as the model exposure input, the predictive time-series U-MAA excretion rates (on were found to be significantly correlated with those creatinine-adjusted MAA excretion measurements deriving from the real field study (Spearman correlation coefficient, $r = 0.972$, $p < 0.0001$, Figs. 1a & 1b). As a whole, this result shows that this developed PBPK model can be reasonably assumed to be appropriate for application to this ME field study.

Figure 1a & 1b. A comparison of measurements from the field study with PBPK model predicted values. Urinary MAA measurements (mg/g Cr.) are the creatinine-adjusted urinary MAA concentrations in daily pre- and post-working shift urine samples deriving from the field study (Figure 1a, on top). Urinary MAA excretion rates (μg/min) were estimated by the PBPK modeling techniques based on the daily arithmetic means of measured time-weighted average (TWA) ME concentrations amongst 18 workers in a Taiwanese semiconductor copper-laminate circuit board-manufacturing plant as exposure inputs for eight hours throughout the PBPK model simulation (Figure 1b, the bottom).



Using this validated PBPK model, we found the skin absorption is arising from exposure to ME vapor at a TLV-TWA level of five ppm for eight hours, as compared to that of inhalation, is about 1.3 times the level at the end of exposure. The skin-to-inhalation ratio curve then follows a consistently-increasing trend peaking at 2.9 times at 152 hours, the morning of the seventh day from the commencement of worker exposure.

Conclusions

This study demonstrated the potential applicability of a PBPK model for estimating exposure to ME in a steady and simple occupational-exposure scenario. The skin absorption of ME vapor resulting from occupational exposure clearly deserves more attention.

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Dermal exposure to resin acids in sawmills

Eriksson K [1], Lundgren C [2], Levin J-O [2]

[1.] Department of Occupational and Environmental Medicine, University Hospital of Northern Sweden, Umeå, Sweden, e-mail Kare.Eriksson@niwl.se
[2.] National Institute for Working Life, Programme for Chemical Exposure Assessment, Umeå Sweden

Introduction

Abietic and dehydroabietic acid are the main constituents in rosin from coniferous trees. The substances are easily oxidised by air and abietic acid is more susceptible to oxidation than dehydroabietic acid is. One of the oxidation products has been identified as 7-oxo-dehydroabietic acid (1). The substances and especially the oxidised acids have an allergenic activity. Exposure to the acids during soldering with a rosin-based flux has caused dermal and respiratory diseases (2). Air sampling in a Canadian sawmill handling pine and spruce has shown that resin acids are present in the workroom air (3).

Assessment of the dermal exposure to resin acids has not been performed earlier. The aim of this study was to determine the dermal exposure to abietic, dehydroabietic and 7-oxo-dehydroabietic acid among Swedish sawmill workers.

Material and Methods

The dermal exposure was assessed during the sawing and edging processes of pine. Patches (10 cm^2) of a transparent surgical tape, were attached onto the skin of the forehead and the hands of sawmill workers and unexposed individuals. The unexposed individuals were working in the office of the sawmill. The sampling time was approximately 4 hours.

After the sampling period, the sampler was directly put into a glass vial. The vials were stored at –20 °C until desorption with dichloromethane. Before analysis by gas chromatography – mass spectrometry the resin acids were derivatised to their methylester.

Results

Abietic and dehydroabietic were identified from the patches attached at the hands and the forehead of sawmill workers. Mass spectrometric data indicates that 7-oxo-dehydroabietic acid also was deposited on the patches. Traces of the resin acids were detected on patches from some of the unexposed individuals. The dermal exposure of the resin acids on the forehead is up to 0.72 $\mu g/cm^2/h$ for abietic acid, 0.76 $\mu g/cm^2/h$ for dehydroabietic acid and 0.06 $\mu g/cm^2/h$ for 7-oxo-dehydroabietic acid. The skin area of the hands and the forehead is estimated to 2 x 410 cm^2 and 650 cm^2 respectively (4). Assuming uniform deposition, the actual exposure during an eight-hour workday has been estimated between ≤ 1.0 – 4,700 µg on the hands and between ≤ 1.0 - 7,700 µg on the forehead.

Discussion

This pilot study shows that the dermal exposure to resin acids in sawmills can be assessed by attaching patches on the skin of the exposed workers. The resin acids are probably present as an aerosol or adsorbed to the wood dust particles. Deposition is thus most likely the dominating dermal exposure process. The variability in exposure between the workers may be explained by the distance from the emitting source and/or by differences in work practice.

The relatively small amounts of resin acids detected on the patches from some of the office workers may indicate that resin acids and/or wood dust from the sawmill is entering the ventilation system of the office.

Conclusions

There is an actual dermal exposure to resin acids and an oxidised acid in sawmills. Due to the allergenic effects of these substances, precautions should be performed to minimise the exposure.

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Assessment of airborne and dermal exposure to latex proteins with a sandwich EIA using polyclonal rabbit anti-latex IgG

Gert Doekes (1) , Maikel van Niftrik (1) , Lützen Portengen (1), Vesna J Tomazic-Jezic (2), Zhiping Chen (3), Evelyn Tjoe Nij (1), Siegfried de Wind (1), and Dick Heederik (1).

[1] *Institute for Risk Assessment Sciences, Division Environmental and Occupational Health (IRAS/EOH), Utrecht University, The Netherlands.*
[2] *Food and Drug Agency,Center for Devices and Radiological Health (FDA/CDRH), Rockville, MD, USA.*
[3] *Berufsgenossenschaftliches Institut für Arbeitsmedizin (BGFA) , Bochum, Germany.*
e-mail: G.Doekes@vet.uu.nl

Background

There is increased awareness of the risks of occupational latex allergy, especially in health care professions. Methods for measuring latex allergens in personal airborne or skin exposure samples are however not commonly available. Most studies have thus far employed inhibition immunoassays with pools of IgE anti-latex positive patients' sera, which are difficult to standardize because of the limited amounts of available sera. Moreover, since different serum pools may qualitatively differ in their reaction patterns, the IgE inhibition assays may vary widely in sensitivity and specificity. Monoclonal antibody-based assays may provide a useful alternative, but up to now no predominant major latex allergens have been identified that would be good candidate markers for exposure, and for which monoclonal antibodies are commonly available with which a sensitive assay can be performed. Since in previous studies highly sensitive and specific assays for airborne allergens like rodent urinary proteins and fungal α-amylase could be developed with polyclonal rabbit IgG, we investigated the feasibility of a similar approach for latex allergenic proteins.

Aim

Main objectives of the study were to develop a sensitive and specific sandwich enzyme immunoassay (EIA) for measuring latex proteins, using polyclonal IgG from rabbit anti-latex antiserum, and to evaluate the use of the assay for airborne and dermal exposure assessment in an experimental set-up and a population study in hospital workers.

Methods

Starting material was a rabbit anti-natural rubber latex(NRL) antiserum, that was raised and used previously at FDA/CDRH for the analysis of latex proteins in gloves. The IgG fraction was isolated by ammonium sulfate precipitation and anion exchange chromatography, and part of the isolated IgG was labelled with biotin. In the sandwich EIA, test samples were incubated in microwells coated with anti-NRL IgG at 100 ng/well, and latex protein binding to the coating was detected by incubation with the biotinylated anti-NRL IgG, followed by incubations with avidine-peroxidase, and finally o-phenylenediamine as the peroxidase substrate. Various brands of gloves were tested by direct extraction, and by collecting airborne dust samples in a hood where gloves were shaken and manipulated for several hours.

The population study was performed in several departments of three hospitals, of which in total 140 workers participated in exposure measurements. Personal and ambient airborne dust samples were taken with PAS-6 sampling heads, and latex proteins were measured in 1 mL extracts made in PBS-Tween. Skin exposure was assessed in two ways:

- measurement of latex proteins in 1 mL extracts made in PBS-Tween of 25x40 mm self-adhesive pads (Mefix®) that were attached to the inner side of the right middle finger directly after wearing gloves, and removed after 2 minutes.
- measurement of latex protein in 250 mL of PBS in which participants rinsed their hands for 30 sec. directly after wearing gloves, and after the pad test.

To compare results with that of other assays, extracts of gloves and airborne dust were also tested in IgE inhibition assay used in earlier studies at the BGFA in Bochum.

Results

A steep dose-response curve was obtained with a standard NRL preparation, indicating a sensitivity of 1-4 ng/mL. The assay was highly specific, showing no reaction with a large series of extracts of various other immunogenic protein preparations like wheat, milk, animal urine and danders, house dust and storage mite extracts, etc. Extracts of two different brands of latex-containing gloves showed parallel dose-response curves, from which a mean NRL content of approx. 4 and 400 microgram latex protein per glove was calculated. Experiments with generated airborne dust from these gloves indicated that airborne concentrations of latex protein could be detected of approximately 175 and 1,800 ng/m3, at dust levels of 0.3-1.2 mg/m3. Validation and comparison analyses with the IgE inhibition assay at BGFA showed moderate to high correlations for both airborne dust samples (r^2 = 0.7-0.8) and glove extracts (r^2 = 0.9), but absolute values obtained with the two assays showed a systematic difference.

In the population study, airborne latex protein was detectable in 20 of 118 airborne dust samples, at levels of 4-11 ng/m^3 (geometric means per department) at workplaces where powdered latex gloves were used, while no airborne latex (<4 ng/m^3) could be detected where non-powdered latex or latex-free gloves were used. The two methods used to assess dermal exposure showed a higher sensitivity. Positive pads and hand wash solutions were found in >90% samples taken after use of powdered latex gloves, with (estimated) total levels of 0.5-8 μg per hand. Low but detectable levels could also be found in a number of pads (4 of 47) and hand wash samples (4 of 26) taken after wearing non-powdered latex gloves. Only one weakly positive pad (out of 7) was observed, and none of 7 hand wash fluids, among the samples taken after wearing non-latex gloves.

Conclusion

The data indicate that the polyclonal rabbit IgG anti-NRL based sandwich EIA may be a useful and reliable tool for measuring airborne and particularly dermal latex allergen exposure. Further validation and comparison with existing methods is nevertheless required before widespread routine application.

Field effectiveness of protective clothing against non-agricultural pesticides

Cherrie JW [1] [2], Soutar A [1], Phillips A [3]

1. Institute of Occupational Medicine, 8 Roxburgh Place, Edinburgh, EH8 9SU, UK
2. Department of Environmental and Occupational Medicine, University of Aberdeen, Aberdeen AB25 2ZP, UK
3. Health and Safety Executive, HD D4, Room 418, Magdalen House, Stanley Precinct, Bootle. L20 3QZ. UK

email: john.cherrie@abdn.ac.uk

Introduction

A wide variety of pesticide formulations are used in non-agricultural applications. In most cases the skin is the major route of uptake. When applying pesticides, protective clothing is normally relied on to minimise skin exposure. In this study we assessed the effectiveness of three different types of protective overalls when spraying pesticides during timber preservation.

Methods

The effectiveness of three types of protective overalls that are commonly worn by pesticide sprayers was investigated. The selected overalls were:

- Polyester hooded cotton overalls
- A disposable garment made from low air-permeability non-woven fabric
- A disposable garment made from high air-permeability non-woven fabric

During the field surveys, sampling suits (35% cotton, 65% polyester) were worn underneath the selected protective overalls. Eleven 10 cm x 10 cm absorbent patches, made from the same material as the sampling suits, were attached to the outside of the protective overalls. These patches were backed by aluminium foil and reinforced with Tenza self-adhesive plastic. Patches were attached to the overalls using safety pins. The location of the patches was: right hand side of the hood; front torso, right hand side; back torso, between the shoulder blades; upper arms, midway between elbow and shoulder; lower arms, midway between the elbow and wrist; upper legs, mid thigh and lower legs, midway between the knee and ankle. At the end of the survey, the protective overall was removed, then the sampling suit. Patches were removed from the sampling suit and placed in sealed jars. The sampling overalls were cut into 11 sections, corresponding to the patches and these were then placed in sealed jars.

Two different types of pesticide were used in the surveys, for half of the surveys a permethrin based product was used and for the remainder a boron based product. Permethrin was extracted using acetone. Samples were analysed by gas chromatography/mass spectrometry. Boron was extracted using water. Samples were analysed using Inductively Coupled Plasma/Atomic emission Spectroscopy.

For the patches, exposure was calculated by extrapolating the amount of contaminant on the patch to the surface area of the suit area they represented. The penetration factor was calculated by dividing the mass of pesticide measured on the inner suit by the sum of that measured on the inner suit and the estimated mass on the outer suit and multiplying the result by 100 (1).

The amount of fluid on the outer protective suits and the inner sampling suits was calculated by dividing the amount of active ingredient detected by the concentration for the working strength solution used. The relationship between the amounts of pesticides detected on the individual sections of the inner sampling suit and that estimated on individual sections of the other protective suit was estimated by regression analysis.

Results

There was a wide range of penetration factors for the whole overalls, ranging from 0.5 to 37% (Geometric Mean = 6.7%) for permethrin and 0.1 to 9% (Geometric Mean = 1.7%) for boron (table 1). Penetration factors could not be calculated in three cases (company D) since no pesticide was detected on the inner suits. Very small amounts of pesticide were detected on the outer suits from these sites and it would appear that the operators forgot to add pesticide when preparing the working strength formulation.

Table 1 - Penetration factors for whole suit

Company code	Polyester cotton suit	Low air permeability suit	High air permeability suit
Permethrin-based pesticides (%)			
A	8	37	3
			6
B & D	13	NC	0.5
	NC	NC	17
Boron-based pesticides (%)			
C	0.1	1	3
E	1	8	9

Where "NC" = no penetration factor calculated

Estimated challenge masses ranged from 16mg to 516 mg permethrin in the first six surveys (omitting the results from two surveys, where the operators apparently forgot to add pesticide). For the second six surveys, a wide range of challenge masses was also observed for the boron, with masses ranging from 16 mg to 1090 mg. The masses on the sampling suits ranged from 0.5 to 94 mg for permethrin (again omitting the results from two surveys) and from 0.3 to 11 mg for boron.

In figure 1 the quantity of pesticide detected on each section of the inner sampling suit has been plotted against the estimated quantity on the corresponding sections on the outer suit. The 1:1 line indicates where the amounts inside and outside are equal.

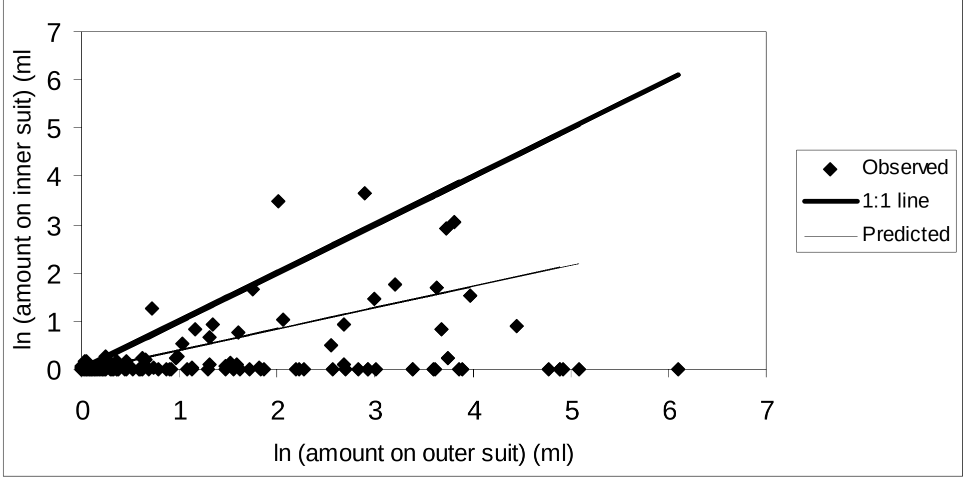

Figure 1 - Amount of fluid outside and inside protective overalls

Where quantity of fluid could be calculated for both outer and inner sections, a significant correlation of 0.67 ($p < 0.001$) was obtained. The regression equation is:

Ln(quantity on outer suit section) = 0.44 Ln(quantity on inner suit section) – 0.04

Only the slope was significant.

Discussion

Contamination occurred even after very short surveys, suggesting that duration of spraying is not an important variable. Typically, the timber treatment only made up a very small proportion of an operator's work shift, with the majority of the time being spent in preparation of the surfaces prior to treatment and other ancillary operations.

There was very little difference in the protection afforded by the different overalls, with penetration factors varying widely from one test site to another. There was a small difference in the average protection factor between the two pesticide formulations, but these were not statistically significant.

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Use of the Zendzian dermal toxicity data base to estimate percutaneous absorption of toxic chemicals

Dellarco M [(1)], Zendzian, R P [(2)]

[1.] *U.S. Environmental Protection Agency, National Center for Environmental Assessment Washington, DC, USA* *dellarco.mike@epa.gov*
[2.] *U.S. Environmental Protection Agency, Office of Pesticide Programs Washington, DC, USA* *zendzian.robert@epa.gov*

Introduction

Dermal exposure to chemicals in the environment is an important public health concern in the U.S. Environmental Protection Agency (EPA). The Food Quality Protection Act requires the Office of Pesticide Programs to account for all exposure pathways when estimating the potential hazards of pesticides. This requirement has sparked concern about dermal contact of pesticide residues from treated areas. In the Office of Solid Waste and Emergency Response (OSWER), the dermal route is a major concern about the risk to industrial chemicals at hazardous waste sites to workers involved in site clean-up and to people who live near these sites. In regulatory reviews, the Office of Water (OW) considers exposure to chemical contaminates during bathing or showering. However, the ability address dermal risk of chemical contaminates in the environment has been hampered by a lack of adequate percutaneous absorption data.

The EPA's National Center for Environmental Assessment conducts research to improve risk assessment methodology. To improve dermal risk assessment methods, our research is devoted to characterize exposure from contaminated water and soil and to predict the percutaneous absorption potential of environmental contaminates. Specifically, we are conducting investigations to validate in vitro percutaneous absorption measurement methods and to improve percutaneous absorption models. Since the quality of percutaneous absorption validation studies in the published literature is highly variable, we investigated if dermal toxicity studies submitted by pesticide registrants using the Zendzian protocol could be used to validate in vitro percutaneous absorption methods.

Methods

We examined in vivo percutaneous absorption studies for specific pesticides submitted to the U.S. EPA Office of Pesticides Programs (OPP) for these investigations. These studies are conducted according to the Zendzian protocol (Zendzian, 1994, 2000). The protocol requires that each study be conducted with a minimum of four rats, in vivo, over a four log dose range at specific time intervals for a minimum of 24 hours. Registrants are required to submit detailed reports of the experimental design, dose preparation, animal/skin sample preparation, dose administration, sample collection and sample analysis. All raw data generated in the studies are reported in tabular form. Additionally, some registrants have submitted in vitro experimental results too. This allows comparison of both dose and time related variation of dermal penetration and comparisons of in vitro percutaneous absorption methods.

Results

To date we have completed experiments with Acetochlor but studies with other chemicals are in progress. This study was evaluated for completeness and accuracy. In this study, in vivo, doses were 3.0, 42.5, 270, and 2934 ug/cm^2. Comparable doses were used in the in vitro experiment. The exposure intervals were 0.5, 2.0, 4.0, 10.0, and 24.0 hours for the in vivo and the in vitro experiments. In vivo, percent absorption ranged from 3.8 to 31.3 with the greatest percent absorption occurring at the two lowest doses. In vitro, results ranged from 0.5 to 77.3 percent, exceeding the in vivo results by two to seven fold in most all instances (table 1). Importantly, there was no evidence of any trend with the in vitro method. These results show that this in vitro method over estimated percutaneous absorption compared to the in vivo method. Furthermore, these results show that studies using the Zendzian protocol can be used to validate in vitro percutaneous absorption methods.

Table 1. Acetochlor rat in vivo and in vitro dermal absorption study results

Dose ug/cm^2	Exposure Duration (hours) 0.5	1.0	2.0	4.0	10.0	24.0
				in vivo		
3.0	3.8	4.3	7.3	9.9	19.5	31.3
42.5	4.0	6.0	4.4	9.2	23.1	29.6
270	4.8	5.6	3.0	4.8	9.3	17.5
2934	1.4	5.2	3.4	2.7	4.5	12.6
				in vitro		
3.03	13.7	27.1	37.8	45.2	71.2	70.1
47.3	4.2	8.2	21.7	33.8	43.8	60.7
318	2.1	6.7	10.5	25.4	57.2	77.3
3095	---	0.5	3.4	4.4	8.5	24.5

Discussion

This study demonstrates the ability to use in vivo dermal toxicity studies conducted with the Zendzian protocol to evaluate in vitro percutaneous absorption methods. The range of doses and time intervals required by the protocol, provides the rigor required to compare these two methods. Results show that this in vitro method does not compare well to the data collected according to the Zendzian protocol. Initial results with other chemicals in the Zendzian database show similar findings.

These results have implications for dermal risk assessment. Reliance on in vitro percutaneous absorption methods has considerable appeal due to their ease and economy. However, these procedures have not been standardized nor validated. Results reported in the literature are highly variable and of limited value for risk analysis. This study clearly shows that in vitro methods may over estimate dermal absorption greatly. Therefore, use of in vitro percutaneous absorption results may invite unacceptable error if used in risk assessments.

Success with data collected from the Zendzian database shows that unpublished existing data submitted for regulatory purposes may be used for percutaneous absorption investigations.

Efforts are underway to compare in vitro and in vivo studies for other chemicals in the Zendzian database and to identify similar kinds of data in other programs at EPA and in academic laboratories.

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Validation of five industrial hygienists' assessments of motor exhaust exposure in 36 occupations in Stockholm during 1945-1994 – development of a job-exposure matrix

Nils Plato [1,2], Marie Lewne [1,3], Gun Nise [1,2], Patrik Nise [1] , Per Gustavsson[1,2], and the SHEEP study group

1. Dept of Occupational Health, Stockholm County Council, Stockholm, Sweden
2. Division of Occupational Medicine, Dept of Public Health Science, Karolinska Institute, Solna, Sweden
3. Dept of Environmental Medicine, Stockholm County Council, Stockholm, Sweden
e-mail: nils.plato@smd.sll.se

Introduction

A job-exposure matrix for occupational motor exhaust exposure was developed by a group of five industrial hygienists to be used in a population based case-control study of myocardial infarction in Stockholm (SHEEP). The matrix was developed by a consensus method.

We investigated how initial and independent assessments made by each of the five hygienists differed from the consensus assessments, considered as a "golden standard". Further we investigated the reliability of the assessments by repeating them four years later.

The aim of the study was to evaluate how much the individual assessments of each of the hygienist differed from the golden standard, and how much the consensus discussions held at the first occasion influenced the assessments made four years later.

Method

The life-time occupational history was obtained from 3973 cases of myocardial infarction and population referents (1). Occupations involving motor exhaust exposure during any period from 1945 to 1994 were identified. In all, 36 occupations, classified by the Swedish ISCO code (on 5-digit level), were associated with motor exhaust exposure (diesel, gasoline or mixed exhausts).

Five industrial hygienists, each with 20 years of professional experience, assessed independently the average exhaust exposure in each occupation during six time periods (1945-49, 1950-59, 1960-69, 1970-79, 1980-89, 1990-94). Four exposure intensity levels were used: no exposure (<1/30 of TLV), low exposure (1/30-1/10) of TLV, medium exposure (1/10-1/3 of TLV), or high exposure (>1/3 of TLV). Carbon monoxide (CO) and nitrogen dioxide (NO_2) were used as indicators.

After having performed exposure assessments individually, the group of hygienists met and made a consensus assessment for each combination of occupation and decade, based on all available knowledge and information from different sources including measurement records/reports (set I).

The individual classifications were repeated by the same five industrial hygienists four years later (set II). No consensus discussions were held at that time.

The concordance in the agreements between the five hygienist was investigated, as well as each of the hygienists concordance with the golden standard. The kappa index (2), expressing the relation of observed agreement and agreement expected by chance, was calculated. To investigate the variability in single links (occupation/decades) we used assessed agreement (pA) for the intensity.

Results

There were 190 links to classify (36 occupations and 6 decades). Some occupations as ”work conductor, bicycle delivery man, car delivery man etc.” had not occurred during all the six decades (= 26 links missing).

Five industrial hygienists have classified exhaust exposure intensity in four levels for 36 occupations during six decades. The 950 assessments were distributed as follows: 92 (9.7 %) not exposed, 412 (43.4 %) low exposed , 359 (37.8 %) median exposed and 87 (9.2 %) high exposed. Only 23 out of 190 links (12,1 %) had pA=1, which means full agreement; all five industrial hygienists assessed the same exposure level for that link. Four of these 23 (pA=1) were found for no exposure, eleven for low exposure, eight for medium and none for high exposure level.

Each industrial hygienist’s estimation for 36 occupation during six decades versus consensus gave a κ range of 0.22-0.53 (mean κ=0.39) for the first set of observations and 0.10-0.59 (mean κ=0.36) for the second set. Average p(A) was 0.62 at the first set and 0.63 at thesecond set.

Each industrial hygienist’s total assessment set I versus set II had a κ range of 0.17-0.81.

Industrial hygienists assessed agreement p(A) during the six decades was fairly constant (0.41-0.54 with increased agreement during later decades. The agreement varied more between the 36 occupations with a range (p(A) 0.25-0.78) with best agreement for ambulance drivers, farmers, truck drivers and park workers.

Discussion

A kappa index above 0.75 represents an excellent reliability, values between 0.4 and 0.75 represent a fair to good reliability while values below 0.4 represent poor reliability. The kappa index in this study did not increase at the second time of estimation, and thus, the consensus discussions held at the first occasion had no or small influence on the estimation at the second time. One industrial hygienist has increased his/her p(A) from set I to set II by 18 %, another 4 %, while three other decrease their p(A) with 17%, 11% respectively 1%. The time between those estimations was long (four years) and the result indicate that the basic knowledge did not change.

Assessed agreement gave higher values than kappa value. Assessed agreement take into consideration both deviation from the consensus as well as the level of deviation of steps in our four scale exposure level ranking.

Conclusion

To use one industrial hygienist instead of a group of five industrial hygienists increased the misclassification by about 40% (a factor 1.4). On a four scale intensity exposure level this corresponded to one step on a four digit scale of exposure intensity. Reliability test after four years indicated only small changes in the assessment.

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A model to assess individual exposure to motor exhaust by the use of a job exposure matrix in a population-based case-referent study (SHEEP)

Lewné M [1,2,3], Plato N [1,2], Nise G [1,2], Gustavsson P [1,2], and the SHEEP study group

[1] *Department of Occupational Health, Stockholm County Council, SE-171 76 Stockholm, Sweden*
[2] *Division of Occupational Medicine, Karolinska Institute, SE-171 77 Stockholm, Sweden*
[3] *Department of Environmental Health, Stockholm County Council, SE-171 76 Stockholm, Sweden*

e-mail: marie.lewne@smd.sll.se

Introduction

Stockholm Heart Epidemiology Program (SHEEP) is a community-based case-referent study of etiological factors for first-time myocardial infarctions among men and women in Stockholm County. One of the associations to be explored concerned whether occupational exposure to motor exhaust was associated with an increased risk of myocardial infarction (1).

The aim was to perform assessments of the exposure to motor exhaust retrospectively over the lifetime occupational history for the cases and referents in the study. A Job-Exposure Matrix (JEM) was developed to increase the validity in the estimations. We integrated the information on job- and time-specific motor exhaust exposure - obtained from the matrix - with individual data on work tasks (frequency, duration etc.) and work conditions to obtain an assessment of each individuals exposure intensity per work period.

Methods

There were 3973 men and women in the study (1675 cases and 2298 referents). A questionnaire gathered information on all occupations/work tasks with a duration of at least one year. The name of the company and its production, as well as the profession and specific work tasks for the person was recorded. Also the person's subjective judgement of motor exhaust exposure (hours/day, indoors/outdoors and connected to what kind of tasks), was recorded.

Before classification all questionnaires were scrutinized and completed with telephone interviews to get additional information on certain job tasks.

A job-exposure matrix (JEM) for motor exhaust exposure was developed to increase the validity in the classification. The occupations in the JEM were selected from the Swedish ISCO-code (1985) on five-digit level. Occupations with a probability of motor exhaust exposure of > 10% were selected. 36 occupations fulfilled these criteria.

Carbon monoxide (CO) and nitrogen dioxide (NO_2) were used as indicators for motor exhaust exposure in the JEM. The JEM specified the average intensity level in each occupation per time period: 1945-49, 1950-59, 1960-69, 1970-79, 1980-89 and 1990-1994).

The initial JEM (with four exposure levels), was developed and validated by five occupational hygienists (see Nils Plato's abstract). It was further developed by two industrial hygienists to a JEM with six exposure levels. The cut-off levels are presented in table.

In the individual exposure classification all available information was used; questions about the working-place, information from the JEM and the persons own apprehension of his/her exposure. The hygienist who coded the exposure was not aware of the case-referent status of the individuals.

The probability of exposure for each work period was assessed as 0%, 20%, 50% or 100% on the basis of the estimated exposure prevalence within each occupation/job task.

The cumulative exposure to motor exhaust was calculated as the product of exposure intensity, probability, and duration.

Results

In the final JEM, five occupational titles had the highest exposure-level during some time-period. These titles were: garage workers, car mechanics, miners, tunnel workers and lumberjacks. None of these titles had the highest level during all the six time-periods.

Many of the occupations in the JEM showed a similar trend with low exposure level during the first time-periods, higher levels during the 60s- and 70s and again lower levels later on. Two examples from the matrix are presented in table.

Class	**Exposure level (ppm)**		**1945 – 1949**		**1950 – 1959**		**1960 – 1969**		**1970 – 1979**		**1980 – 1989**		**1990 - 1994**	
5	CO NO_2	> 10 > 0.3		**2**		**2**		**2**		**2**				
4	CO NO_2	6 - 10 0.2 - 0.3			**1**		**1**					**2**		
3	CO NO_2	3 - 6 0.1 - 0.2	**1**											**2**
2	CO NO_2	2 - 3 0.06 - 0.1												
1	CO NO_2	1 - 2 0.03 - 0.06							**1**		**1**		**1**	
0	CO NO_2	< 1 < 0.003												

1 Petrol station attendant   **2** Car mechanic

The full job-exposure matrix for motor exhaust will be presented on the poster.

Among the 3973 persons (cases and controls) included in the SHEEP-study, 1065 (27%) were classified as motor exhaust exposed for at least one year during their occupational career. The average cumulative exposure among controls exposed to motor-exhaust was 57.5 ppm-years of CO (range: 0-492).

Discussion

The model for exposure classification presented here is general, but the JEM is only relevant for conditions in Stockholm County.

Background data (measurement reports) were available for some occupations only, and were of varying quality.

Most of the individuals that were exposed to motor exhaust had been exposed to a mixture of exhausts from petrol- and diesel-fuelled vehicles.

The resources required to develop the matrix and perform the individual exposure classification were extensive.

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Probabilistic job exposure matrices - effects of assessment errors when applied in case-control studies

Björk J[1], Strömberg U[1]

[1] *Department of Occupational and Environmental Medicine, Lund University Hospital, Lund, Sweden, e-mail: jonas.bjork@ymed.lu.se*

Introduction

A job exposure matrix (JEM) provides group-level exposure data in at least two dimensions: occupational groups and exposures. Further dimensions may include calendar time, geographical location, and gender.(1) In a probabilistic JEM, the basic entry is the estimated proportion of exposed individuals for each occupational group, also interpreted as the exposure probability of a randomly selected group member.(2) A probabilistic JEM can be used as an alternative to individual-level exposure assessments in occupational case-control studies, especially in population-based settings where individual-level data on job histories, disease status, and covariates can be obtained from registries.

Assuming that the odds ratio (OR) can be interpreted as a relative risk, the true association between the exposure proportion *x* and the OR in each occupational group is linear in the absence of confounding(2)

$$OR(x) = 1 + \beta x \, ,$$

where β is the regression parameter. Accordingly, $OR(1) = 1 + \beta$ is a valid estimator of the individual-level OR for exposed versus unexposed subjects if the exposure proportions are assessed without errors. Individual-level data on potential confounders can be incorporated in the model as multiplicative terms.(2) The attributable fraction (AF), *ie*, the estimated proportion of cases that are related to exposure, is

$$AF = \frac{\bar{x}(OR(1) - 1)}{1 + \bar{x}(OR(1) - 1)} = \frac{\beta \bar{x}}{1 + \beta \bar{x}} \, ,$$

where $\bar{x}$ is the true overall exposure prevalence. The aim of this study was to investigate effects of assessment errors in the estimated exposure proportions on the estimates of the OR and the AF, using simulated case-control data.

Methods

We studied several exposure scenarios where the true overall exposure prevalence ranged between 0.07 and 0.63. Assessment errors were simulated for occupational groups comprising truly unexposed subjects only, as well as for groups with true non-zero exposure proportions. For each scenario, we generated 1000 unmatched case-control studies with 250 cases and 250 controls and a true OR of 3.0. Binary regression and standard maximum likelihood technique were used. Effects on bias, coverage of 95% confidence intervals (CIs), and precision were investigated.

Results

Errors in the estimated exposure proportions for occupational groups with true non-zero exposure proportions implied bias of the OR estimates and thereby decreased coverage of the

95% CIs. In contrast, such assessment errors did not bias the AF estimates, unless the direction of the estimated effect was reversed, but reduced precision. Systematic errors in the estimated exposure proportions lead to more severe bias, positive as well as negative, of the OR estimates than random fluctuation around the truth, which implied bias towards the null. The magnitude of the bias was generally approximately equal to the bias in ordinary linear regression in corresponding error situations.

The presence of exposed subjects within occupational groups regarded as truly unexposed had more pronounced effects on the AF estimates than on the OR estimates in terms of bias towards the null and decreased coverage of 95% CIs. The magnitude of the bias of the AF estimates was generally bounded by

$$\frac{\bar{x}_0}{\bar{x}} AF ,$$

where *AF* is the true attributable fraction, $\bar{x}$ is the true overall exposure prevalence, and $\bar{x}_0$ is the true mean exposure proportions of the occupational groups falsely assumed to comprise unexposed subjects only.

Discussion

The case-control design with group-level exposure data obtained from a probabilistic JEM may well be a rapid and cost-efficient approach to conduct population-based studies. However, the validity of such an approach depends on the quality of the exposure assessment for various occupational groups. For the OR estimates, the direction and the magnitude of the bias can be evaluated under assumptions about the validity and precision of the estimated exposure proportions. Since the proportions are bounded between zero and one, certain error structures are occasionally more likely to occur than others.

The AF measure may identify risk factors for which effective interventions have great public health impact. Similar to the alternative threshold method for estimating the AF, which classifies all subjects in groups with non-zero exposure proportions as exposed,[3] the investigated AF estimator was generally unbiased if the grouping of subjects was 100% sensitive, *ie*, if assessment errors were present only for occupational groups with true non-zero exposure proportions. In contrast, even small fractions (3-9%) of exposed subjects within occupational groups regarded as truly unexposed had severe effects.

Conclusions

Systematic errors in the estimated exposure proportions should be of more concern than random fluctuations when establishing probabilistic JEMs. It is important that the exposure proportion is assessed also for occupational groups where the exposure is expected to be rare, and not only regarded as zero.

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Is job title in registers of deaths a valid proxy for exposure?

Andersson E [(1)], Nilsson R [(1)], Torén K [(1)]

[(1)] *Occupational and Environmental Medicine, Sahlgrenska University Hospital, Sweden, e-mail: eva.andersson@ymk.gu.se*

Introduction

The effect of misclassification of exposure on estimates of relative risks depends on true exposure frequency, sensitivity and specificity of exposure assessment (1). The aim of this study was to validate the exposure assessment in an earlier performed case-control study on asthma and cancer among sulphite mill workers (2). The exposure assessment there was based on job titles in local register of deaths. The three chosen mills were the dominant industry in the surrounding parishes. We now perform a cohort study, which gave us the opportunity to compare job titles from one of these parishes against personnel files from that mill. We also did this for a sulphate mill earlier studied in another case-control study. The risk for brain tumour was increased in both case-control studies. This was used as an example for calculating the effect of misclassification of exposure on the odds ratio.

Material and methods

The local registers of deaths and burials between 1960 and 1989 in two parishes were used to obtain job titles and cause of death. In all, 680 deaths among men aged 40 to 75 years at death were identified. The occupational titles “factory worker”, and the few “sulphite/sulphate worker” were regarded as exposed and subjects with other titles were classified as unexposed. Job title was missing for 24 persons.

For the cohort study, personnel files from 1940-2000 were obtained from these pulp mills and all workers with more than half a year of employment were registered. From these files the 600 men deceased between 1960-1989 aged 40-75 years at death were identified.

We compared the local parish register with the personnel files. Of the mill workers 55% were found to have died in the surrounding parish. Sensitivity, specificity and predictive value of the job title were calculated. Data in the personnel files were regarded as the true exposure. With the result from those files as exposure assessment and the obtained sensitivity and specificity of job title an expected odds ratio for job title was calculated and compared with that found.

Results

About half of the “truly exposed” men were classified as exposed in the local register of deaths and burials, table 1. The number of false positive was only 5%. Mean duration of employment time was 32.1 years among workers with the job title regarded as exposed, compared with 21.4 years for other mill workers deceased in the parish. For mill workers deceased else where it was 9.9 years.

The risk for brain tumour is here used as an example of the effect of misclassification of exposure on the odds ratios. The theoretically calculated odds ratio for brain tumour assuming a 50% sensitivity was similar to that found using the job title, table 2.

Table 1	"True" exposure frequency	Sensitivity for job title	Specificity for job title	Predictive value job title
Local register of deaths	**48.8%** 332/680	**50.6%** 161/318	**95.9%** 324/338	**92.1%**
Aged 40-65 year at death	**46,6%** 129/277	**46.8%** 58/124	**94.4%** 134/142	**87.9%**
Aged 66-75 year at death	**50.4%** 203/403	**53.1%** 103/194	**96.9%** 190/196	**94.6%**

Table 2. Fourfold tables for brain tumour/other causes of death with different exposure assessment. Crude odds ratios were calculated with 90% confidence intervals (90%CI).

Exposure personnel files

		+	-
Brain tumour	+	8	2
Other death	-	324	346

OR=4.3 (1.2-16)

Calculated with 50% sensitivity

		+	-
Brain tumour	+	4	6
Other death	-	162	508

OR=2.1

Exposure job title

		+	-
Brain tumour	+	4	5
Other death	-	171	476

OR=2.2 (0.7-6.8)

Discussion and conclusions

The job title factory worker in local registers of death and burials used as a proxy for pulp millwork had a high specificity and predictive value even if the sensitivity was low. The odds ratio was underestimated especially as the exposure frequency was high and the sensitivity low. With a low exposure frequency it is more important to have a high specificity (1).

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A Microsoft® application for expert assessment in multi-centre studies

’t Mannetje A [(1)], Fevotte J [(2)], Fletcher T [(3)], Brennan P [(1)]

[(1)] *Unit of Environmental Cancer Epidemiology, International Agency for Research on Cancer, Lyon, France, e-mail: mannetje@iarc.fr.*
[(2)] *Laboratoire de Médecine du Travail, Lyon, France.*
[(3)] *London School of Hygiene and Tropical Medicine, London, UK.*

Introduction

Since the 1980’s, expert assessment has been put forward as a promising method for estimating occupational exposure in case-control studies. Case-by-case expert assessment strives to evaluate the exposure of each study subject retrospectively, by combining the information that the study subject can give, with the specialised knowledge of experts.

In multi-centre studies, this type of assessment is preferably done by local experts, because they can take into account the regional differences in use of materials, production processes, prevention measures and resulting levels of exposure. This however has a consequence, that experts involved in the same study, work separately from each other in space and time. Providing standardised rules for the expert assessment and a continuous evaluation of this standardisation, is therefore important to avoid systematic differences between the experts.

In several multi-centre case-control studies co-ordinated by the International Agency for Research on Cancer (IARC), local experts were trained during workshops to apply the methodology as described in a detailed protocol. Standardised working materials were developed for the study, among which an Access application as described here. The Access database was designed for data entry, but also to check for data entry errors, and to find, organise and summarise the data of the expert assessment, in order to improve the quality and homogeneity of the exposure assessment within and between centres.

Methods

The database management system for expert exposure assessment, was developed using Microsoft® Access 97. This application was available to all experts involved in the study and allowed for small adjustments to meet centre-specific needs of the database, without specific knowledge of the programming language. Incorporated in the database were reference tables including the following information:

- A list of exposures to be evaluated by the experts, consisting of around 70 exposures specific for the disease under study.
- A list of all full-text titles of the International Standard Classification of Occupations (ISCO), of the International Labour Office, 1968.
- A list of all full-text titles of the Statistical Classification of Economic Activities in the European Community (NACE Rev. 1), of Eurostat.
- Job-exposure matrices (JEM) based on ISCO and NACE codes, that could be used as a source of information for the expert assessment.

By means of “Forms”, a data entry interface was developed. By means of “Queries” and “Reports”, the entered data were organised in different ways, to allow easy sorting and summarising of entered data by job, exposure or dates.

Results

The database occupies around 3 MB of hard disc. When entering the database, the form for data entry of the exposure assessment is opened. One screen of the form represents the exposure assessment of one job period of one subject. Variables to enter are 1) The ID number 2) the job number 3) year start of the job 4) year end of the job 5) ISCO '68 code 6) NACE Rev.1 code 7) the exposure assessment consisting of the exposure code and for each exposure the intensity, frequency and confidence.

Only the codes need to be entered in the form and are saved in the tables. In the form view however, the full-text of ISCO, NACE and exposure codes appears on screen, to make the database more practical for daily use. Only existing ISCO, NACE and exposure codes can be entered, avoiding data entry errors. To facilitate the search for the most appropriate NACE and ISCO code, job and industry titles can be searched automatically for keywords using the same database. The assessment of each job period including full-text ISCO, NACE, and exposure assessment, can be printed for filing.

Job-exposure matrices for some exposures can be consulted directly in the form, based on the ISCO and NACE code entered for the job period. With one click the database will search the JEM to see if exposure is likely, based on the NACE and ISCO code alone. The experts base their assessment however on all information available, including the questionnaire and their own expert knowledge.

Different reports are available that give summaries of entered data, among which summaries of exposure by occupation, occupation by exposure, prevalence of exposure, and distribution of intensity, confidence and frequency by exposure. When a substantial amount of data is entered, the reports result in a study specific job-exposure matrix. All reports are automatically updated when more data are entered.

The tables with the entered data can be directly analysed with Excel and reports can be directly published in Word.

Discussion

When several experts work separately on one study, the availability of a protocol with detailed criteria for judging exposure is important. Just as important are the regular evaluation of compliance to the guidelines, and the evaluation of systematic differences that can be produced despite of the guidelines. In several multi-centre studies co-ordinated by IARC, this process was facilitated by a computer application that produces automatic reports of entered data. The reports can be consulted by the expert, or other people involved in the study, at any moment in time.

The database is useful for the experts by allowing for an easy return to earlier assessments, by offering direct access to other databases such as job-exposure matrices, and by offering different overviews of already entered data. This will give the expert the opportunity to make optimal use of available data, including the data of their own assessments. Also comparisons between centres are facilitated by the database. At any moment during the study, updated reports of the exposure assessment can be sent to IARC. The standardised reports enable direct comparison of results between centres. Especially for more subjective exposure judgements, such as confidence of presence of exposure, substantial differences can exist between experts. Comparing the assessments of experts and discussing their differences at an early stage of the study, can avoid systematic differences in the final data set.

Conclusions

A Microsoft® Access application was developed for daily use by occupational exposure experts involved in a multicentre case-control study. The application can be used for data entry, as well as for improving the quality and homogeneity of the exposure assessment within and between centres.

Exposure modeling using static and dynamic definitions of physical workload and regional musculoskeletal symptoms in women and men

Smith KF (1,2), Flowers L (2)

[1.] *Innovative Clinical and Consulting Services, Atlanta, Georgia, USA, email: ksmith@bellsouth.net*
[2.] *Emory University, Atlanta, Georgia, USA, email: lmflowe@hotmail.com*

Introduction

Exposure modeling of physical workloads in epidemiologic studies of musculoskeletal disorders has gained importance due to the large amount of data that can be collected (1). Also, the multidimensional nature of workplace exposures lends itself to modeling (2). Another advantage of exposure modeling is its potential for defining *a priori* the framework of pathomechanisms (3, 4). Workload that requires movement is defined as dynamic. Static workload involves tension only and may involve fixed posture. Static loads can be prolonged or repetitive (3). Both types of loads can be applied to the whole body or to a specific body region, thus associated with particular symptoms of musculoskeletal disorders.

The aim of this study is to define *a priori* workload exposure models and to assess their association with regional musculoskeletal symptoms.

Materials and Methods

Subjects. The study group consisted of 222 females and 209 males below the age of 59 years in 1993 (5). Exposure. Data concerning twelve items on different aspects of physical activities at work were used to construct three exposure models using static and dynamic definitions. The models used were repetitive hand movement (rephand: *a priori* thought to be associated with neck, shoulder, elbow, hand, and upper back symptoms), dynamic whole body work (dynamicwb: *a priori* thought to be associated with neck, shoulder, elbow, upper back, lower back, hip/thigh, and knee symptoms), and static whole body work (staticwb: *a priori* thought to be associated with neck, shoulder, upper back, lower back, and hip/thigh symptoms). Outcome. Data concerning regional musculoskeletal symptoms in the last 12 months were collected using the Nordic Musculoskeletal Questionnaire (NMQ) (6). Statistical Analysis. All data were analyzed using SAS v.6.12. The prevalence of exposure and regional musculoskeletal symptoms were studied and prevalence rate ratios (PR) and 95% confidence intervals (c.i.) were calculated by gender.

Results

The prevalence of exposure to repetitive hand movement and dynamic whole body work were higher among women than men (43.24% vs. 36.84% and 63.96% vs. 59.81%, respectively). Static whole body work was higher among men (31.58% vs. 25.68%). The overall one-year prevalence for musculoskeletal symptoms was highest in the lower back (52.80%), followed by shoulder (43.56%), neck (41.49%), knee (31.38%), hand/wrist (24.30%), elbow (22.66%), foot/ankle (20.09%), upper back (18.44%), and hip/thigh (18.37%). The prevalence of symptoms was higher among females for all regions except the knee (30.00% vs. 32.85%). PR are presented in Table 1 for each exposure model, by gender.

Table 1. Prevalence ratios and 95% confidence intervals for regional musculoskeletal symptoms based on exposure modeling.

Region	Rephand	Dynamicwb	Staticwb
Men			
Neck	*1.06(0.71-1.58)	*1.41(0.92-2.15)	*0.78(0.50-1.23)
Shoulder	*1.30(0.92-1.83)	*1.45(0.99-2.13)	*0.73(0.49-1.11)
Elbow	*1.27(0.77-2.11)	*1.58(0.90-2.78)	*0.66(0.36-1.22)
Hand	*0.98(0.57-1.69)	1.44(0.81-2.55)	*0.56(0.29-1.09)
Upper Back	*1.33(0.63-2.77)	*1.76(0.77-4.02)	*0.29(0.09-0.94)
Lower Back	1.20(0.92-1.56)	*1.44(1.07-1.95)	*0.59(0.42-0.85)
Hip/Thigh	2.49(1.30-4.75)	*2.94(1.26-6.82)	0.40(0.16-0.99)
Knee	1.21(0.82-1.79)	*2.01(1.25-3.22)	0.52(0.30-0.88)
Foot/Ankle	1.07(0.60-1.92)	1.95(1.00-3.78)	0.56(0.27-1.15)
Women			
Neck	*1.20(0.93-1.56)	*1.02(0.77-1.35)	*1.00(0.74-1.35)
Shoulder	*1.05(0.80-1.38)	*1.37(1.00-1.87)	*0.77(0.54-1.10)
Elbow	*0.96(0.59-1.58)	*1.48(0.85-2.57)	*0.80(0.44-1.46)
Hand	*1.14(0.74-1.76)	1.46(0.89-2.38)	*0.71(0.41-1.24)
Upper Back	*1.23(0.77-1.96)	*0.95(0.59-1.54)	*1.13(0.67-1.89)
Lower Back	1.12(0.88-1.43)	*1.06(0.82-1.36)	*1.05(0.80-1.37)
Hip/Thigh	0.74(0.44-1.27)	*1.33(0.76-2.33)	0.59(0.30-1.19)
Knee	1.10(0.73-1.64)	*1.07(0.70-1.64)	0.77(0.46-1.28)
Foot/Ankle	0.67(0.39-1.16)	1.02(0.60-1.72)	0.77(0.41-1.44)

*Indicates the musculoskeletal region was defined *a priori* as positively associated with the exposure model.

Discussion

Associations between the workplace exposure models and the *a priori* body regions were established in the case of repetitive hand movement and dynamic whole body work. There were markedly fewer associations with static whole body work. These results were consistent in women and men.

The repetitive hand movement exposure model was associated with hand, neck and upper back symptoms in women. Likewise, Punnett, et al. found increased PR for shoulder (2.0), wrist (4.0) and hand pain (3.0) in female garment workers exposed to repetitive hand motion, compared to female hospital employees unexposed to repetitive hand motion (7). Within the dynamic whole body exposure model, the greatest PR was found to be in the elbow for women and the hip/thigh for men. Similarly, Vingard, et al. found an increased relative risk of 2.42 (1.45-4.04) for development of coxarthrosis in men with high exposure to static and dynamic workloads, compared to men with low exposure (8). The static whole body work exposure model was associated with upper back and lower back symptoms in women. In a previous review by Jin, et al., static posture was identified as a risk factor for lower back pain (9).

Exposure modeling of physical workloads is an important and in many cases a necessary step in analyzing associations with musculoskeletal disorders. In this study, the models for repetitive and dynamic work were associated with musculoskeletal symptoms. This was not the case for static work. In order to perform physical work, three load demands are necessary: 1. moving the body or isolated body parts; 2. transporting or moving of objects, as in carrying or lifting; 3. maintaining body postures, as in stooping or working with raised arms. It has been suggested that static and posture load can be overlooked, whereas dynamic work is obvious when being performed (10). This may be the case in this study in defining the static model. Further investigation into alternative static models may be necessary for clearer understanding of physical workload exposure.

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Differences in measurement accuracy between two wrist goniometer systems

P. M. Jonsson [(1)] and P. W. Johnson [(1)]

[1.] *Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg, Sweden, e-mail: per.jonsson@ymk.gu.se*

Introduction

With the introduction of electrogoniometers collection of continuous wrist postural data is possible. A goal of electrogoniometry is to accurately measure and characterize wrist posture. Accuracy and fidelity of the measurement system is essential in wrist postural studies.

The purpose of this study was to compare, over a wide range of wrist movements, a commonly used biaxial, ***single transducer*** electrogoniometer system to a biaxial, ***two-transducer*** electrogoniometer system integrated into a glove. Studies have shown that wrist goniometers can be prone to measurement errors particularly due to crosstalk [1]. Crosstalk is where movement in one wrist plane causes a false goniometer signal in the other wrist plane.

Materials and methods

Subjects

Twenty different wrist postures were tested on five women and three men free from upper extremity disorders. The wrist was in 90º pronation during the test.

Goniometer Systems

Two goniometer systems were evaluated and designated as System **A** and System **B**. Fig. 1.

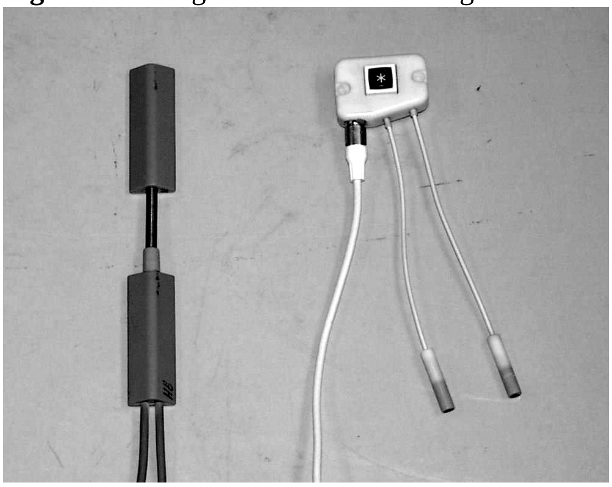
System **A** consisted of a biaxial, single sensor electrogoniometer (Biometrics; model X 65; Gwent, UK) connected to a data logger (Biometrics; model DL 1001) with 8-bits of resolution limiting the accuracy to 1.8°. The goniometer was applied to the right wrist as described by Buchholtz, B et al. [1]. System A was calibrated by putting the subject's wrist in a neutral F/E and R/U position and offsetting/recording the zero position.

System **B** consisted of a biaxial, two- sensor goniometer (WristSystem, Greenleaf Medical, Palo Alto, California, USA) integrated into a fingerless glove. System **B** was connected to a logger with 12 bits of resolution providing angle measurement accuracy to 0.1°. The goniometer was applied by sliding the fingerless glove with the goniometer onto the subject's hand and snugly securing the system to the subject's wrist using three velcro straps attached to the glove. The gloves came in three different sizes to accommodate different sized hands. System **B** employed a 5-point calibration and the data logger used a linear algorithm, based on wrist angle, to correct and compensate for crosstalk [2].

Measurement procedure

The two systems were calibrated with the subject's hand in 90° of pronation. A fixture was used to repeatedly position the wrist at known flexion/extension (F/E) and radial/ulnar deviation (R/U) angles. The fixture allowed wrist movement in one plane (the flexion/extension or radial/ulnar deviation plane) while simultaneously restricting motion in the other plane. The fixture was rigidly attached to an adjustable height table. The subject's chair was adjusted so their feet rested flat on the floor and the table was adjusted so the subject's arm was resting comfortably at their side, forming a 90° angle at the elbow. R/U and F/E angles were defined according to clinically accepted standards. To ensure the repeatable repositioning of the subject's hand, outlines of the hand were traced on the base of the calibration fixture for the various R/U positions and the analogue F/E scale settings on calibration fixture were noted for each F/E position.

Fig. 1: Wrist angle sensors: left **A** & right **B**



Results

System **A** both over- and underestimated F/E (F/E Crosstalk), which was dependant on the amount of R/U deviation. R/U deviation was also over- or underestimated (R/U Crosstalk), depending on the amount of F/E. (Figure 2)

As shown in the right half of Figure 2, System **B**'s F/E data was slightly offset with a tendency toward overestimating extension. System **B** was less prone to crosstalk in both F/E and R/U deviation compared to System **A**.

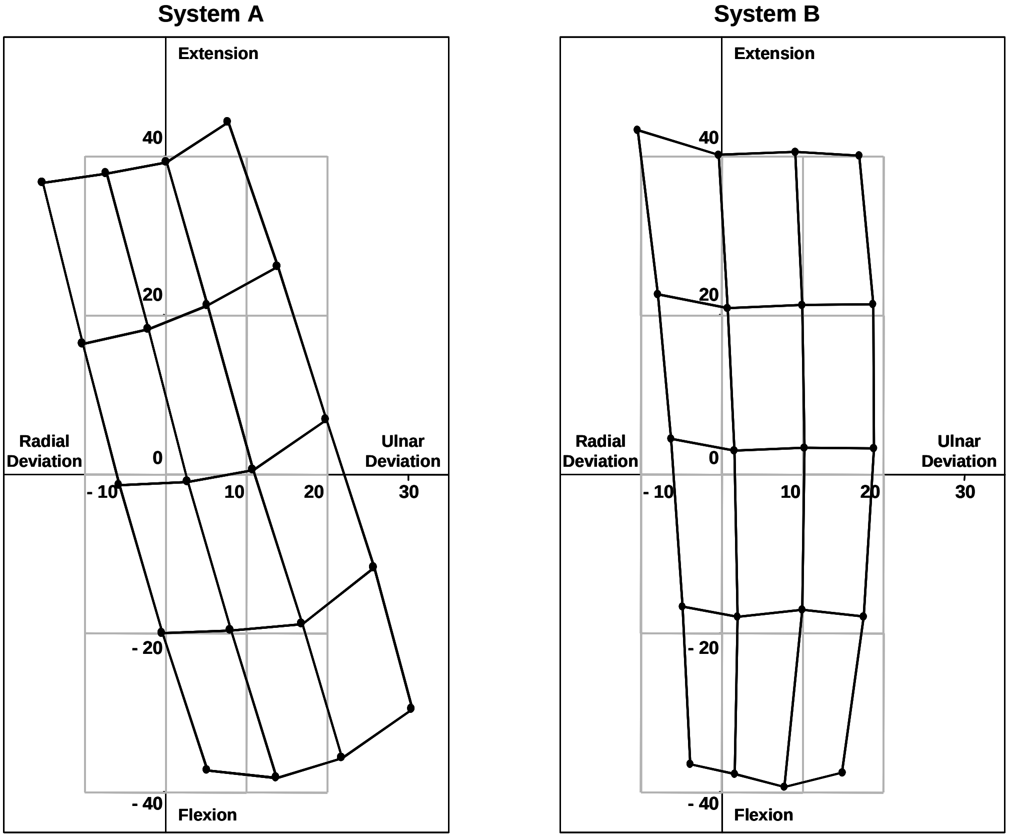


Fig. 2: Comparison of System **A** and **B**, when wrist in pronation 90º. The grid in light grey indicates the actual movements performed (gold standard).

Discussion and conclusions

Both systems show deviations in measurements from the actual positions. System **B** was more accurate than System **A** in measuring radial/ulnar deviation. This difference in measurement accuracy may be due to differences in calibration procedures, calibration algorithm for system **B** and/or how the two goniometer systems reside on the wrist relative to the joint centres of rotation.

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Acknowledgments

The authors wish to thank Alexander Areskoug for his contribution to very carefully performed measurements.

Radon in underground mines - validity of historical data in assessment of past exposure

Bergdahl IA [(1)] Åkerblom G [(2)] Jonsson H [(3)] Järvholm B [(4)] Andersson K [(5)] Kågström L [(6)] Damber L [(3)]

(1) Department of Occupational and Environmental Medicine, Norrland's University Hospital, Umeå, Sweden, e-mail: ingvar.bergdahl@envmed.umu.se
[(2)] Swedish Radiation Protection Institute, Stockholm, Sweden
[(3)] Oncological Centre, Norrland's University Hospital, Umeå, Sweden
[(4)] Occupational Medicine, Department of Public Health and Clinical Medicine, Umeå University, Umeå, Sweden [(5)] LKAB, Kiruna, Sweden [(6)] LKAB, Malmberget, Sweden

Introduction

Much of our knowledge about the lung cancer risk of radon exposure stems from epidemiological studies of underground miners. One of these studies has been carried out on a population from the iron mine in Malmberget, Sweden (1). A new study of a cohort from the two iron mines in Malmberget and Kiruna is now under preparation. Historical data, with inherent problems, such as poorly defined sampling strategies, will then be used for exposure assessment. In the present study we have investigated the validity of these historical data.

Methods

The two mines have different geology, with higher uranium concentrations in Malmberget than in Kiruna, especially in the northwestern parts of Malmberget. Underground mining has dominated in Malmberget since the 1920's and in Kiruna since the 1960's.

Radon, or radon daughter, concentrations have been measured since 1969. The sampling strategies have been a mixture of several different approaches: monitoring of working areas, investigations of areas to be used, "worst case", evaluation of actions taken, etc. Measurements were also carried out in the air stream coming out from the ventilation system, in order to get a proxy for the mean concentration in the mine. Both the mining company, LKAB, and The Swedish Radiation Protection Institute, SSI, carried out measurements during the 1970's. Later on, LKAB were responsible for all measurements.

Ventilation systems with closed ventilation tubes, leading the fresh air to the workplaces, were introduced in the early 1970's. The systems replaced the previous systems, where air was drawn through shafts and became radon contaminated already before arriving to the workplaces. The changes made to the ventilation systems led to significant decreases of the radon concentrations, for the Kiruna mine during 1974, and for the Malmberget mine during 1973.

Both radon and radon daughters have been measured, but in most cases only either of them. An equilibrium factor of 0.7 has been used for converting the measurements of radon daughters to radon concentration.

Results

Parallel determinations of radon gas and radon daughters, carried out 1970-1977 gave a mean equilibrium factor of 0.7, both in the mine in Malmberget and in Kiruna. Also, when results below 10 pCi/L (370 Bq/m^3) were disregarded, the resulting equilibrium factor became 0.7.

Data obtained from the mining company, LKAB, were in accordance with those from The Swedish Radiation Protection Institute, SSI, with the exception of the early years in Kiruna (Figure 1).

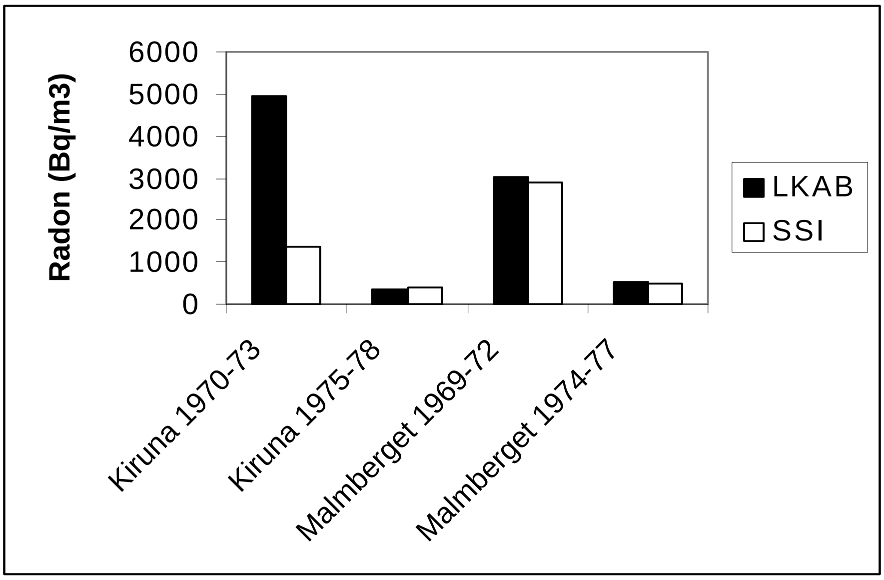

Figure 1. Data (mean values) from the mining company, LKAB, and The Swedish Radiation Protection Institute, SSI.

Data from Malmberget were similar for results obtained from measurements carried out in the air stream from the ventilation system and stationary measurements in the mine (1974-1992). Only a small difference was indicated between stationary and personal measurements (1992-1998) (Figure 2).

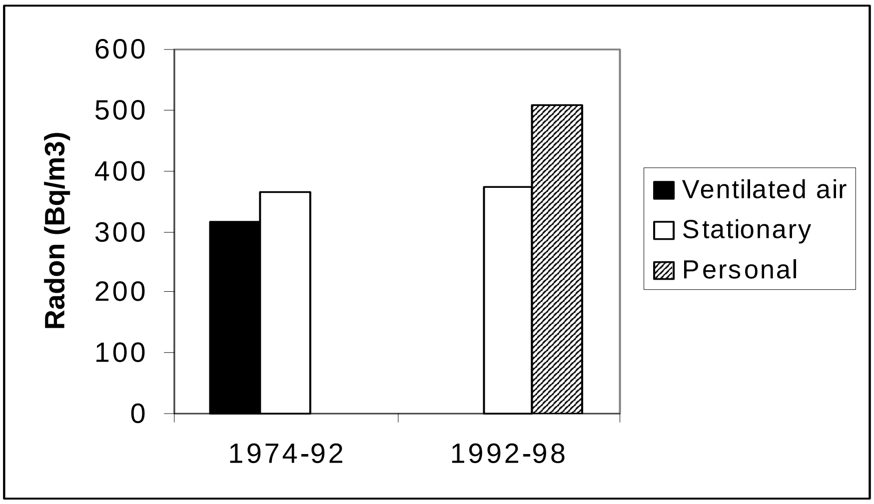

Figure 2. Mean radon concentrations resulting from different sampling strategies used in Malmberget.

Discussion

We have, in historic data, compared different sampling strategies, in order to evaluate the magnitude of systematic errors introduced. In general, differences were relatively small, being less than a factor of two.

The strategies used would generally lead to an overestimation of the exposure. The Swedish legislation about radon measurements in underground work stated that measurements should be carried out in workplaces, places where work is planned, and places where there are reasons to expect high radon concentrations. Moreover, a closer interval between measurements is to be used in places with high concentrations. Taken together, this means that only an overestimation can be expected. On the other hand, the measurements in the air stream from the ventilation system, supposed to give an estimate of the mean radon concentration in the mine, did not differ very much from the other results. Therefore, we believe that the errors introduced were relatively small.

The only alarming difference found was that the Kiruna data from the mining company were much higher than those from SSI during the early years. The difference was probably a result of differences in sampling strategies: SSI were mainly mapping and monitoring the mine, while the mining company carried out measurements in order to find, and eliminate, high radon exposures.

Conclusion

The data should give a relatively precise estimate of the radon exposure - an error of a factor of two or more appears unlikely.

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Whole body vibration measurements in haul trucks – exposure assessment according to the new standard ISO 2631:1997 and euro standard proposal 2000

Per Jonsson [1], Lars Ekström [2]

[1.] *Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg, Sweden, e-mail: per.jonsson@ymk.gu.se*
[2.] *Department of Orthopedics, Sahlgrenska University Hospital, Göteborg, Sweden, e-mail: lars.ekstrom@orthop.gu.se*

Introduction

Port of Gothenburg (Göteborgs Hamn AB) initiated this exposure assessment report based on their drivers reporting severe discomfort, caused by seat movements in haul trucks when loading trailers on “roll on – roll of” (ro-ro) ships.

Methods

Instrumentation
Whole body vibration was measured with a B&K 2231 instrument connected to the vibration adaptor B&K 2522 and the printer B&K 2318. The instrument calculated frequency weighed acceleration accordingly to SS-ISO 2631, 1985 and, after arbitrary integration time, presented the energy equivalent vibration-accelerations, a_w (an approximate time average level). The vibration on the seat was registered in tree perpendicular directions and the seat accelerometer disc B&K 4322 was used as transducer.

Strategy
Two haul trucks with different suspensions and two ships with different access ramps (passageways) were chosen. Experienced drivers performed loading and unloading of trailers.

See picture above.

Results

Haul truck	Measurement period	Maximal level during period	a_w
Truck 805, low suspension, loading ship with smoother ramp.	51 minutes	3,4 m/s^2	**0,65 m/s^2**
Truck 805, low suspension, loading ship with bumpier ramp.	1:15 hour/minutes	4,7 m/s^2	**0,72 m/s^2**
Truck 831, high suspension, loading ship with bumpier ramp.	27 minutes	5,0 m/s^2	**0,60 m/s^2**

The highest average level, a_w, was obtained from the low suspension truck loading a ship with a bumpy access ramp. Maximal vibration direction was up and down (vertical) along the length of the spine. The great difference between Maximal level and Average level resulted in a high "crest factor". High levels of acceleration occurred when the haul trucks ran over the access ramps.

Hygienic exposure assessment according to ISO 2631-1:1997

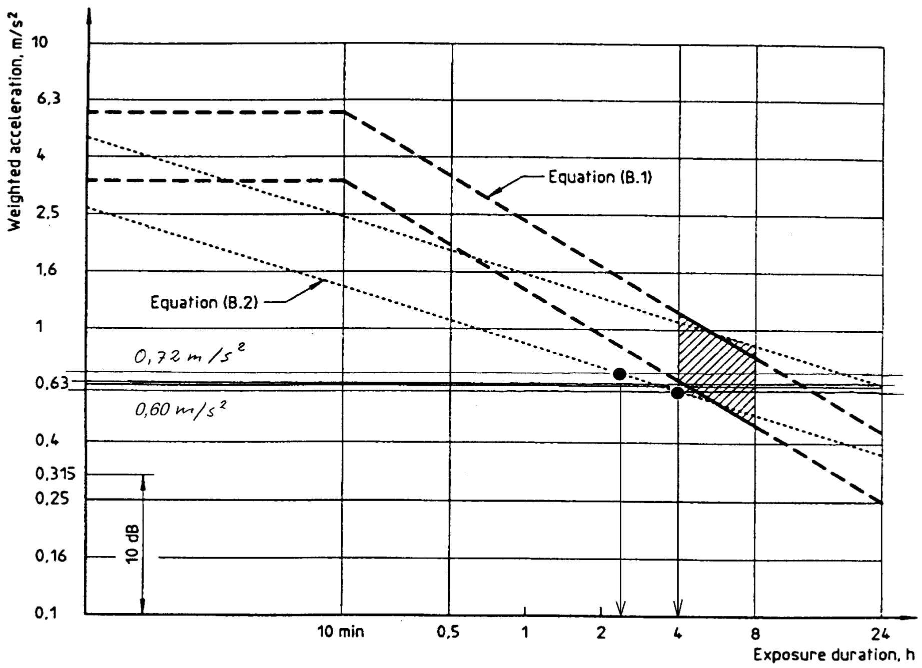

Figure B.1 — Health guidance caution zones

Figure B.1, Swedish Standard SS-ISO 2631-1:1997, Annex B, B.3.1

The figure shows two zones, equation B.1 & B.2, representing two alternative assessment criteria. For exposures below the zones (dotted and dashed lines), health effects have not been clearly documented and/or objectively observed; in the zone (between the dotted and dashed lines), caution with respect to potential health risks is indicated; and above the zones, health risks are likely. In this report, the highest average truck seat vibration was 0,72 m/s^2 and the lowest 0,60 m/s^2. Our recommendation is an exposure below both of the zones. The recommended exposure time sitting in the truck with the highest vibration should therefore be below 2,5 hours/day. Consequently the time in the truck with the lowest vibration should be below 4 hours/day. Since the drivers reported a typical daily driving time of 5 to 6 hours/day, this recommendation is violated and potential health risks are present. The high crest factor indicates that the standard may even underestimate the potential health risk.

Hygienic exposure assessment according to European Union (EU) proposal

The proposal states that:
1) the daily exposure limit value shall be 1,15 m/s^2 and no worker should be exposed to values above this limit.2) The daily exposure action value shall be 0,6 m/s^2, and if exposure values are above this limit, preventative measures are necessary to reduce risks to the workers.

In this report, the average truck seat vibration was 0,6 m/s^2 and above, more than the exposure action value which indicates preventive measures are necessary to reduce risks to the workers.

Summary

Uneven and bumpy access ramps are the main reason for the relatively high vibration magnitude on haul truck seats. Advanced seat suspension did not manage to reduce these low-frequency vibrations. The wheel suspension probably affects the seat vibrations. Exposure assessment according to the new ISO standard and euro standard proposal indicate potential health risks.

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Significance of radiation exposure from work-related chest x-rays for epidemiologic studies of radiation workers

Cardarelli JJ [(1)], Spitz H [(1,2)], Rice C [(3)], Buncher CR [(3)], Elson H [(4)], Succop P [(3)]

[1.] *National Institute for Occupational Safety and Health, Robert A. Taft Laboratories (R-44), 4676 Columbia Parkway, Cincinnati, Ohio, United States,*
e-mail: jjc0@cdc.gov
[2.] *University of Cincinnati, Department of Mechanical, Industrial and Nuclear Engineering, 598 Rhodes Hall, Cincinnati, Ohio, United States,*
e-mail: henry.spitz@uc.edu
[3.] *University of Cincinnati, Department of Environmental Health, Kettering Laboratory, Cincinnati, Ohio, United States, e-mails: alerdilr@uc.edu, bunchecr@uc.edu, paul.succop@uc.edu*
[4.] *University of Cincinnati, Barret Cancer Center, Cincinnati, Ohio, United States,*
e-mail: elsonhr@healthall.com

Introduction

Occupational epidemiologic studies provide an opportunity to evaluate the health risks from exposure to low-levels of ionizing radiation. These studies rarely include exposures from medical sources. In two studies of atomic bomb survivors, the authors concluded that medical x-ray exposures should be evaluated to better understand the effects for low-level exposures to ionizing radiation *(Yamamoto et al., 1988; Antoku et al., 1972)*. The aim of this study is to investigate multiple sources of worker exposures to external ionizing radiation at a uranium enrichment plant (a low-level exposure facility) between the early 1940s and 1990s and determine if work-related x-ray exposures added substantially to their cumulative occupational dose.

Methods

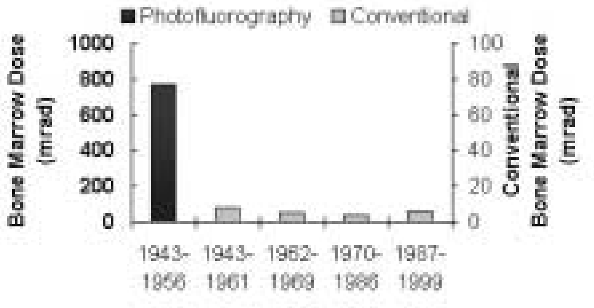
Bone-marrow doses from work-related x-rays were estimated for 297 workers, who are cases and controls for a multiple myeloma study, at a gaseous diffusion plant between the early 1940s through the late 1990s. Only 45 of these workers had other occupational radiation exposures monitored with personal dosimeters. Radiation exposure from work-related x-rays was determined by the number and type of x-rays conducted on the 297 workers at the facility. Cumulative bone marrow doses due to these x-ray exposures were calculated by converting entrance-skin-exposures to bone marrow doses *(ICRP 1987, ICRU 1988, Kereiakes et al., 1980)*. Conversion factors account for different types and energy of radiation, partial body irradiation, exposure times, orientation, type of x-ray examination, and the configuration and composition of body.

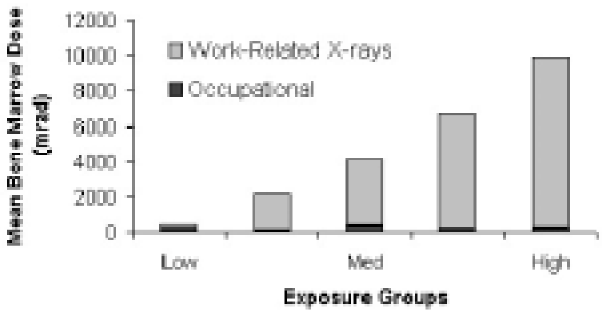
Work-related x-ray exposure data from all 297 workers were evaluated to describe the distribution of bone marrow doses associated with x-ray techniques used in the medical surveillance program. A comparison of bone marrow doses from external radiation exposure and from work-related x-rays was performed on the subset of 45 workers to investigate the significance of each source of radiation exposure to their respective cumulative dose. Also evaluated was the potential for misclassification resulting from excluding work-related x-ray exposures from the cumulative dose, and the presence of any statistical relationships between these sources of radiation exposure.

Results

Among these 297 workers, the chest x-ray was performed most frequently (78.6%), followed by extremities (12.3%), lumbar spine (2.3%), and skull (2.2%). Seven different examinations account for the remaining x-rays (4.6%).

Chest x-rays using the photofluorographic technique during the 1940s and 1950s delivered a bone marrow dose that was two orders of magnitude greater than the conventional method (viz., _ 800 mrad vs. <10 mrad, respectively) (figure 1).





Evaluation of cosmic radiation exposures of flight crew for epidemiologic studies

Waters M [(1)], Bloom T [(1)], Grajewski B [(1)]

(1) National Institute for Occupational Safety and Health (NIOSH), Cincinnati, Ohio, USA, e-mail: mwaters@cdc.gov

Introduction

Flight crew are exposed to elevated levels of cosmic ionizing radiation of galactic and solar origin and are among the more highly exposed occupational groups to ionizing radiation in the U.S., with annual doses ranging from approximately 0.2-5 mSv. Cosmic radiation dose depends primarily on altitude and geomagnetic latitude and to a lesser degree on solar activity and phase of the solar cycle. NIOSH is conducting several epidemiologic studies examining the relationship between cosmic radiation exposure, among other factors, and reproductive health of female flight attendants. Estimation of historical cosmic radiation dose is an essential component of these studies. One aim of this study was to measure cosmic radiation doses on a series of flights as a function of altitude, distance flown, latitude and longitude, and to compare dose-equivalent data collected on specific flights with doses estimated using the CARI computer program developed by the Federal Aviation Administration. CARI estimates will be used for dose reconstruction for the epidemiologic studies.

Methods

Flight segments (n=38) were selected to include north-south, east-west, trans-arctic circle and trans-equatorial flights within three flight duration categories: <2, 2-8, and >8 hours. Pilots recorded flight altitude and geographical position every 30 minutes and for every change in altitude.

Measurements were made with a tissue-equivalent proportional counter (TEPC) with a 5-inch spherical detector made of a tissue-equivalent plastic wall filled with 7 mmHg of tissue-equivalent gas to simulate a cell size of 2 microns. The detector was connected to a 256 bin multichannel analyzer with a lineal energy range from 0.2-1000 keV/*u*m. The energy resolution was 0.1 keV/*u*m below 20 keV/*u*m and 5 keV/*u*m above 20 keV/*u*m. The full lineal energy spectrum was recorded every minute from gate departure to gate arrival. Absorbed dose was calculated by summing the number of events per channel times the mean energy of each channel and multiplying by a factor which includes the mass and area of the simulated site. Dose equivalent data were calculated based on quality factors in International Commission on Radiological Protection Publication 60, Table A-1 (ICRP, 1991). Two TEPCs were used on each flight and were placed in the overhead compartment mid-aircraft.

Estimates of cosmic radiation dose were computed using CARI-3C (2) for the same origin-destination city pairs as the survey flights, using pilot records of altitude and time. Input parameters included origin and destination cities, flight date, ascent time(s), each altitude level and time at altitude, and descent time.

Results

Measurements for 17 of the flight segments are given in Table 1. In general the CARI-3C estimates of equivalent dose were lower than the measurements for the same flight segments, although for one very short high latitude flight (Nome (65°N) to Anchorage (61°N)) and for a trans-equatorial flight the model estimate was higher than the measured dose equivalent. The percent difference ranged from +11% to -46% for flights less than two hours long, from -1.5% to -56% for flights between two and eight hours in length, and from -14% to -44% for flights longer than 8 hours. No trend in % difference between measured and estimated doses by flight time was found. With respect to the relationship between flight latitudes and % difference, the measured dose was in fairly good agreement with the estimated dose for the two trans-equatorial flights. However, the comparability between the two metrics was reduced at higher latitudes.

Table 1. Measured dose equivalent and CARI-3C estimated equivalent dose with percent difference for flights ranging from 36-540 minutes (n=17).

Origin-destination	altitudes (K ft)	flt time (min)	measured (μSv)	estimated (μSv)	% diff
Kotzebue-Nome	25	36	0.64	0.34	-47
Anchorage-Nome	33	74	3.3	2.8	-15
Nome-Anchorage	33	83	2.78	3.1	+12
San Francisco-Seattle	35	96	5.84	3.87	-33
Miami-Dallas	22/ 31	143	7.15	2.95	-56
Miami-Boston	29/ 27	160	5.80	4.2	-28
Boston-Miami	35	175	12.0	8.93	-26
Seattle-Anchorage	35	181	12.5	11.3	-11
Anchorage-Seattle	33	198	15.6	10.9	-30
Tokyo-Saipan	37	201	6.02	5.90	-1.5
Dallas-San Francisco	35/23	208	13.0	8.36	-34
Saipan-Tokyo	29	225	4.42	3.70	-13
Seattle-Miami	37/41	311	32.0	23.3	-27
Miami-Buenos Aires	33/37	475	16.4	15.9	-2.8
Buenos Aires -Miami	28/29/35/37	521	16.9	17.7	+4.4
Tokyo-LA	31/33/35/37	534	37.0	24.5	-34
Seattle-Tokyo	31/35/36/38	540	50.9	32.6	-32

Discussion

The measured radiation doses measured represent a complex function of duration of flight, latitude, and altitude. One aim of this work was to compare CARI dose estimates with measured doses on a limited number of flights to assess the suitability of estimating flight segment doses using CARI from flight attendant work histories. CARI-3C estimates of equivalent dose ranged from 11% higher than TEPC measurements of dose equivalent to 56% lower (median 26% lower). Less model bias was observed for low latitude flights. Possible explanations for the observed bias are: (1) the TEPC detector simulates a measurement of dose equivalent at the body's surface, whereas CARI-3C model estimates the equivalent dose to the bone marrow and skeletal tissue; and (2) the measurements are made in an aircraft, whereas the CARI-3C estimate does not take into account any effect of aircraft shielding. However, by comparison with balloon measurements, Foelsche (1) has shown that aircraft masses did not increase neutron spectra and doses by more than 5-10%. The relationship between latitude and model bias will be explored further by partitioning flight segments into periods of relatively constant latitude and comparing measured with estimated doses for these shorter periods of flight.

To estimate historical cosmic radiation doses for epidemiologic studies where individual flight histories are available, the CARI model and a set of standard assumptions for altitudes and times for each phase of flight can be used to estimate cosmic radiation doses per flight segment with some bias as described here. These doses can be subsequently cumulated over the time period of epidemiologic interest.

Conclusions

Few cosmic radiation measurement data exist for aircraft flying commercial transport routes. The measurements described here were compared to an empirical model for estimating cosmic radiation dose for a variety of flight segments. Doses computed from TEPC measurements tend to be greater that those estimated by the CARI model. Differences in measured versus modeled data should be considered when assigning doses estimated from the use of CARI for epidemiologic studies.

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The utility of task-based noise exposure assessments in epidemiology: lessons learned from compliance sampling in machining and stamping plants

Woskie, S.R.[*1] Prince, M.[(1)] Waters, M. [(1)] Zhou, X.[(1)]

(*) University of Massachusetts Lowell, Lowell, MA, USA (Susan_Woskie@uml.edu)
(1) National Institute of Occupational Safety and Health, Cincinnati, OH, USA
(Mprince@cdc.gov, Mwaters@cdc.gov, XZhou@cdc.gov)

Introduction

As part of a study to evaluate the effectiveness of hearing conservation programs, NIOSH received access to noise exposure surveys conducted every two years during the 1990's at two large U.S. automobile manufacturing facilities. The facilities used a task-based data collection method that involved developing detailed sound exposure profiles for each unique department/job combination in the plants. These exposure databases provide a unique opportunity to examine the nature of daily and task noise exposures in parts machining and stamping operations. Because of the task based nature of the data, it also provides an opportunity to investigate the utility of bootstrap sampling methods for efficient estimation of noise exposures for epidemiologic studies and exposure control.

Methods

Sound exposure profiling, or task-based sampling (TBS) for exposure assessment, has been used in the large automotive parts manufacturing plants covered by this study because of the efficiency introduced by the method and the ability to customize hearing loss prevention evaluations for a large number of workers (1). The approach is similar to that described for chemical exposures where task level times time is summed across all tasks and divided by the total work time to estimate the daily TWA. However, in the case of noise, the calculation differs somewhat due to the logarithmic dB scale of noise measurement.

The first step in a TBS evaluation is to determine the tasks that comprise the representative work assignment. The list of tasks is developed based on an understanding of the job under study through observation, and interviews with supervisors and workers. The supervisor provides information about what the job entails and the amount of time spent on each activity. Once the tasks are defined, sound level measurements are made in the hearing zone of the worker as each of the activities is performed. Typically this involves measurement over several repeated occurrences of each activity. The compilation of these activities is defined as a profile. These profiles typically include the daily average sound level (TWA in dBA), the minimum and maximum sound level during the day, as well as the peak sound level, if an unweighted peak exposure of over 120 decibels is recorded.

Each profile created from a survey was exported to a SAS database. Daily time weighted average and task noise levels, as well as the task time estimates were examined for normality and descriptive statistics developed for the whole dataset and by time periods by job, task, noise source and control method used. Of particular interest was whether job complexity (number of tasks within a job) had an impact on exposure variability.

Results

The database for the machining plant contains 2659 daily time weighted average estimates over the period of 1990 to 1999. Examination of the daily TWA's by job and by department show most subsets to be approximately normally distributed. Within the machining plant, jobs vary in task complexity, containing from 1 to 9 activities with a mean/median of 4 activities (SD = 1). The mean/median number of activities decreased from 4 in 1990 to 3 in 1999. There was no significant difference in the number of activities associated with production and non-production jobs. However, as the complexity of the jobs increased in non-production, the standard deviation of the 8 hour TWA noise level decreased, while for production jobs the standard deviation of the 8 hour TWA increased with increasing complexity.

The database for the machining plant contains 8874 task-based samples. These samples consist of 2016 unique activities. Only 52% of the activities listed a specific noise source. Of those, the most common noise source (26%) was "part impact" (noise caused by the impact of a part against a work surface), followed by "machine mechanical" (9%) (noise resulting from internal machine components).

Within this data set, job level exposure assessments were done 1 to 216 times. Twenty-five percent (25%) of the jobs had 14 or more assessments. Since each job assessment has a median of 3 to 4 activities, this is a substantial sampling effort. We are currently using a bootstrap resampling approach to evaluate the optimal number of assessments of individual task levels and task times needed to reliably estimate a job exposure level.

Discussion

Little has been published describing the nature of noise exposures. Of particular interest is how variable noise exposures are within jobs, tasks and noise sources. Such information is key to the development of sampling strategies for noise exposure assessment. The task-based approach to noise sampling described here is also relevant for chemical exposure assessment. For example, the time in specific tasks was shown to be a significant predictor of daily dust and endotoxin exposure level of farmers, helping to explain significant portions of the variability in worker exposures (2). Task-based sampling in the construction environment is particularly useful because the tasks, environmental conditions and exposure sources are all highly variable (3). Thus, a full shift sample will not provide useful information about how to protect workers from transient high exposures. However, a task-specific sampling strategy can identify which tasks contribute most to the overall exposure level (4).

Task based sampling approaches have not been widely used in occupational epidemiology. However, when task exposure levels are highly variable and the fraction of time a task is performed is highly variable as well, then a task-based exposure assessment may even provide more precise estimates of the mean exposure (5). Bootstrap sampling has been used to estimate the optimal sample size for evaluating lumbar posture at work (6) but has not yet been applied to optimizing task-based daily exposure estimation. In this study, we use the bootstrap technique to estimate the most efficient sampling strategy for task-based sampling using our noise exposure assessment database.

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Substituting air sampling with measurement of biomarkers?

Droz PO

Institute of Occupational Health Sciences, Lausanne University, Lausanne, Switzerland, e-mail : pierre-olivier.droz@inst.hospvd.ch

Introduction

Over the last 20 years there has been an important development of biomarkers in occupational health, and their applications in epidemiological research and in routine exposure assessment have been considered and discussed on several occasions. Three categories of biomarkers can be distinguished : indicators of dose, indicators of health effects and indicators of susceptibility (2). Only indicators of exposure are considered here, and they will mainly refer to chemical hazard exposures. Despite their potential numerous advantages over air monitoring, biomarkers of exposure are not used very often in epidemiological research (3), and even in practice.

The aim of this presentation is to compare, in a quantitative manner when possible, the advantages and disadvantages of both approaches. Several aspects are considered such as the objective of exposure assessment (epidemiological study, compliance, practice), the type of chemical, the type of health effects, and the exposure situation.

Methods

After a literature review, 3 types of studies relating air monitoring and biomarkers are considered here to discuss their respective advantages and disadvantages : toxicokinetic experimental studies on volunteers, biological monitoring investigations in occupationally exposed workers, and toxicokinetic modelling. Modelling is furthermore based on tools of various complexities going from simple one-compartment (OC) toxicokinetic models, to elaborated physiologically-based pharmacokinetic (PBPK) models. In several cases toxicokinetic models are associated with statistical modelling techniques to study and quantify variability which is an essential parameter in the comparison of air and biological monitoring.

Results and discussion

Marker persistence. One drawback of biomarkers is their limited persistence in the body or target tissues. This is especially true for retrospective studies. Data from an OC model are presented to estimate the contributions of different exposure periods for a specific biomarker, as a function of its half-life. General rules can then be established for different categories of biomarkers.

Dose estimation. Exposure dose or the dose at the target site can be assessed both by air and biological monitoring, with varying degree of bias and random error. As a rule, biomarkers can be considered to have lower bias, taking into account physical workload, distribution, dermal or oral exposure. There are however cases, such as local toxicity at the site of entry, where they can introduce further bias.

Exposure variability. The statistical simulation of exposure variability gives results with varying consequences on air and biological indicator results. An analysis show that respective advantages depend mainly on the half-life of the chemical in the body, slowly eliminated chemicals showing much less variability then their corresponding air monitoring results.

Individual variability. Individual factors affecting the behaviour of the chemicals in the body lead to a rather important biomarker variability. This can be introduced in a comparison with air monitoring data, based either on a OC or PBPK model. Simulation data show that the interpretation of the observed variability is a function of the environmental variability too. In the case of highly fluctuating exposures, biological variability plays a marginal role. It becomes however predominant for rather stable environments.

Epidemiological studies. Some applications of biomarkers of exposure in epidemiological studies are presented and discussed. This traditional use of biomarkers contrasts with the potential applications and promising future of health effects or susceptibility biomarkers now often considered in molecular epidemiology (1)

Routine use. For several well studied biomarkers, all necessary elements have been available for a relatively long time (toxicokinetic information, dose-responses, criteria for evaluation). However their use is still limited and this can be explained by several factors such as : ethical issues, health and safety professionals preferences, effectiveness in interventions or control measures testing.

Conclusions

Consideration and application of biomarkers and their associated body of knowledge in epidemiological studies and in practice can contribute to improve our understanding of the risk assessment paradigm. For routine use it is clear that biomarkers often bring better or complementary information about the risk of current or recent exposure, which is often the point of interest. In the case of epidemiological studies (retrospective) biomarkers can often not be substituted to air monitoring or other ecological measures of exposure. It can however help to understand the mechanism and time dependence of the toxic processes, and therefore favour the design of relevant exposure indicators, based on biomarkers, air monitoring and other ecological indicators.

However in many cases the choice between biomarkers and air monitoring does not rest on systematic technical criteria, but on personal and social preferences.

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Development of a job-exposure matrix for current exposure to formaldehyde in Quebec: A preliminary study

Gérin M [(1)], Bégin D [(1)], Perrault G [(2)], Hébert F [(2)], Duguay P [(2)], Arcand R [(3)], Lefebvre P [(4)], Pallage S [(4)]

[1.] *Department of Environmental and Occupational Health, Université de Montréal, Montréal, Québec, Canada, e-mail:* michel.gerin@umontreal.ca
[2.] *Institut de recherche Robert-Sauvé en santé et en sécurité du travail, Montréal, Québec, Canada*
[3.] *Direction régionale de la santé publique, Montréal, Québec, Canada*
[4.] *Université du Québec à Montréal, Montréal, Québec, Canada*

Introduction

Formaldehyde is an irritant, a sensitizing agent and a probable human carcinogen which is found in a wide range of occupations and industries. In Quebec the present limit value of 2 ppm (ceiling) is being evaluated as to its possible lowering. A study has been commissioned to estimate the economic and health impacts of various limit value scenarios. A preliminary study was undertaken to examine applicable methodologies, including methods that can be applied to the drafting of an accurate profile of current exposure in Quebec workplaces.

Methods

Sources of exposure data, both internal and external, were examined as well as literature regarding occupational exposure data banks and job-exposure matrices. US industry and occupation classifications were converted to equivalent Quebec/Canada codes and data on number of workers by industry code were retrieved from a 1996 survey by Statistics Canada.

Results

There is no comprehensive data source on formaldehyde exposure in Quebec. However, evaluations made by governmental industrial hygiene teams in a number of priority economic sectors since 1994 have been compiled in a data bank (SMEST) including industry and occupation codes. These cover 2,029 workers in 266 jobs. Another bank (IRSST) which includes only industry codes regroups 2459 results of analyses on sampling tubes in Quebec since 1990. In the framework of a regulatory impact assessment OSHA (1) has produced in 1987 an industry-exposure matrix with estimates of the number of workers exposed within preset ranges of exposure levels. A similar exercise using exposure data from the SMEST and IRSST banks, equivalent industry codes and number of workers by industry code in Quebec indicates that some 90,000 workers would be exposed in some 2,500 companies. Similarly to the US data, exposure above 2 ppm occurs mostly in the wood, furniture and plastics/resins industries with additional sectors found, however, such as the paper, food and pharmaceutical industries. No Quebec data were found for several important sectors including funeral homes and medical laboratories. Other readily available sources of systematic exposure data include two external job-exposure matrices: FINJEM (2) from Finland and SUMEX (3) from France.

Discussion

This preliminary assessment indicates that present local data is insufficient to evaluate formaldehyde in Quebec in a comprehensive and representative manner. Local data banks are incomplete, covering a limited number of jobs in priority sectors. Thus in those sectors where exposure has been measured exposure profiles are probably biased towards the high end while data is completely lacking in many sectors. External data such as from the US, Finland and France and from the general literature should be useful in identifying exposed industries and occupations and in providing a rough estimate of potential exposure levels. Professional judgment could, however, be fruitfully exercised regarding similarity of processes and work conditions between various countries in order to apply external data.

Conclusions

Building a useful exposure profile will involve collecting considerably more exposure measurements in several industrial sectors and thoroughly documenting existing data, both internal and external. A two-tier approach is recommended with 1) a measurement survey undertaken in those sectors with potentially high levels with the aim of completing existing exposure data and 2) the use of mainly external and literature data for other sectors. A team of hygienists will interpret ensuing data, sector by sector, in order to build a job-exposure matrix integrating both industry and occupation codes.

Comparison exercises will be undertaken in order to validate the various procedures and external data sources.

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Exposure assessment for epidemiology, expressing variability and uncertainty using Monte Carlo simulations

Glass D.C.[(1)] and Gray C.N.[(2)]

[(1)] *Monash University, Victoria, Australia; deborah.glass.med.monash.edu.au*
Formerly Health Watch, The University of Melbourne, Victoria, Australia
[(2)] *Deakin University, Victoria, Australia; cgray@deakin.edu.au*

Introduction

In occupational epidemiology, exposures are usually expressed as point estimates for each job and are used in conjunction with occupational histories to calculate metrics such as cumulative exposure in ppm-years or average exposure intensity in ppm, for each subject. These exposure metrics ignore the day-to-day variability that is known to be associated with exposure as a result of process and environmental variations and with person-to-person differences that result from individual work practices (1). If there is evidence of a non-linear relationship between exposure and risk, as there is for benzene and leukaemia (2), the risk may be associated mainly with periods of higher exposure intensity that are not expressed in the simple exposure metrics. In addition there is usually considerable uncertainty in the exposure estimates and this can lead to misclassification and consequential error in the exposure-risk relationship. These problems could be overcome if the distribution of exposures for each individual were known, but sufficient exposure data is almost never available. An alternative approach is to model the exposures using a deterministic algorithm and to include estimates of variability and uncertainty for each of the model variables. Exposure distributions for each individual can then be calculated using numerically intensive methods such as Monte Carlo simulation (3).

Methods

A case control study was carried out to investigate the association between lymphohaematopoetic (LH) cancers and exposure to benzene in the Australian Petroleum Industry. A deterministic algorithm described elsewhere (4) similar to that used in other petroleum industry studies (5, 6), was used to estimate exposure retrospectively. The algorithm used exposure data from Australian petroleum companies, and exposure-modifying factors to account for changes in technology, products etc. Exposures were calculated on an individual subject basis, using detailed work histories as well as site-specific and period-specific information in order to derive a cumulative benzene exposure (ppm-years) for each subject and an average intensity of exposure (ppm) for each job.

In order to examine the possible effects of variability and uncertainty on the estimated exposures, the road tanker drivers were selected as a manageable sub-set. Tanker drivers were chosen for two reasons; firstly because they are the group identified as having perhaps the highest risk of leukaemia among distribution and refinery workers, (7, 8) and secondly because their jobs were well defined and the variation and uncertainty in the exposure modifying factors could be estimated. Twenty drivers who carried gasoline and loaded their own bulk tankers were identified and selected for study. The inputs to the exposure estimation algorithm for tanker drivers were; the arithmetic mean of Australian exposure measurements for three major tasks: "Top Loading", "Bottom Loading" and "Driving & Unloading", work hours per week, the percentage of benzene in gasoline, the proportion gasoline loaded, the number of loads a day, the number of days per week and the time per load (hours). Mean values and probable distributions were attributed to the various inputs on an individual driver basis from information taken from the driver's personal interview or stated as being typical of that site, during the exposure estimation investigation. Judgements were made of the mean and distribution of the variability and the uncertainty about these inputs based on an understanding of the available data, their limitations and their sources. Monte Carlo simulation was applied to the algorithm for tanker drivers, to integrate the sources of uncertainty and variability, drawing values at random from the distribution for each of the variables. This resulted in a probability distribution of daily exposure for each tanker driver, for each period of time where conditions were stable. The daily averaging time was chosen because there is evidence from pharmacokinetic modelling that shorter fluctuations in exposure are physiologically damped at the bone marrow target site (9). The computer program Crystal Ball™, an add-in to Microsoft Excel™, was used to carry out the iterations.

Each time one of the algorithm inputs changed, for example the hours worked per week or the proportion of the load that was gasoline, the algorithm was recalculated with the new value, giving rise to 43 driver/periods. The exception to this approach was the percentage of benzene in gasoline, this was averaged over each driver/period. The Monte Carlo simulations were run using the exposure modifiers and then separately with the estimated variability and uncertainty distributions alone.

Results

The results for the 20 drivers were broadly similar and those for one driver are presented in Figures 1 to 3 for illustration. The calculated distribution of daily average exposures, including both the variability and uncertainty terms, for driver 1.1 had a mean of 0.29 ppm and a range of 0.01-4.32 ppm (Figure 1). Using the uncertainty estimates alone resulted in a distribution of exposures with a much narrower distribution but a similar mean 0.28, (range 0.2-0.37) (Figure 2). This represents the estimated uncertainty on the average exposure for this individual. In a similar way the variability in daily exposure was simulated, resulting in a mean of 0.28, and a range of 0.01-2.99 (Figure 3).

The simulated uncertainty was found to have an approximately normal distribution with a standard deviation of 0.03, and the variability an approximately lognormal distribution. As an approximation, the distribution of uncertainty can be applied to the whole range of exposure estimates for this subject, for example the mean exposure could be expressed plus or minus 2 standard deviations (0.29 ± 0.06 ppm). This analysis indicates that the underlying variability makes a much larger contribution to the overall variation shown in Figure 1 than does the uncertainty.

Discussion

Most quantitative exposure assessments for occupational epidemiology have produced point estimates of average exposure for each identifiable group of workers. Estimates of the uncertainty and variability associated with the exposure estimate are uncommon. These quantities are important because uncertainty can result in misclassification and variability means that some exposures can be considerably greater than the average and can contribute disproportionately to the risk for some diseases. One method by which these can be estimated has been investigated. The method relies on a detailed model of exposure and requires measurement or estimation of the variability and uncertainty in the various inputs to the model. Monte Carlo simulation is then used to combine the variables in an iterative calculation in order to generate a probability distribution of exposures.

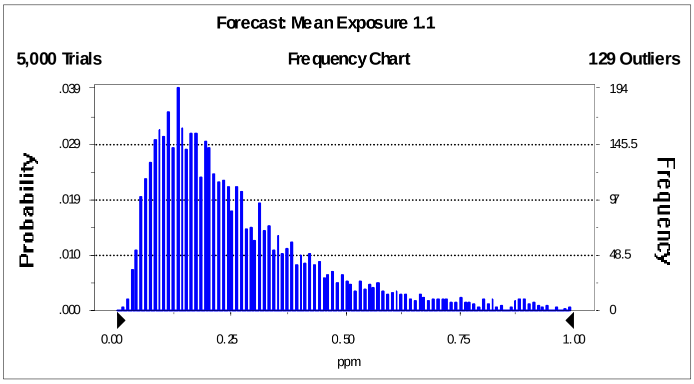

Figure 1. Mean daily exposure (ppm) probability distribution for driver 1.1 including uncertainty and variability
(note 129 outliers)

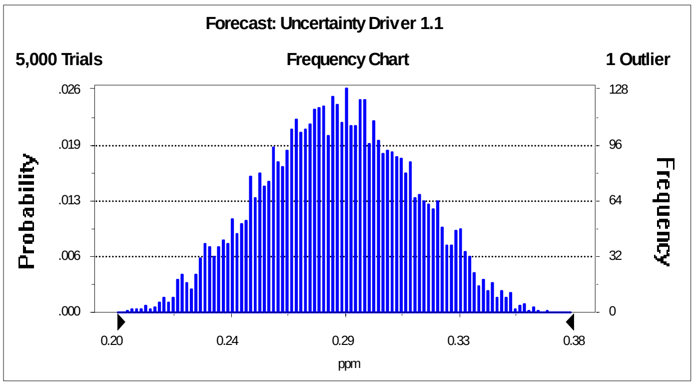

Figure 2. Distribution of uncertainty associated with mean daily exposure (ppm) for individual driver period 1.1

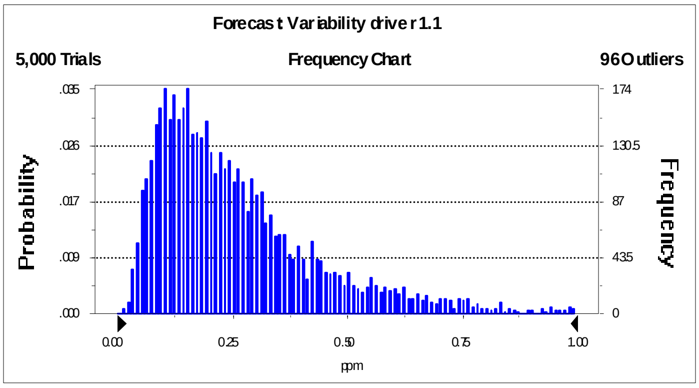

Figure 3. Distribution of variability associated with mean daily exposure (ppm) driver 1.1
(note 96 outliers)

Conclusion

Monte Carlo simulation is a useful tool for investigating the uncertainty and variability in retrospectively assessed exposures. Combined with a reliable exposure algorithm and input values, it can be used to produce a probability distribution that is more informative than a point estimate of exposure. This can then be used to assess the possible extent of exposure misclassification and to allow analysis of the contribution of high exposures to disease risk.

Acknowledgments

The authors would like to thank The Commonwealth Government, MSA, The Energy Research and Development Corporation, the Australian Institute of Petroleum and The University of Melbourne who financed and supported this study. The authors gladly acknowledge the valuable help from several petroleum companies and their employees and other members of the Health Watch team.

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Combining Job Specific Modules (JSMs) and Exposure Matrices for retrospective exposure assessment

Benke G [(1)], Fritschi L [(2)], Hughes A [(3)], Kricker A [(3)], Armstrong B [(3)]

[1.] *Department of Epidemiology and Preventive Medicine, Monash University, Victoria, Australia, e-mail:* geza.benke@med.monash.edu.au
[2.] *Department of Public Health and Medicine, University of Western Australia, WA, Australia, e-mail:* linf@dph.uwa.edu.au
[3.] *Cancer Research and Registers Division, New South Wales Cancer Council, NSW, Australia, e-mail:* ahughes@nswcc.org.au

Introduction

Job specific questionnaires or modules [1,2] have been used in the past five years to improve exposure assessment in retrospective community-based case-control studies. The method can be thought of as an extension of the expert exposure assessment method, whereby the subject is given a lengthy questionnaire or module (hereafter we shall refer only to modules) for occupations or industries that were reported in their job history. The answers elicited from a subject for a module are then reviewed and assessed for exposure by a hygienist or expert panel.

The Job Specific Modules (JSMs) approach was developed in isolation of the Job Exposure Matrix (JEMs) exposure assessment method. In a community-based case-control study investigating Non-Hodgkin Lymphoma (NHL) we first used JSMs as the primary method of exposure assessment. However we wished to investigate whether exposure assessment in a study could be enhanced if JSMs could be combined with JEMs and exposure matrices. This approach may also improve the reliability of the exposure assessment in a study compared to simply employing JSMs and expert assessments, which are known to produce variable reliability [3].

Methods

The NSW NHL study is a collaborative community based case-control study, which aims to recruit 800 cases and 800 controls (by the end of 2001) matched by age and sex. Immunological, infectious, occupational and environmental risk factors for NHL are being investigated. The occupational exposures investigated include phenoxy herbicides, benzene and other solvents, metal dusts, organic dusts and PCBs. Subjects are initially provided with a self-administered postal questionnaire, then a computer assisted telephone interview (CATI) is undertaken, which may involve the use of up to 5 JSMs per subject.

A total of 44 occupation and industry JSMs were constructed for the study, and were based on a collection of approximately 70 modules developed for the NCI, Bethesda, Maryland, USA [2].

A ‘Pesticide Exposure Matrix’ was constructed for the study, which had the three primary axes: crop types, pesticide type, time of use (i.e start date and finish date of use). The matrix also contained information on application types and exposures, trade names and PPE use. A retired expert formerly with the Department of Agriculture was consulted to review and make comments regarding use patterns, over time and in different geographical regions. Exposure matrices were also constructed for PCBs, formaldehyde and benzene, but these are crude in comparison to the pesticide matrix. It was our aim to also routinely consult community-based JEMs [4,5] during the exposure assessment process.

Other sources of information included: the Internet; MEDLINE [6]; ILO Encyclopaedia [7]; various professional, government, employer, labor organizations; hygiene/occupational medicine texts and conference proceedings. A network of consultant, corporate and government occupational hygienists were also consulted.

Results

Of the 988 completed JSMs received to date it has been found that over 70% of allocations were for the ten most frequently used modules. The assessment of pesticide exposure for the 111-farmer/farm worker modules was highly dependent upon the pesticide exposure matrix. The expert assessor could confidently only assess 23 of the farmer modules, without reference to the pesticide exposure matrix. The exposure to benzene in the driver JSMs was dependent upon the benzene exposure matrix and similarly for capacitor workers and PCBs. The formaldehyde matrix was useful in identifying occupations and industries where a JSM was not available.

Reference to the community-based JEMs was necessary in the majority of the JSMs assessed for exposure to metals, solvents and where little information was locally available. We found that in 16 of the 44 modules, the community-based JEMs were the primary reference used to identify exposure. They often also provided confirmatory information to the exposure assessment when the primary reference source was the substance specific exposure matrices.

Discussion

We found that exposure assessment using JSMs and expert evaluation was greatly enhanced when combined with the use of substance specific exposure matrices. In particular pesticide exposure to farmers was confidently undertaken following reference to a pesticide specific exposure matrix. This was similarly the case for other ‘generic’ exposures, e.g. metals and solvents, where exposure assessment was greatly enhanced by reference to community-based JEMs. Even for more specific exposures e.g. PCBs and benzene, consistent exposure assessment was difficult for the expert without reference to substance specific exposure matrices.

This firstly suggests that JSMs, substance specific exposure matrices and JEMs can be successfully used in combination with the expert panel or hygienists for enhanced retrospective exposure assessment. However, our findings also suggest that optimal use of JSMs may necessarily involve the use of substance specific exposure matrices and JEMs. In particular, community-based JEMs are useful as they can alert experts to situations where exposure may occur in jobs of which they have no or little first hand knowledge. However, ‘idiosyncratic’ exposures i.e. where exposure was not expected by the experts, to the chemical of interest, still remain a limitation to this combined approach e.g. farmers and solvent exposure. A further limitation is comparability with other studies, if different JSMs are used.

Our current research involves the application of a neural network to the learning database that we have established with the exposure assessments of the JSMs in the NSW NHL study. The neural network could possibly in the future import then analyze data directly from the JSMs then assess exposure, independent of the expert.

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A field evaluation of techniques used to construct a quantitative job exposure matrix

Zaebst D [(1)], McCammon C [(2)], Martyny J [(3)], Schonbeck M [(4)]

[1] *National Institute for Occupational Safety and Health, Cincinnati, Ohio, email: dzaebst@cdc.gov*
[2] *Tri-County Health Department, Denver CO, email: jbm2@earthlink.net*
[3] *Tri-County Health Department, Denver CO, email: Jmartyny@compuserve.com*
[4] *Colorado Department of Health and Environment, Denver, CO, email: Margaret.Schonbeck@state.co.us*

Introduction

A quantitative job exposure matrix (JEM) was created for historical exposures to a number of chemicals, including beryllium, at a U.S. Department of Energy (DOE) site. Monitoring data were limited or non-existent for many jobs and exposures, and much of the JEM was completed by using qualitative information obtained from employee interviews, and published data for similar operations and tasks from industry or other DOE sites. Since all available data had been used in estimating exposures, the estimates could not be directly validated at the DOE site. Instead, these techniques were evaluated by constructing a similar beryllium JEM at a separate industrial site (plant A, which also machined beryllium), and comparing the estimates to an independent set of beryllium measurement data, withheld from the estimation process, collected in 1996 and 1997 at plant A.

Methods

At Plant A, a small team of occupational health professionals, led by an experienced industrial hygienist, formed job groups and estimated exposures to beryllium, blinded to the 1996/97 monitoring data. Ten collapsed jobs were initially ranked based on employee interview information. A limited monitoring data set (n = 42) generated by plant personnel in the mid-1980s was used to develop initial estimates of exposure, similar to what was done at the DOE site. Published monitoring data from other beryllium plants were reviewed and applied, adjusting for frequency and duration of exposures, and differences in processes, equipment, and controls. Additional final adjustments to the estimates were made for several process and control changes between the mid-1980's and 1996/97 at Plant A (e.g., removal of air pressure hoses). These were judged to collectively reduce exposures by about 20%. Once the estimates were complete for each of ten collapsed jobs, they were paired with the geometric mean for the same job calculated from the 1996/97 data and statistically analyzed.

Results

Table 1. Beryllium exposure estimates (µg/m^3) and monitored geometric means.

Rank	Job/Task	Estimated Exposure	Measured GM (N)
1	Grinding	1.6	0.65 (35)
2	Deburr	0.96	1.41 (45)
3	Lathe	0.64	0.64 (15)
4	Milling	0.60	0.35 (39)
5	NC Mill	0.48	0.17 (9)
6	Lapping	0.25	0.20 (39)
7	Maintenance	0.1	0.16 (1)
8*	Inspection, Tooling, & Assembly	0.01	0.015 (6)

* Three unmonitored jobs assumed unexposed; Plant A ambient background measurements were used for comparison.

Table 1 lists each job in descending order of the estimated exposure. The bias between the two paired sets was 0.10 µg/m^3 (Estimate – GM), the precision was 0.36 µg/m^3, and the total accuracy was 0.37 µg/m^3, about 103% of the mean concentration of 0.36 µg/m^3 in the ten collapsed jobs. Figure 1 displays the1996/97 independent beryllium monitoring data for the collapsed jobs, from which the geometric means were calculated. The high-range data points in the deburr and grinding job groups suggest that non-homogenous tasks have been combined. It was not possible, after the fact, to exclude these points or divide the job into two or more different job groupings for the purpose of the paired comparison, since the estimates had been made for all tasks within the deburr and grinding jobs.

A moderately strong relationship (Pearson's R = 0.73; p = 0.017) exists between the estimates and the geometric means of the 1996/97 data (Figure 2). The intercept of the regression line is near zero (0.075, p=0.62). The calculated slope is less than the expected value of 1 but not significantly less (0.60, p = 0.10). The grinding job had a larger than average influence on the regression (leverage of 0.64; and a studentized residual of -3.1, more than three times the average value). Removal of this point improved the results considerably (R = 0.89, intercept = -0.064, and slope = 1.16). Using all ten pairs, a paired t-test (p = 0.39), a sign test (p = 0.75), and a signed ranks test (p = 0.84), all indicate no significant differences on the average between the paired values of estimated exposure and geometric mean exposure. Spearman’s rank correlation coefficient (0.98, p = 0.0003) also indicated relatively accurate comparative rankings.

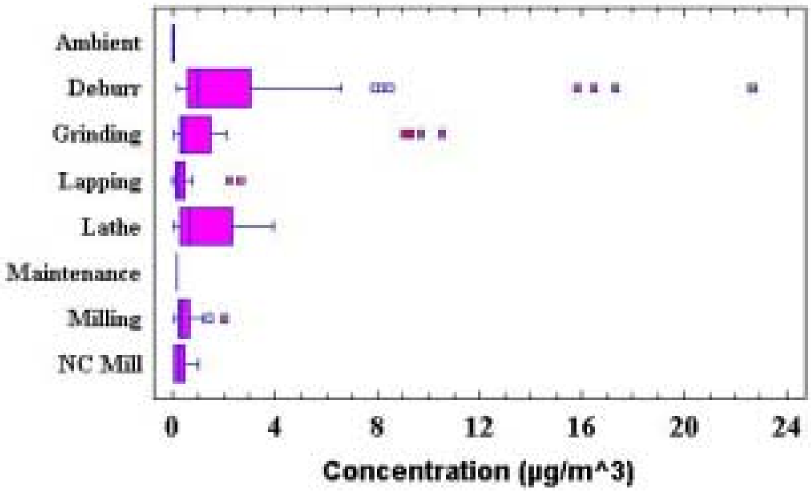

Figure 1. Box-whisker plot of 1996-97 data (N = 189). The central box shows the interquartile range (25th-75th percentile), the vertical line within the box shows the median, and the whiskers extend to 1.5 times the interquartile range. Points marked with + are >3 times the interquartile range. There four such points for deburr, and six for grinding.

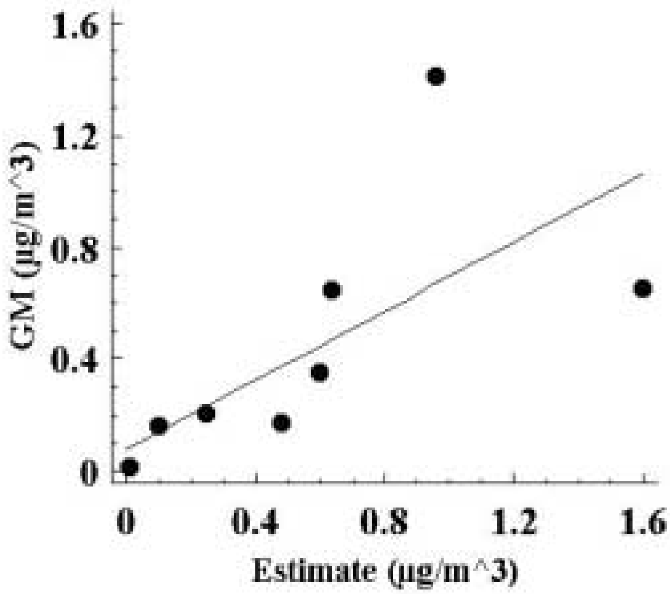

Figure 2. Scatter plot of ten values from Table 1, and linear least squares regression.

Discussion

The job rankings obtained at Plant A in this evaluation (Table 1) were not identical. In particular, two pairs of closely ranked jobs (grinding vs. deburr, and NC Mill vs. lapping) were reversed compared with actual geometric mean exposures. However, in general, the overall placements were surprisingly good, meaning that highly ranked jobs had the highest estimates, and the lowest ranked jobs had the lowest estimates. In addition, the exposure estimates were very similar to the measured exposures.

Conclusions

The results of this study suggest that acceptable estimates of exposure may be obtained through interviews with knowledgeable workers, by carefully applying published quantitative exposure monitoring data, and using that information with careful adjustments for known determinants of exposure in the workplace. The results further suggest that the JEM estimates for the DOE-site, which used the same techniques for several different chemical exposures, are reasonable. Extensive knowledge of processes, conditions, and determinants of exposure, gained primarily from employee interviews, coupled with published literature values where this information is also well documented, are important for valid application of these techniques.

An expert system to model to predict indicative exposure distributions

Warren N

Health and Safety Laboratory Broad Lane, Sheffield, S3 7HQ, UK.
email:Nick.Warren@HSL.gov.uk

Introduction

Since 1992, the Health and Safety Executive has conducted research into dermal exposure to non-agricultural pesticides in a number of different situations: public hygiene insecticides (3), remedial products - timber preservatives and masonry biocides (1), timber pre-treatment preservatives (2) and antifoulant products (unpublished). Further studies are ongoing. Sufficient data have been collected to support the development of simple empirical models that attempt to predict exposures in a variety of situations. It has been proposed that potential dermal exposure, expressed as an accumulation rate (mg of product per minute) can be adequately described for screening level risk assessments by assuming a log normal distribution with a limited number of combinations of standard deviation (3 levels) and median value (4 levels). These twelve combinations with their associated medians, 75th percentiles and 95th percentiles are referred to as 'the indicative distributions matrix'. Previously gathered data on 12 distinct exposure scenarios has been fitted to the scheme. For wider application to exposure scenarios/jobs without supporting exposure data a model has been developed to guide an assessor to a particular cell of the matrix.

Model

The model uses fuzzy logic and a rule base derived from the expert knowledge of occupational hygienists to compare a hypothetical exposure scenario with measured exposure data on workplace and amateur exposures. This data is contained in a newly developed database and is grouped according to the task/activity performed and the workplace scenario. The model takes information on the task(s) performed, substance, technique and equipment used and compares this with the corresponding data on each scenario in the database using the knowledge encapsulated in the rule base as the reasoning for its conclusions. Rather than attempting to find a single closest match and adopting the exposures for this group as the prediction, the model assigns to each distinct scenario in the database a quantitative measure of its similarity with assessment scenario. This quantitative measure takes the form a probability distribution for the distance between the two exposure scenarios in the indicative distributions matrix.

With this mathematical structure imposed upon the problem maximum likelihood estimation can be employed to predict the position of the new exposure scenario in the matrix of indicative distributions. This fundamental statistical technique locates the assessment scenario in the matrix cell which maximises the statistical likelihood of the measured exposure data given the strength of their supposed relation to the assessment scenario.

Discussion

No assumptions are made about the magnitude and size of the effects of exposure determinants. Instead the expert knowledge of hygienists is used to draw up a list of factors that *may* account for variation in exposure distributions and these used to assess how similar two jobs' exposure distributions are likely to be. The actual effects of the determinants (if any) should manifest themselves through the likelihood of the exposure data. As a consequence, the model presented is fairly robust to alterations to its subjective (and somewhat arbitrary) parameters such as the membership functions used in the fuzzy logic stage.

The structure of the model allows extensions to be made to incorporate other forms of information. The model is particularly suited to being incorporated within a larger Bayesian solution to exposure prediction. For example, an occupational hygienist's expert opinion can be translated into a prior distribution for the position of an exposure scenario in the matrix and then the likelihood matrix based on the related jobs updates this into a Bayesian posterior distribution. This in turn can be updated with data on the actual exposure scenario being considered. This model thus provides a format for integrating all forms of information in a consistent and uniform manner. With increasing data on the actual exposure scenario there is a smooth transition from a prediction based entirely on the data on related jobs to one based totally on the new data.

Conclusions

A sophisticated and novel approach to empirical exposure modelling has been devised.

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Quartz exposure measurements in the construction industry for risk assessment of pneumoconiosis

Tjoe Nij E[(1)], Spierings, J[(1)], Steffens, F[(1)], Heederik, D [(1)]

[(1)] *Division of Environmental and Occupational Health, Institute of Risk Assessment Sciences, University of Utrecht, Utrecht, the Netherlands, e-mail: E.TjoeNij@vet.uu.nl*

Introduction

A recent survey among 1335 Dutch construction workers, with potential exposure to high levels of quartz containing dust [1] suggested the existence of a mixed dust type of pneumoconiosis (ILO category 1/1 or greater, mainly irregular opacities) among 2.9% of the studied population. The presence of radiological abnormalities was associated with a considerable decrease in lung function. The radiographic abnormalities were related to duration of exposure (working years in the construction trade). For a more refined risk assessment, based on job-titles, respirable quartz dust was measured for the occupational groups included. Expert judgment was also used for rating dust and quartz exposures.

Methods

Exposure measurements were performed among construction workers performing the following specialized tasks: concrete drilling, recess milling, cleaning of construction sites, tuck pointing, inner wall construction and demolition. It was planned to obtain repeated measurements for as many individuals as possible. Personal air sampling for respirable dust was conducted during full workdays (6 to 8 hours), using Dewell - Higgins cyclones from The Casella Group Ltd. (Bedford, UK), connected with Gilian® Gilair5™ portable pumps at a flow rate of 1.9 liter per minute. After gravimetric determination of dust on the filters, α-quartz was analyzed in Galten, Denmark at the Danish Environmental Center (MILJØ-KEMI). In all dust samples, quartz was determined by infrared spectroscopy (NIOSH method 7602 [2]). Occupational group-based exposure levels were calculated. Variance components were calculated for the intra- and inter-individual variance in exposure using a nested analysis of variance [3].
Three Dutch certified occupational hygienists, with experience in the construction sector, carried out the expert judgment. They had no prior knowledge of the health effects study. They rated exposures for all occupational groups represented in the health survey. They assigned a number between 0 and 10 to all jobs. Although only workers with 6 different job categories (pointers, demolition workers, natural stone workers, recess millers, concrete workers and terrazzo workers) were invited for the health effects study, 36 jobs had to be classified for both current and past exposure, because many construction workers in the population had had different jobs in the past.

Results

During tuck-pointing, recess milling and demolition respirable dust levels exceeded the Dutch MAC value for respirable nuisance dust (5 mg/m^3) (table 1). Average quartz exposure also exceeded the MAC value in these three groups. The MAC value for quartz in the construction industry in the Netherlands is 0.15 mg/m^3.

Table 1 Respirable dust (mg/m^3) and respirable quartz (mg/m^3) by construction workers sub-group and within- and between worker variation.

			Respirable dust (mg/m^3)				Respirable quartz (mg/m^3)			
Group	N[1]	n[2]	AM min-max	GM (GSD[3])	$_{bw}R_{95}$[4] (GSD)	$_{ww}R_{95}$[5] (GSD)	AM min-max	GM (GSD)	$_{bw}R_{95}$ (GSD)	$_{ww}R_{95}$ (GSD)
Total	34	68	2.2 0.1-11.5	1.1 (3.5)	31 (2.4)	38 (2.5)	0.35 0.002-3.77	0.086 (6.6)	600 (5.1)	47 (2.7)
Tuck pointers	4	10	3.5 0.6-8.0	2.2 (2.9)	1 (1.0)	69 (2.9)	0.56 0.089-1.65	0.35 (2.8)	1 (1.0)	110 (3.3)
Recess millers/ concrete workers	8	14	2.8 0.2-11.5	1.4 (3.4)	12 (1.9)	62 (2.9)	0.84 0.028-3.77	0.31 (5.3)	47 (2.7)	174 (3.7)
Demolition workers	10	22	2.4 0.2-9.4	1.4 (3.1)	25 (2.3)	21 (2.2)	0.25 0.038-1.26	0.14 (2.7)	14 (2.0)	20 (2.1)
Inner wall constructor	2	4	2.1 0.6-4.0	1.5 (2.5)	1 (1.0)	57 (2.8)	0.043 0.016-.084	0.036 (2.0)	1 (1.0)	25 (2.3)
Construction site cleaners	6	12	1.0 0.1-2.5	0.5 (3.7)	8 (1.7)	114 (3.4)	0.032 0.002-0.097	0.017 (3.6)	55 (2.8)	29 (2.4)
Background exposed group	4	6	0.3 0.1-0.4	0.2 (1.8)	10 (1.8)	3 (1.3)	0.005 0.002-0.015	0.003 (2.4)	22 (2.2)	8 (1.7)

[1] number of measured workers
[2] number of measurements
[3] geometric standard deviation
[4] $_{bw}R_{95}$: between worker ratio of the 97.5th and 2.5th percentile of the log normally distributed exposure
[5] $_{ww}R_{95}$: within worker ratio of the 97.5th and 2.5th percentile of the log normally distributed exposure

The construction workers performing recess milling and concrete drilling had a high average quartz exposure, but mostly recess milling was responsible for these levels. Recess milling resulted in exposures 6 to 7 times higher than concrete drilling (results not shown). The construction site cleaners and workers only exposed to dust generated by other workers, are exposed to much lower levels of respirable quartz and respirable dust. Quartz content of respirable dust, inhaled by the inner wall construction workers, construction site cleaners and the background group were below 5%.

The $_{bw}R_{95}$ and $_{ww}R_{95}$ were large for both dust and quartz exposure for the whole group. The large between worker component ($_{bw}R_{95}$ =600) indicates a large difference between occupational subgroups. Analysis by sub-group however, showed a higher within worker component, indicating that the exposure for a given subject varies to a great extent from day-to-day.

Median result of the three expert judges classified demolition workers, workers that clear rubble and recess millers as the three highest exposed groups, for both dust and quartz exposure (median score: 100%). Tuck-pointing received an exposure intensity score of 80%. The inner wall construction workers received a score of 40%, while the construction site cleaners and background group had a median exposure score of 30%.

Discussion

The high levels of quartz containing respirable dust measured during construction work are indicative of a risk of silicosis. Research in the mining industry has shown that risk of silicosis is mainly correlated with cumulative quartz dust exposure and that it has a long latency period (about 20 years). Exposure measurements among the construction workers revealed that especially the day-to-day variance (within-worker) is very large, which makes the calculation of a cumulative exposure estimate for individuals for risk assessment purposes very inaccurate. A group-based analysis of exposure data for exposure assessment for epidemiology is favourable when within worker variance is larger than between worker variance [4]. A measurement programme with more repeated measurements might give a more precise estimate of the individuals' exposure. Even if with a much larger exposure measurement programme, more accurate exposure data would be generated, its applicability for assessment of past exposure is doubtful, as jobs, techniques, materials, products, size of projects, specialization rate etc in the construction industry have changed in time.

Health effect studies among construction workers, indicate radiological abnormalities on chest *x*-rays. The prevalence of radiological abnormalities was clearly related with duration of exposure [1]. When cumulative exposure measures were calculated based on the above-mentioned measurements, the risk estimates for pneumoconiosis did not improve. Duration of exposure was still the best risk estimate. Cumulative exposure in this case is not the best exposure estimate because of the large day-to-day variance, and because only construction worker subgroups with potential quartz dust exposure participated in the survey.

The results of the expert judgement, although they are relative and subjective measures, are in accordance with the personal exposure measurements and might be a useful tool in assessment of cumulative exposure within the construction workers group.

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Benzene in blood and urine and t,t-muconic acid in urine of occupationally exposed workers

Brugnone F, Perbellini L, Cerpelloni M, Franceschi A, Pasini F, Romeo L

Occupational Medicine, Department of Medicine and Public Health, University of Verona – Policlinico GB Rossi, Verona , Italy, e-mail: brucecco@borgoroma.univr.it

Introduction

Benzene exposure in current industrial activity is much lower than it was in the recent past, with the result that it is often impossible to distinguish between workers occupationally exposed in the work place and the general population environmentally exposed under normal living conditions. For an evaluation of the environmental risk and levels to which workers in industrial plants are exposed, this piece of research reports the results of monitoring of a group of workers exposed in a petrol refinery plant.

Subjects and methods

In 192 workers employed in a petrol refinery plant, occupational benzene exposure was studied by measuring benzene at the workplace, in blood and urine and t,t-muconic acid in urine. Benzene exposure was measured during the 8 hours of the work shift using personal samplers, collecting environmental air in charcoal activated tubes (200/400 mg) with a flow rate of 500 ml/min. Environmental sample analysis was done by gas chromatography with a flame ionization detector (FID). Benzene in venous blood and urine, collected at the end of work and the following morning before resuming work were placed in clear glass vials (12.5 ml volume), which were closed with PTFE-lined butyl rubber septa and crimped with holed aluminium seals. Blood and urine benzene were determined by head space GC-mass-spectrometry (1). Urinary t,t-muconic acid was determined by HPLC method.

Results

Mean benzene exposure (table 1) was equal to 90.1 ng/l with a range of 5-1535 ng/l. The mean blood benzene level measured at the end of shift was (table 1) 273.9 ng/l (range 15-1506 ng/l), significantly higher ($F = 8.6$; $p < 0.005$; table 2) than that measured the following morning before the workers resumed work (203.1 ng/l ; range 15-1189 ng/l). The mean urinary benzene level (Table 1) measured at the end of the shift (565.4 ng/l) was not significantly different from that measured the morning after (435 ng/l; Table 1). Even the mean urinary t,t-muconic acid (Table 1) showed no statistically significant difference between the end of the shift (151.1 µg/grCreat.) and the morning after (113.0 µg/grCreat.). Both at the end of shift and the morning after, blood benzene concentrations (table 2) were significantly higher in smokers (mean 406 ng/l and 329 ng/l, respectively) than in non-smokers (mean 183.4 ng/l and 116.8 ng/l respectively).

The best correlation was found in non-smoking workers between workplace benzene concentration (x) and the blood benzene concentration (y) measured at the end of the shift ($y = 0.846x + 92$; $n = 114$; $r = 0.739$). In non-smoking workers too, urine benzene concentration collected at the end of the shift (y) correlated significantly ($y = 2.7x + 116$; $n = 113$; $r = 0,540$) with workplace benzene concentration (x), but the correlation coefficient was lower than that reported for blood benzene. A significant correlation was found between the blood benzene concentration measured at the end of the workshift (x) and the morning after (y = 0.36x +105; n = 192; r = 0.511).

Table 1 - Benzene concentration (ng/l) in environmental air (CiBNZngL), blood (CbBNZngL) and urine (CuBNZngL) and t,t-muconic acid (t,tMAµgCr) in urine (µg/grCreat) measured at the end of the shift (eS) and the morning after (mA).

	Count	Average	Minimum	Maximum
CiBNZngL	192	90,1	5,0	1535,0
CbBNZeSngL	192	273,9	15,0	1506,0
CbBNZmAngL	192	203.1	15,0	1169,0
CuBNZeSngL	191	565,4	17,0	9404,0
CuBNZmASngL	190	435,0	14,0	4208,0
t,t-MAeSµgCr	147	151,1	10,0	592,0
t,tMAmAµgCr	95	113,0	10,0	1618,0

Discussion

Data in Table 1 show that the occupational benzene exposure we studied was very low, 90.1 ng/l on average, not unlike that found in some urban environments with heavy traffic pollution (2). According to the distribution of the values recorded, benzene exposure was lower than 100 ng/l (mean 30.7 ng/l) in 155 workers and higher than 100 ng/l (mean 338.7 ng/l) in 37 workers (table 2). In 90 out of the 114 non-smoking workers studied (table 2), whose workplace exposure was <100 ng/l, the blood benzene was 107 ng/l at the end of exposure and 98 ng/l the morning after, without any statistically significant difference (F=0.2). This suggests the hypothesis that the 90 non-smokers were exposed to the same environmental benzene levels (<100 ng/l) in the plant and in normal living conditions away from the workplace. The remaining 24 non-smokers exposed to benzene level >100 ng/l showed blood benzene levels of 469 and 186 ng/l, significantly different (F=12.5; p<0.0009), at the end of exposure and the morning after, respectively. This result suggests that the benzene exposure of these 24 workers after the end of work under normal living conditions at home was lower than that measured during the workshift.

Considering all the 192 workers employed in the refinery plant, our data show that blood benzene levels were significantly different between the end of shift and the morning after. Otherwise, no statistically significant difference was found between the end of the shift and the morning after, for both urine benzene levels and t,t-muconic acid. The observation that blood benzene levels measured the morning after was significantly lower than that at the end of shift suggests the hypothesis that the blood benzene level has to be considered a biomarker of exposure, better than benzene and t,t-muconic acid in urine, which were not statistically different between the end of the shift and the morning after. The other results showing that at the end of the shift, in non-smoking workers, blood benzene levels correlated with the workplace benzene levels better than urine benzene and t,t-muconic acid, seems to confirm that the blood benzene measurements have to be considered the best reliable biomarker of occupational benzene exposure in the refinery plant.

Blood benzene concentrations in non-smoking workers (table 2) were 183.4 ng/l at the end of the shift and 116.8 ng/l the morning after. Previously, we reported in 171 non-smokers in the general population (3) a blood benzene level of 123 ng/l, very similar to that found in the

114 non-smoking workers in the refinery plant, the following morning before resuming work. Finally, it emerges that cigarette-smoking significantly affects the blood benzene levels in workers occupationally exposed to low environmental benzene levels.

Table 2 – Blood benzene concentration (Cb) measured at the end of shift (eS) and the morning after (mA) in workers exposed to workplace concentration (Ci) lower or higher than 100 ng/l

	Non-smokers			Smokers			ALL		
	count	ng/l		count	ng/l		count	ng/l	
CbeS/Ci<100 ng/l	90	107	F=0.2 p=NS	65	369	F=3.4 p=NS	155	217	F=2.2 p=NS
CbmA/Ci<100 ng/l	90	98		65	298		155	183	
CbeS/Ci>100 ng/l	24	469	F=12.5 p<.0009	*13*	592	F=1.4 p=NS	37	512	F=11.5 p<.001
CbmA/Ci>100 ng/l	24	186		*13*	485		37	291	
CbeS/Ci-total	*114*	183	F=6.5 p<.01	*78*	406	F=4.3 p<.05	*192*	274	F=8.6 p<.005
CbmA/Ci-total	*114*	117		*78*	329		*192*	203	

According to our data, various researchers suggest that urinary benzene and t,t-muconic acid are not reliable biomarkers in environmental and occupational exposure to low benzene level. Acid urine pH (4) and sorbic acid in food as preservative (5) may be responsible for an elevated urine level of benzene and t,t-muconic acid respectively, without any correlation with the environmental or occupational benzene exposure.

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Elimination of benzene in exhaled air in seamen after occupational exposure to petrol on tankers

Melin J (1), Nordlinder R (1,2), Ljungkvist G (1), Sällsten G (1), Barregård L (1), Nilsson R (1)

[1.] Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg, Sweden, e-mail: jens.melin@ymk.gu.se
[2.] Present address: IVF, Mölndal, Sweden

Introduction

Benzene is a well-known leukaemogen and has also been suspected to cause other malignancies such as lymphoma and multiple myeloma. Crew on deck on tankers may be highly exposed to benzene during short time periods when loading petrol or cleaning tanks. The aim of this study was to measure the concentration of benzene in end-exhaled air in order to assess the elimination after occupational exposure.

Methods

The exposure levels of benzene were measured in the seamen's breathing zones during working hours with diffusive samplers. Measurements were made during various working tasks such as unloading of petrol and tank cleaning.

Benzene in end-exhaled air after a working shift was measured with a field method developed at the department (1, 2). 100 ml of end-exhaled air was collected directly on an adsorbent tube with a manual sampling pump. The tube was stored and subsequently analysed by automated thermal desorption and gas chromatography.

The seamen were followed during exposure and periods between exposures. For four mates the periods between two exposures were long enough to study the elimination of benzene in exhaled air.

Before any calculations were done, the data were corrected for background levels of benzene in air for each subject. In each subject, models with one or two compartments were fitted to the decrease in benzene concentration in end-exhaled air, assuming an exponential decrease, by non-linear least squares regression. This was done with the NLIN procedure in the SAS statistical program (3). Also, all four individual curves were analysed simultaneously, calculating the best fit, on the assumption that all subjects had a common half life. This was done with the EXPFIT program (4).

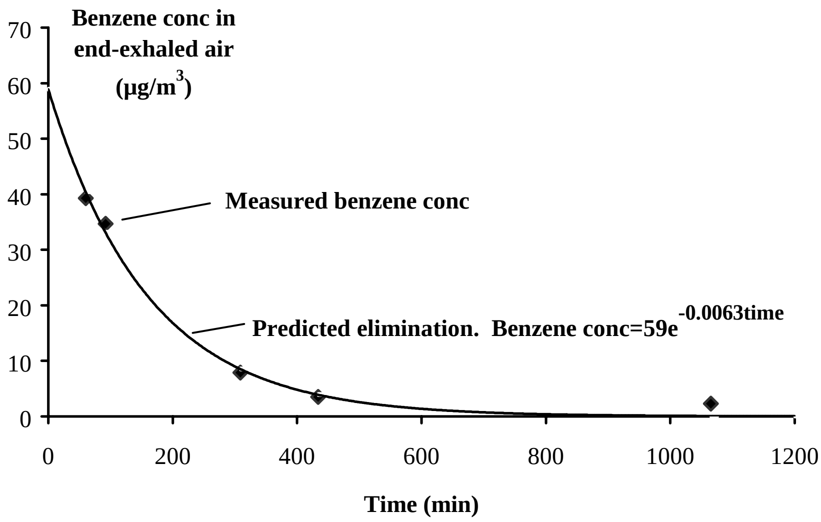
Results

In Table 1 the exposure levels, exposure times and half lives are shown for each subject. Results from calculations with one compartment are presented since calculations with two compartments resulted in models with a non-significant second compartment

Table 1. Exposure levels, exposure times and half lives calculated with different methods for each subject. Subject 1 and 2 were working with unloading petrol and subject 3 and 4 were cleaning tanks. The subjects were followed for 1065, 360, 1247 and 295 minutes after exposure respectively.

Subject	Exposure		Half life (min)		
	Benzene conc. mg/m^3	Time min	EXPFIT n=3	EXPFIT n=4	SAS
1	0.745	210	88	123	110
2	1.78	240	88	123	96
3	4.40	133	88	123	82
4	143	209		123	123

Figure 1. Elimination kinetic of benzene in end-exhaled air for subject 1. Individually predicted elimination curve calculated with SAS.



Discussion

The seamen are highly exposed to benzene during tank cleaning with a level well above the Swedish short time exposure limit (3 mg/m^3 for 15 min). For subject 4 even the occupational exposure limit (1.5 mg/m^3 for 8 h) was exceeded.

Since the seamen did not have long exposure-free periods on the tankers we could only study one compartment of the elimination in air. To study two compartments samples of post-exposure benzene in end-exhaled air have to be sampled during at least two days after exposure.

The individually calculated half lives are quite similar even though the exposure levels were not the same and the fit was not statistically better than a model with a common half life. The latter was however highly affected by subject 4, the most exposed subject. Literature data on benzene half life in exhaled air is scarce. Our results is in accordance with other studies showing half lives between 1-2.5 h (5).

Conclusions

In our opinion this non-invasive method is more suitable for repeated sampling in field studies than benzene in blood. Subjects with different working tasks and exposure to benzene had half lives of 1.5-2 h for benzene in end-exhaled air.

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Micro porous membrane extraction of benzene in urine

Ljungkvist G[(1)], Wing K[(1)], Azimi A[(1)], Mathiasson L[(2)]

[1.] *Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg, Sweden, e-mail: goran.ljungkvist@ymk.gu.se.*
[2.] *Department of Analytical Chemistry, Lund University, Lund, Sweden.*

Introduction

Urinary benzene is a promising biomarker of benzene exposure because it is specific and reflects air exposure even at low levels (1,2). As the concentrations are low, it is essential to have a work-up procedure that is selective and can concentrate the analyte to achieve the sensitivity needed. We present an alternative approach to static or dynamic headspace, using micro porous membrane extraction. The aim was a robust work-up procedure that had a high recovery, could handle large sample volumes and could be easily automated.

Materials and methods

A schematic diagram of the experimental set-up is shown in Fig. 1. The membrane was clamped between two chemically inert PTFE-blocks. In each block a groove was machined, forming a channel at both sides of the membrane, each with a volume of 0.5 ml.

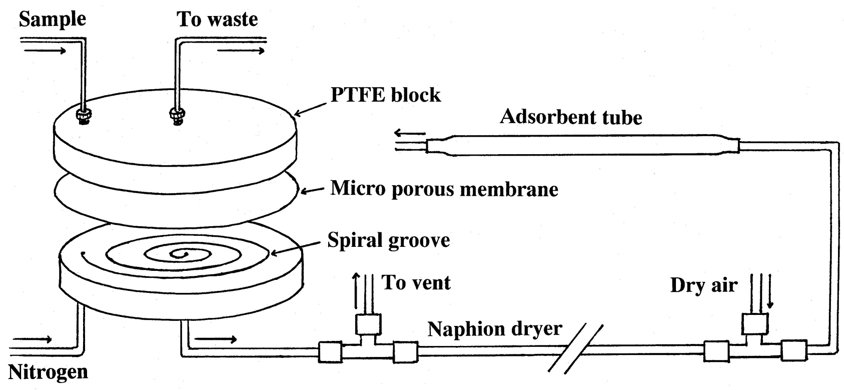

Fig. 1. Schematic diagram of the experimental set-up.

The membrane was a micro porous membrane made of polypropylene (porosity 41%, thickness 25 µm, Celgard 2400; Celgard, Charlotte, NC, USA). The donor phase (MilliQ-water or urine spiked with benzene) was pumped on one side of the membrane by a syringe pump. The analyte diffused through the membrane and was carried by the acceptor phase (an inert gas stream of purified nitrogen) to a solid adsorbent (about 1 g of Tenax TA), where it was enriched. Ideally, the donor and the acceptor phases should move counter-current for optimal mass transfer. However, to avoid problems with gas leakage through the micro porous membrane to the donor phase, the phases moved in the same direction.

A permeable membrane dryer (Perma Pure MD-125-12T; Perma Pure Products, Toms River, NJ, USA) was used to remove water vapour from the sample stream before it reached the adsorbent. The adsorbent tube was subsequently thermally desorbed and the analyte was cryo-focussed in a cold-trap. The cold-trap was desorbed and the analysis was made by gas chromatography and mass-selective detection (2).

Results

The acceptor flow rate was optimised by keeping the donor flow rate constant at 0.5 ml/min and varying the acceptor flow rate. The extraction was performed at room temperature. At an acceptor to donor flow ratio of 50, corresponding to a gas flow of 25 ml/min, the recovery was 95% (Fig.2).

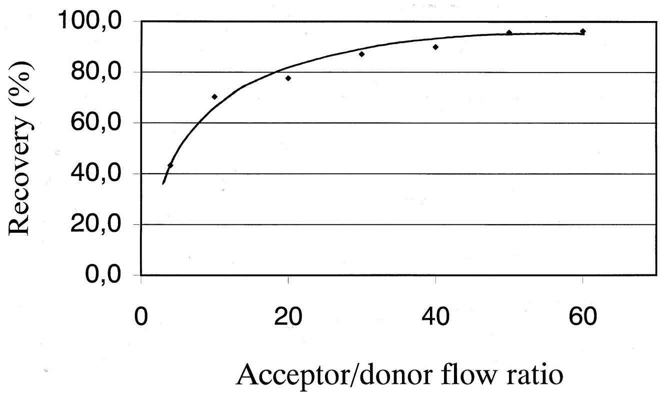

Fig. 2. Optimisation of the acceptor to donor flow ratio. The donor flow rate was kept constant at 0.5 ml/min.

The recovery at different donor flow rates, keeping the acceptor to donor flow ratio at 60, was a gradually decreasing. Increasing the temperature of the membrane unit to 50 °C, by submerging it into a water bath, did only change the recovery marginally (Table 1).

Donor flow rate ml/min	Acceptor flow rate ml/min	Recovery at 26 °C %	Recovery at 50 °C %
0.5	30	95	96
1.0	60	86	87
1.5	90	83	89
2.0	120	73	74

Table 1. Recovery at different donor flow rates at a constant acceptor to donor flow ratio of 60.

In the following validation experiments the donor flow rate was kept at 0.5 ml/min and the acceptor flow rate at 30 ml/min. The extractions were made at room temperature and the extraction time was 10 minutes.

The carry over was investigated by analysing a sample spiked with 2000 ng/L benzene and then, after purging the donor side with purified water, analysing a water blank. After purging with 10 ml water the carry over was less than 2%.

The linearity was investigated by analysing spiked water samples in duplicate. Two concentration intervals were studied; blank to 400 ng/L and 20 to 4000 ng/L. The correlation coefficients were 0.9968 and 0.9996 respectively.

The limit of detection (including sample work-up and analysis) was 25 ng/L and the limit of quantification 83 ng/L.

The repeatability was determined by repeated measurements (n=5) of urine spiked with benzene to 50 and 400 ng/L. The repeatability was 1.4 and 1.2% respectively.

Discussion

Sample work-up procedures based on static headspace, including SPME, are based on an equilibrium of the analyte between two or more phases and only a fraction of the analyte is transferred to the analytical system. This can make the enrichment insufficient to achieve a low detection limit and also make the procedure sensitive to small changes in extraction parameters like temperature and stirring. A dynamic headspace procedure usually have high recovery and can handle larger sample volumes, but is laborious to perform.

The proposed work-up procedure has the same advantages as dynamic headspace, but by using a commercially available autosampler it can be easily automated. The recovery is almost quantitative which make the procedure insensitive to changes in the main extraction parameters, that is flow rates and temperature.

The limit of detection and the linearity facilitate assessment of benzene exposure of occupationally exposed subjects and smokers in the general population. To determine benzene in urine from non-smokers, a lower detection limit must be achieved. This can be done by increasing the extracted sample volume.

Conclusions

The proposed work-up procedure for benzene in urine, based on liquid-gas extraction through a micro porous membrane, is a favourable alternative to other procedures. It can also be applied for the determination of other volatile compounds in water matrices.

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Benzene and 1,3-butadiene in the breath, blood and urine of environmentally exposed people

Brugnone F, Perbellini L, Cerpelloni M, Pasini F, Marcheselli S, Romeo L

Occupational Medicine, Department of Medicine and Public Health, University of Verona – Policlinico GB Rossi, Verona, Italy, e-mail: brucecco@borgoroma.univr.it

Introduction

1,3-Butadiene is not known to occur as a natural product, but it is an anthropogenic, industrial pollutant, widespread in ambient air, water and food (1), together with benzene (2-4). In general, concentrations of butadiene in urban air have been reported to range from 1 to 10 ppb (5, 6). Butadiene and benzene are emitted in automobile exhaust fumes and are produced by house fires and tobacco combustion (7). Butadiene constitutes roughly 0.35% of the total hydrocarbons in exhaust emissions (8). This research paper reports the results of measuring butadiene and benzene in the alveolar air, blood and urine of people living in a small mountain village and working in forestry.

Subjects and methods

Benzene and 1,3-butadiene were measured in samples of breath, blood and urine taken from 67 forestry workers living in small mountain villages. In the morning, after their overnight rest, the workers came to our medical surveillance service, where samples were collected. Breath, blood and urine were put into clear head space glass vials (12.5 ml volume) which were analysed by the GC-mass-spectrometric method. The vials were placed into the carousel of an auto-sampler and shaken for 60 minutes before the headspace was withdrawn. The breath and blood samples, but not the urine samples, were heated at 50°C inside the carousel. For statistical analysis samples with a butadiene level lower than the detection limit (DL) were recorded as equal to half the DL.

Results

The mean alveolar butadiene level (table 1) was 1.8 ng/l (range 0.4-13.2 ng/l), significantly higher ($F=36.1$; $p<0.00001$) in smokers (mean 3.6 ng/l) than in non- smokers (mean 1.0 ng/l). The mean blood butadiene was 4.5 ng/l (range of 1-50.2 ng/l), higher than mean urine butadiene (1.9 ng/l; range 0.5-8.9 ng/l). In both blood and urine (table 1), the butadiene concentrations were significantly higher in smokers (mean 11.6 ng/l and 3.9 ng/l respectively) than in non-smokers (mean 2.0 ng/l and 1.1 ng/l respectively).

The mean benzene level (table 2) was 7.6 ng/l (range 1.5-25.2 ng/l) in alveolar air, 93.1 ng/l (range 33.5-487.2 ng/l) in blood and 170.7 ng/l (range 25.8-1099 ng/l) in urine. The benzene level was always significantly higher in smokers than in non-smokers in all biological matrices (table 2).

Discussion

Butadiene, never reported previously in human biological matrices, was identified in all the forestry workers we studied. In 9/67 alveolar air samples and in 21/66 urine samples, butadiene was lower than the detection limit (0.8 ng/l and 1 ng/l respectively).

Table 1 – Alveolar (Ca), Blood (Cb) and Urine (Cu) Concentrations (ng/l) of 1,3-Butadiene measured in forest workers						
		Count	Average ng/l	Minimum	Maximum	
Ca BTD	Non-smokers	48	1.0	0.4	1.97	F=36.1 p<.0000
	Smokers	19	3.6	1.1	13.2	
	ALL	67	1.8	0.4	13.2	
Cb BTD	Non-smokers	44	2.0	0.97	3.53	F=18.9 p<.0001
	Smokers	16	11.6	1.2	50.2	
	ALL	60	4.5	0.97	50.2	
Cu BTD	Non-smokers	48	1.1	0.5	7.9	F=32.1 p<.0000
	Smokers	18	3.9	0.5	8.9	
	ALL	66	1.9	0.5	8.9	

According to its blood/air partition coefficient (9,10) equal to 0.9-1.8, the butadiene level was higher in blood (4.5 ng/l) than in urine (1.9 ng/l) the partition coefficient of which has to be considered similar to the saline/air partition coefficient corresponding to 0.088 (10). Assuming a pulmonary retention (Ca/Ci, where Ci= inhalation concentration and Ca= alveolar concentration) equal to 0.8 (9), the mean alveolar butadiene measured in a forestry worker (1.8 ng/l) allows us to estimate a mean environmental butadiene exposure of about 2.25 ng/l (1 ppb).

Table 2 – Alveolar (Ca), Blood (Cb) and Urine (Cu) Concentrations (ng/l) of Benzene measured in forest workers						
		Count	Average ng/l	Minimum	Maximum	
Ca BNZ	Non-smokers	48	5.3	1.5	12.2	F=52.1 p<.0000
	Smokers	19	13.2	6.1	25.2	
	ALL	67	7.6	*1.5*	25.2	
Cb BNZ	Non-smokers	46	57.4	33.5	112.4	F=42.3 p<.0000
	Smokers	15	202.4	46.3	487.2	
	ALL	61	93.1	*33.5*	487.2	
Cu BNZ	Non-smokers	48	88.6	25.8	531.3	F=35.7 p<.0000
	Smokers	18	389.5	45.2	1099.1	
	ALL	66	170.7	*25.8*	1099.1	

Butadiene was significantly higher in smokers than in non-smokers, without exception, in all matrices. The best correlation was between blood (x) and alveolar (y) butadiene (y = 0.21x + 0.8; n = 60; r = 0.903). Urine butadiene correlated similarly with alveolar butadiene (r = 0.743) and blood butadiene (r = 0.70).

The identification and quantification of butadiene in all the biological matrices, in people living in non-urban environments, suggests the hypothesis that butadiene must be considered a ubiquitous pollutant throughout all human living environments.

The values of benzene concentrations measured in the alveolar air (7.6 ng/l) and blood (93.1 ng/l) of the forestry workers turned out to be lower than those we reported previously in the alveolar air (11 ng/l) and blood (165 ng/l) in environmentally exposed people living in an urban environment (11, 12). For urine benzene (170.7 ng/l) we did not find any significant difference in comparison with previous examinations (184 –198 ng/l) in normal urban people (13, 14). The best correlation turned out to be between blood (x) and alveolar (y) benzene (y = 0.04 + 2.9; n = 61; r = 0.858). Urine benzene showed the worst correlation with both alveolar (r = 0.436) and blood benzene (r = 0.454).

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Exposure surveillance as indicator of change in working conditions

Viikari-Juntura E [1]

[1] *Musculoskeletal Research Unit, Department of Physiology, Finnish Institute of Occupational Health, Helsinki, Finland, e-mail: eira.viikari-juntura@occuphealth.fi*

Surveillance has been defined as the systematic collection, analysis and interpretation of health and exposure data in the process of describing and monitoring a health event (3). Surveillance of workplace exposures can give useful information of the conditions at workplaces at company level, nationally, or internationally. In the Scandinavian countries, it has been a long tradition to collect data on workers' working conditions and health. The data of e.g. Statistics Finland show clear trends in workplace physical exposures and work characteristics from the 1970s until the 1990s (4). More recently, the European Union has started a series of surveys of working conditions and health in the European countries (5). These surveys have been face-to-face interviews.

More extensive surveys have been carried out in Finland by the Finnish Institute of Occupational Health in 1997 and 2000, and these Work and Health interviews (6) will be carried out triannually as computer-assisted telephone interviews. Extensive telephone interviews have also been carried out by the Danish Institute of Occupational Health (1). All the above interviews have been directed to the working-age population (6) or salary earners (4,1). In North-America, a questionnaire survey was carried out in 1998 among employers of large, medium size and small firms (2). This survey will be repeated in 2001.

The exposures and questions differ to some extent in these surveys, but all have included items on repetitive work and manual handling activities. The accumulated data give some idea of trends over time at workplaces in these countries (Table 1).

These data suggest that exposure to some common risk factors, e.g. repetitive monotonous movements, increased in the 1970s and 1980s and has remained fairly stable in the 1990s. National data from Finland suggest that manual handling of loads has been stable in the 1980s and 1990s, whereas data from the European Union suggest an increase in the handling of loads. This is noteworthy as it occurs at the same time when major efforts have been undertaken to regulate exposure to these factors.

Table 1. Examples of interview-based surveillance data on repetitive activities (a) and manual handling (b)

a. Repetitive work

Source	Item	Year	Prevalence(%)
Quality of Life Survey (4)	Repetitive monotonous movements	1977 1984 1990 1997	22 26 28 30
Work and Health in Finland (6)	Repetitive movements of hand several times/min	1997 2000	33 33
Danish Wage Earners' Work Environment and Health (1)	Repetitive monotonous work	1990 1995	10 10
European Survey (5)	Repetitive movements on a permanent basis	1995 2000	33 31

b. Manual handling

Source	Item	Year	Prevalence (%)
Quality of Life Survey (4)	Heavy lifting	1984 1990 1997	29 31 30
Work and Health in Finland (6)	Lifting, carrying, or holding manually or with manually assisted hoists	1997 2000	63 65
European Survey (5)	Handling heavy loads	1990 1995 2000	31 33 37

The employer survey in the State of Washington, especially the follow-up scheduled in 2001, will give some very interesting exposure information, as several items deal with exposures regulated by the Washington State ergonomics rule that became effective after the first survey.

The dilemma with surveillance is that it is interview or questionnaire-based. The accuracy of such information is limited. Several studies exist on the validity of questionnaires about physical loads. The results show that the validity of the best questions usually ranges from modest to good, with very few questions showing excellent validity. An instrument with modest validity may not detect a change, even if there were one.

The validity criteria used in such studies can also be questioned. The golden standard has often been some body posture assessed by observation, and the question is whether the essential has been observed from a biomechanical point of view. The invited papers in the workshop "Ergonomic exposure assessment for health surveillance purposes" deal with the validity of questions appropriate for surveillance. It is also our intention to go beyond the most commonly used validity criteria using a biomechanical analysis of shoulder loads associated with various combinations of postures and hand loads.

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Validity of a self-administered questionnaire assessing physical work loads

Leijon O [(1)], Wiktorin C [(1)], Karlqvist L [(2)], Härenstam A [(2)], Schéele P [(1)], and the MOA research group

[1.] *Department of Occupational Medicine, Community Medicine, Stockholm, Sweden, e-mail: ola.leijon@smd.sll.se*
[2.] *National Institute for Working Life, Stockholm, Sweden*

The present study is part of the Swedish MOA study (Modern work and living conditions for women and men. Development of methods for epidemiological studies), performed 1995-1997 in five Swedish counties.

Introduction

The quantification of physical exposure can be assessed with different (indirect or direct) techniques (1, 2). These techniques range from subjective methods such as self-reports to objective such as recordings of duration and positions of work postures with different technical instruments. The probably most feasible method to use in large general population studies is questionnaires, in which the workers themselves estimate their exposures. Though, questionnaires have been criticized to lack both precision and accuracy (1, 3).

The aim of the present study was to assess the validity of eight questions about physical load, used in the Stockholm Public Health Questionnaire (SPHQ). The possible influence of musculoskeletal complaints on the validity of the responses was also assessed.

Material and methods

203 women and men working in 80 different work places, in both private and public sector, participated in the MOA study, and hence in the present study. Mean age of the women was 38 years (SD ±10.0, range 20-61), and of the men 39 years (SD ±11.2, range 19-62). The subjects represented 85 different job titles.

The eight physical load questions evaluated in the present study concerned; physical general activity, duration of sitting work position, duration of awkward work postures (3 questions), frequency of manual handling of loads ≥10 kg, duration of repetitive movements, and physical exercise/sports. The response scales were at an ordinal level and 4 or 5 pointed.

The questions were validated by means of a structured interview. Each subject was interviewed about work tasks during occupational work an ordinary, “typical” workday, and about physical training/sports habits. The interview method used was considered accurate for the present purpose (4-6). Each interview was categorized into the same response alternatives as the eight questions.

Response agreement at a full scale level was calculated with weighted kappa correlation coefficients (κ_w) with quadratic weights, which correspond to the intra-class correlation coefficient. The validity was also analyzed at a dichotomous level calculating the sensitivity and specificity of each question.

Results

The κ_w coefficients for the total study group varied from 0.38 to 0.81 (table 1). The lowest coefficients were found for the questions concerning; bent/twisted work posture (κ_w 0.38) and repetitive movements (κ_w 0.39), respectively. The subjects reporting musculoskeletal complaints had for all but one question somewhat lower κ_w coefficients, compared with those with no musculoskeletal complaints. Though, the confidence intervals were wide and overlapped each other (table 1). For four of the questions the differences in κ_w coefficients could not be explained by different exposure distributions between the groups. These questions concerned hands above shoulder level, manual handling of loads, hands below knee level, and repetitive movements.

Table 1. Validity of eight physical load questions for all subjects, and stratified on musculoskeletal complaints.

Question	All subjects (n=202)	Musculoskeletal complaints More frequent (n=45)	No/less frequent (n=157)
	κ_w (95% CI)	κ_w (95% CI)	κ_w (95% CI)
General physical activity	0.66 (0.59-0.74)	0.59 (0.37-0.81)	0.68 (0.60-0.76)
Sitting work position	0.81 (0.75-0.86)	0.75 (0.62-0.88)	0.82 (0.77-0.87)
Hands above shoulder level	0.48 (0.33-0.63)	0.34 (0.00-0.69)	0.53 (0.36-0.69)
Hands below knee level	0.48 (0.33-0.64)	0.43 (0.10-0.76)	0.50 (0.33-0.66)
Bent/twisted work posture	0.38 (0.26-0.49)	0.41 (0.17-0.65)	0.35 (0.21-0.48)
Manual handling of loads	0.54 (0.42-0.66)	0.48 (0.24-0.72)	0.56 (0.42-0.69)
Repetitive movements	0.39 (0.26-0.51)	0.12 (0.00-0.41)	0.45 (0.32-0.58)
Physical exercise/sports	0.74 (0.67-0.80)	0.67 (0.48-0.86)	0.74 (0.67-0.81)

When analyzing the validity at a dichotomous level the sensitivity was lowest for the questions concerning; hands below knee level (sensitivity 0.47), and repetitive movements (sensitivity 0.51). The specificity was lowest for the question concerning bent/twisted work posture (specificity 0.55) (table 2).

Table 2. Proportion of exposed , sensitivity and specificity of eight physical load questions (n=202).

Question	Exposed (%)		Sensitivity	Specificity
	Questionnaire	Interview		
General physical activity	42	32	0.88	0.80
Sitting work position	38	45	0.71	0.91
Hands above shoulder level	36	24	0.79	0.76
Hands below knee level	25	36	0.47	0.87
Bent/twisted work posture	58	38	0.81	0.55
Manual handling of loads	20	14	0.67	0.88
Repetitive movements	41	57	0.51	0.74
Physical exercise/sports	42	35	0.92	0.84

Discussion

The results indicated that non-differential misclassification in self-reports of exposure to bent/twisted work posture exists. Differential misclassification, due to musculoskeletal complaints, could not be fully excluded for self-reports of exposures to some of the physical work load questions.

The three questions concerning physical general activity, sitting work position and physical exercise/sports may have sufficient validity to be recommended. These three questions had the highest κ_w coefficients, i.e. inter-method agreement, and the results did not indicate any substantial misclassification of exposure due to musculoskeletal complaints.

Musculoskeletal complaints may bias the self-reports of physical load when used in a case-referent study. It is difficult to investigate the impact of misclassification of highly exposed subjects in a general population study as few subjects will be exposed. Hence, contrasting exposure groups is an alternative when examining misclassification of highly exposed subjects. The findings in the present study need further investigations.

Conclusions

The accuracy of self-reported physical load by means of questionnaires is often low when assessing more detailed exposure levels, but may be useful at a dichotomous level to distinguish exposed subjects from unexposed. However, in some questions musculoskeletal complaints may bias the self-reports of physical load.

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Estimating the association of self-reported occupational physical demands with disabling shoulder pain

Pope D[1,2], Cherry N[3], Silman A[2], Pritchard C[2], Macfarlane G[2,4]

[1]*Department of Public Health, University of Liverpool, Liverpool, United Kingdom, e-mail: danpope@liverpool.ac.uk.*
[2]*ARC Epidemiology Unit, University of Manchester, Manchester, United Kingdom.*
[3]*Centre for Occupational Health, University of Manchester, United Kingdom.*
[4]*Unit of Chronic Disease Epidemiology, University of Manchester, United Kingdom.*

Introduction

Features of the occupational environment believed to be associated with musculoskeletal pain include awkward or uncomfortable working postures, manual handling of loads and repetitive upper limb movements. However studies have rarely carried out accurate or comprehensive assessment of such physical demands or have been based on small numbers or specific occupational groups. The current study aimed to investigate the relationship between self-reported occupational physical demands and disabling shoulder pain, using a previously validated instrument, across a variety of manual occupational settings in the United Kingdom.

Methods

A cross-sectional survey was conducted at 5 manual occupational settings in South Manchester, United Kingdom. Of the 931 employees surveyed, 775 (83%) responded. Information about disabling shoulder pain and occupational risk factors was collected by self-completion questionnaire. The Manchester Occupational Physical Demands Questionnaire (MOPDQ), developed and validated by the authors, was used to assess the physical demands of work (Pope et al, 1998). In addition information was collected relating to psychosocial working environment (according to Karasek's demand (3 items) -control (2 items) -support (1 item) model) and psychological well being (using the General Health Questionnaire (GHQ)).

The duration of working postures, manual handling of loads and repetitive upper limb movements was categorised into three levels (no exposure, low and high duration). Univariate associations with disabling shoulder pain were expressed as prevalence rate ratios (PRR) and 95% confidence intervals (95%CI), using "no exposure" as the referent group. In order to identify a group of factors which were most commonly associated with shoulder pain, a forward stepwise Cox regression procedure was used with candidate variables being all exposures (physical and psychosocial) found to be significantly associated with disabling shoulder pain.

Results

The one-month period prevalence of disabling shoulder pain was 26% and was similar for the 5 manual occupational settings.

Of the 12 occupational physical demands assessed, 7 were significantly associated with disabling shoulder pain (table 1) including one working posture, four manual handling activities and both repetitive upper limb movements.

Table 1. Association of the duration of occupational physical demands (for one specified hour) with disabling shoulder pain

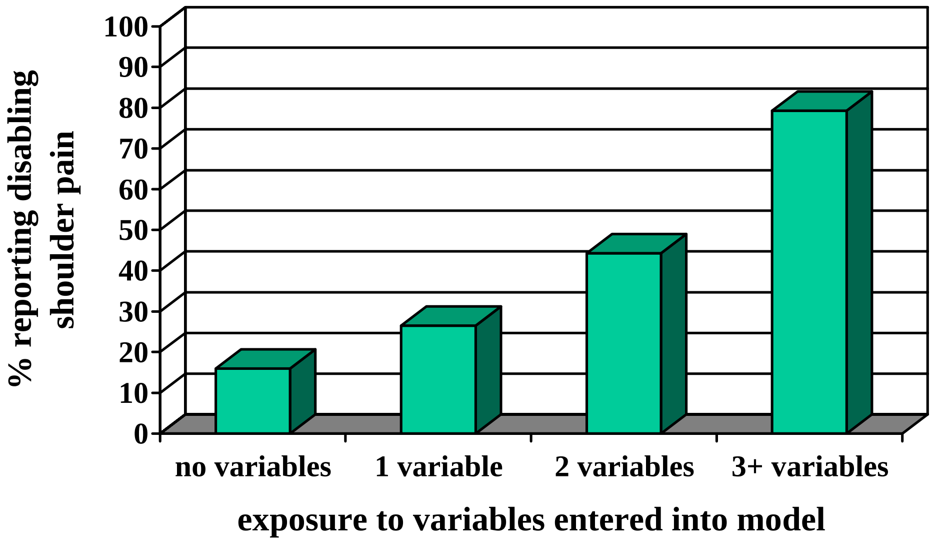
Physical demand	No.	%	PRR (95% CI)*	χ^2 test for trend
Work above shoulder level				
0 mins	108	20	1.0	
0.5-10 mins	45	34	1.8 (1.3,2.6)	p<0.001
10.5-60 mins	45	52	2.6 (1.8,3.7)	
Lifting with one hand				
0 mins	94	19	1.0	
0.1-6 mins	45	33	1.9 (1.3,2.8)	p<0.001
6.1-60mins	57	43	2.3 (1.6,3.2)	
Carrying on one shoulder				
0 mins	179	25	1.0	
0.1-4 mins	7	30	1.4 (0.6,3.2)	p<0.001
4.1-60mins	12	39	1.9 (1.0,3.6)	
Lift above shoulder level				
0 mins	143	23	1.0	
0.1-5 mins	26	35	1.6 (1.0,2.4)	p<0.001
5.1-60mins	29	45	2.0 (1.3,3.1)	
Pulling weights				
0 mins	129	23	1.0	
0.1-5 mins	41	34	1.8 (1.2,2.6)	p=0.004
5.1-60mins	26	35	1.8 (1.2,2.8)	
Repetitive use of the wrists				
0-9 mins	73	20	1.0	
10-40 mins	57	33	1.7 (1.2,2.4)	p<0.001
41-60 mins	66	33	1.6 (1.1,2.3)	
Repetitive use of the arms				
0-9 mins	80	19	1.0	
10-40 mins	56	36	2.0 (1.4,2.8)	p<0.001
41-60 mins	60	34	1.8 (1.3,2.6)	

*Prevalence rate ratio and 95 % confidence interval adjusted for age, sex and occupational setting

In addition, 4 of the 6 factors relating to psychosocial working environment (psychological demands (3 items) and job control (1 item)) and psychological well-being (GHQ score) were significantly associated with disabling shoulder pain.

Of the 11 factors offered as candidates to the regression model, four were entered as best describing the occurrence of disabling shoulder pain in the study population including two physical demands (working above shoulder height and lifting weights with one arm), one psychological demand and psychological well-being. Figure 1 shows how well these factors are related to the reporting of disabling shoulder pain. Only 16% of employees who reported being "not exposed/ low exposure" to all of the variables reported disabling shoulder pain compared to 79% reporting a "high exposure" to three or more variables.

Figure 1. Self-reported disabling shoulder pain by number of variables entered into the regression model



Discussion

The current study has demonstrated the practical application of the MOPDQ. As well as confirming findings from previous studies that have identified associations between working above shoulder level and repetitive upper limb movements with shoulder pain, this study has identified a relationship with such symptoms and manual handling activities. Further, it has been possible to highlight two physical demands that identify a "high risk" group for disabling shoulder pain based on this study population (working above shoulder level and lifting weights with one arm). Using such information it is possible to consider strategies of ergonomic intervention which could be used to reduce the occurrence of musculoskeletal symptoms in the workplace.

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How reliable is the observation of arm posture for the assessment of shoulder load?

Takala E-P [(1)], Freund J [(1)]
[1.] *Musculoskeletal Research Unit, Finnish Institute of Occupational Health, Helsinki, Finland, e-mail: esa-pekka.takala@occuphealth.fi*

Introduction

Shoulder disorders have been associated with working postures characterized by elevated arms. In several studies, the exposure has mainly been assessed by questionnaires or observations. In order to be practicable, the questions should be simple, and they should include only few decisions or categories of loading to be selected by the respondent. As regards observations, there is a trade-off between accuracy and the observer's ability to discriminate between different postures. Due to these practical limitations, working with the hands over shoulder level has been a common selection for questionnaires, as well as for several observation methods. The biomechanical load on the shoulder depends, not only on the posture of the arm, but also on the forces handled. The aim of this study was to investigate the magnitude of errors when only one or few postures are considered in the assessment of shoulder load.

Methods

We built a 3-D biomechanical human model in which the physical parameters were taken from the anthropometric and biomechanical literature. The Matlab® implementation allows one to adjust e.g. body postures and the external forces acting on the body. The outputs of the model are the moment resultants of the external forces at the joints.

With this model we computed the constants needed for calculating the load moment on the shoulder in different arm postures. The constants (c_s, c_o) are given as "nomograms" in figure 1. The posture of the upper arm is defined by the humeral angle (x-axis) and the angle of the elbow (y-axis). The constants in the figure on the left are those due to the subject only. In the figure on the right the constants are those due to the object held in the hand.

The load moment on the shoulder can be calculated as follows:

$$M_{tot} = M + \Delta M, \qquad M = (c_s/100)\, L m_s g, \qquad \Delta M = (c_o/2)\, L m_o g,$$

where

M_{tot} = total load moment on the shoulder joint
M = load moment on the shoulder joint due to the weight of the upper limb
ΔM = additional load moment on the shoulder joint due to the object held in the hand
c_s = constant received from the left nomogram
c_o = constant received from the right nomogram
m_s = mass of the subject

m_o = mass of the object held in the hand
L = height of the subject
g = acceleration due to gravity (9.81 ms^{-2})

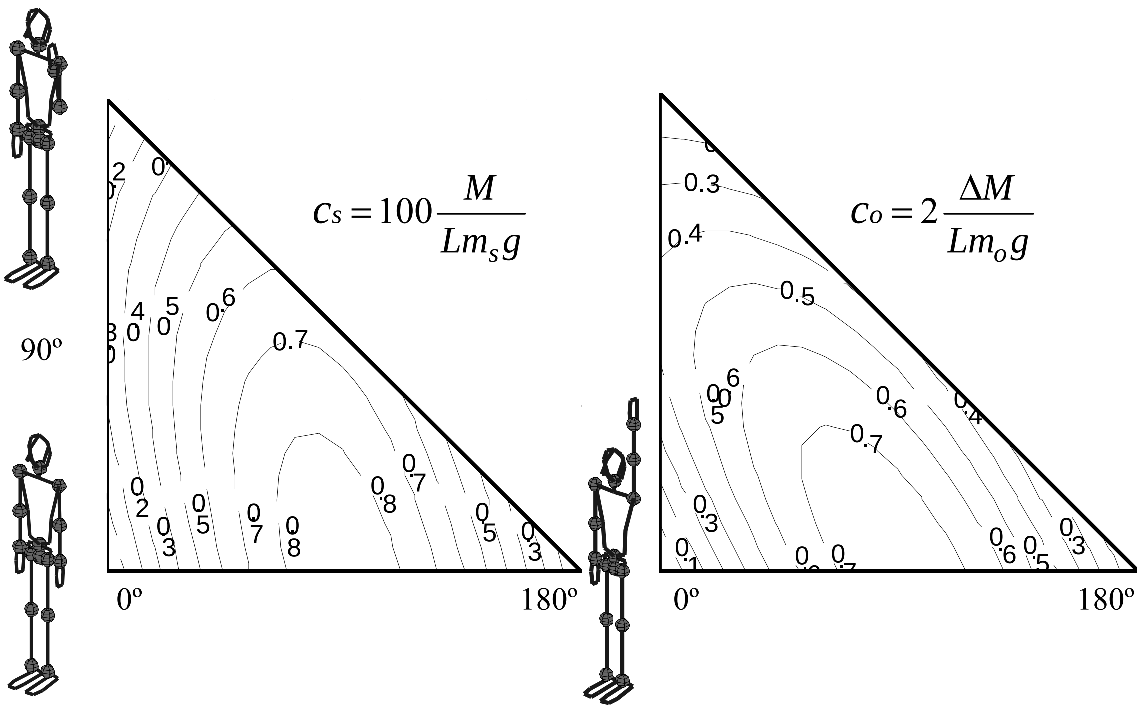

Figure 1. Nomograms of constants for biomechanical calculations by the angle of the humerus and the elbow

Results

In order to determine the relative importance of the body posture and the weight of the object handled on the shoulder load moment, we considered the fraction $\frac{\Delta M}{M} = 50\frac{c_o}{c_s}\frac{m_o}{m_s}$.

The nomograms show that $c_o/c_s \approx 1$ for most postures. Therefore, the contribution of the object handled to M_{tot} is greater than that of the weight of the upper limb if $m_o > m_s/50$. With regard to the working population this means that an object of 1.5–2 kg held in the hand is responsible for about half of the shoulder moment in all working postures; i.e. with greater loads the load on the shoulder is mainly due to the weight handled.

We also have calculated the load moments in different arm postures and for different statures. In a working posture with the hand well below shoulder level (the upper arm flexed 10º and the elbow flexed at 90º), a weight of 1.5 – 2.5 kg will produce a shoulder load moment equal to that of the fully extended arm without any extra load. Handling a weight of 4 – 7 kg will duplicate this shoulder load moment.

Discussion

These calculations show that the biomechanical load on the shoulder is highly dependent on the weight handled, in addition to the working posture. Therefore any arm posture is an insufficient measure of the shoulder loading, if the load in the hand is unknown.

There are limitations to be considered with the biomechanical modeling of working postures. First, a simple biomechanical model neglects the geometrical relationships of the anatomical structures within the body. The distribution of mechanical forces on the tendons and other structures varies in different postures of the joint. For example, when the arm is fully extended upwards the load moment acting on the shoulder is very small. Therefore the load moment alone may not be an adequate measure of the straining of a posture-load combination. A potential solution might be a cost function added to the model. The cost function should, however, have a sound biomechanical and physiological basis.

The second problem is the definition of the safety limits of different loads. It is obvious that the risk of disorders will increase with increasing biomechanical load. One limit is the peak force that will exceed the tolerance of the human tissues and cause mechanical trauma. With lower forces, temporal aspects – duration and frequency – will complicate the defining of safety limits.

Exposure assessment of allergens in schools, day-care centres and the environment

Renström A [(1)], Custovic A [(2)], O'Meara T [(3)], Doekes G [(4)], Smedje G [(5)]

[1] Respiratory Health and Climate Programme, National Institute for Working Life, Stockholm, Sweden. E-mail: Anne.Renstrom@niwl.se
[2] North West Lung Centre, Wythenshawe Hospital, Manchester, UK
[3] Institute of Respiratory Medicine , University of Sydney, Sydney, Australia
[4] Environmental and Occupational Health Group, Utrecht University, Utrecht, The Netherlands
[5] Occupational and Environmental Medicine, Uppsala University Hospital, Uppsala, Sweden

Introduction

Much interest has during the last decade focused on the importance of different exposures for the development of allergy and asthma. To estimate exposure intensity, for instance to assess dose-response-relationships, different strategies can be used. Surrogates of direct exposure measurements may be employed, such as exposure years or presence of control measures. However, to study where and in which situations subjects are exposed to allergens, and to what levels they are exposed, it is necessary to measure the suspected agents. Direct measurements are also needed to assess the levels that lead to sensitisation in subjects, or the levels that provoke symptoms in already sensitised subjects, and to evaluate the effectiveness of allergy reduction strategies.

Methods for assessment of allergen exposure

A number of methods to assess allergen exposure have been developed over the last decade, both enabling and necessitating a choice between methods.

Allergens in the environment may be collected using a variety of sampling techniques. Only lately, efforts have been made to compare or evaluate different sampling methods (3,6). The round table will present and discuss several methods that have been used (dust reservoir sampling, air sampling on filters using pumps, sampling of airborne sedimenting dust using petri dishes, and nasal sampling (7) and compare their different merits, shortcomings, and suitability for different exposure situations and scientific questions.

Immunochemical methods to measure allergen levels in samples use antibodies directed against the allergens. The antibodies may be derived from pooled sera from sensitised patients or from sensitised animals, and the latter may be either polyclonal antibodies (Pabs) or monoclonal antibodies (Mabs). Sandwich or inhibition assay set-ups can be utilised. The choice of antibodies and of allergen analysis assay set-up may greatly influence the resulting values, up to several orders of magnitude (5,8).

A general standardisation of all steps of aeroallergen assessment is thus desirable. In practice, some allergen measurement assays have already gained global spread through commercial availability (e g Mab sandwich ELISA kits for the detection of cat allergen Fel d 1 and house dust mite allergen Der p 1). Standardisation is also necessary before any general risk limits for allergens can be proposed, as defined risk levels are dependent on the methods used. Immunological methods to analyse the allergens and the possibilities of allergen assessment standardisation will be discussed.

Direct and indirect exposures

Several allergens may be present in the child's environment, and may cause or exacerbate allergic symptoms or asthma. The round table will focus on the most commonly measured allergens from pets and house dust, especially cat allergen Fel d 1, and house dust mite. Presence of pets has not surprisingly been shown to give high allergen levels in dust and in air of homes (3). These allergens are however also found in homes or public buildings without pets (9,4). Recently, Almqvist et al showed that also such indirect allergen exposure may be of importance for asthmatic children (2). Moreover, also "outdoor" allergens, such as pollens, may be found indoors and may add to the total allergen exposure.

Exposures to other agents than allergens, for instance to volatile organic compounds, bacteria or pollution, have been shown to influence airway reactivity and susceptibility to allergens (1,9). The importance of measuring such agents in conjunction with allergens will be discussed.

What factors influence exposure levels and how can we reduce exposure?

The presence and levels of allergen in indoor environments are influenced by many factors. In several studies, a wide range of strategies has been tested aiming to reduce allergen levels, with varying results. For instance, air-filtering devices (such as HEPA filters) in offices, schools and homes, heating or acaricides to reduce mite levels, changes in ventilation and cleaning routines in schools have been tested. Factors that can influence allergen levels, and efficacy of several strategies to reduce exposure, on allergen levels and child health, may be discussed.

Finally, the relationships between allergen exposure and development and presence of allergy and asthma are complex. Genetic traits and the use of medicine also greatly influence allergy and asthma development and disease.

Environmental exposure does however play an important role, and it is therefore essential that allergen exposure can be assessed by validated methods, both in exposure-response population studies and in the evaluation of allergen reduction strategies.

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Studying peak exposure – toxicology and exposure statistics

Smith, T.J.

Harvard School of Public Health, Boston, MA, USA
tsmith@hohp.harvard.edu

Practical problems

Occupational hygienists have long recognized that intense airborne exposures of short duration (minutes) can have a significant risk for acute health effects, which are not present with longer, lower intensity exposures. There are many examples, such as irritant gases. While the concept of peak exposures is intuitively clear, it is difficult to rigorously define peaks because exposures are inherently variable and often there is a range of effects which are found a different exposure levels. The ACGIH and other organizations have addressed the acute hazards of peak exposures by setting ceiling limits without a time period for some materials, which are never to be exceeded, and short-term exposure limits (STELs) for other materials with an exposure averaging time of 15 min, and restrictions on the frequency and time between peaks. The choice of 15 min to define a peak was primarily based on the limitations of exposure monitoring. There are also limits on excursions above the 8 hr threshold limit value (TLV) that may occur for part of a work day and in some cases across several work days. Overall, aside from irritant gases, there is very little human dose-response data to guide standard setting for peaks. The application of safety factors is the usual practice to deal with the uncertainties, but the magnitude of these factors and their use is controversial.

Conceptual problems

An exposure (C) over a time period (T) is an administered dose (C*T). Effects of an administered dose are caused by the concentration of an agent in the target tissue. The tissue concentration from the exposure-time profile has a complex temporal relationship (a pharmacokinetic relationship), which is defined by internal processes of uptake, distribution, metabolism and excretion. Toxicologic studies have found that combinations of C and T that give the same C*T dose, will also produce the same degree of effects for a limited range of C and T combinations. Peak exposures, intense exposures of short duration, are a special concern because the high concentration produces a high dose rate (mg/min) into the body and target tissue, which may alter metabolism, overload protective or repair mechanisms, and amplify tissue responses. As a result, a peak can produce more and perhaps different effects than the same administered dose given with less intensity over a longer time period. In toxicologic experiments, C*T is defined by a steady exposure concentration, but an occupational exposure nearly always is variable over time. As a result, time-weighted average (TWA) exposures may contain unrecognized periods of high concentrations (peaks?), and with a nonlinear tissue response, similar TWA's may have different responses. Autocorrelation of exposures across time will tend to clump peaks together, which may also amplify the nonlinear effects.

For some agents, the dose rate (exposure multiplied by uptake rate) is also important for risk, in addition to the total administered dose. This effect is well recognized for acute effects for radiation, irritants, narcosis, and other types of acute toxicity. It also occurs for some chronic effects: carcinogenesis in animals and humans, and for silicosis [1-3]. When dose rate is important, chronic effects may accumulate disproportionately from the days with the highest intensity exposures, or time periods with higher than average exposures. Then the upper tail of the exposure distribution will determine the risk, not the mean. This implies a different definition of relevant peak exposures and a change in intervention strategy – more effort to reduce the highest exposures than just the mean.

Estimation of internal concentrations

Internal concentrations can be estimated by pharmacokinetic (PK) models, which either fit time course data or use a physiologically-based approach (PBPK model) to represent tissues as groups and mathematically represent the kinetics of input and output processes [4]. These models are useful for assessing the impact of exposure variability on target tissue concentrations, and for evaluating biological monitoring strategies. Through these models some of the nonlinear processes have been identified. However, this approach is also subject to the limitations of available data, especially data on human metabolism.

Rappaport investigated the transmission of exposure variation into variations in the body burden using a one compartment model [5]. Short-term variations in inhalation exposure were physiologically smoothed, and the degree of smoothing depended on the autocorrelation within the exposure and the clearance half time of the material. This effect limits the magnitude of tissue concentration which may be produced by inhalation of a peak toxic exposure. This argument will not apply for substances that are rapidly metabolized, or rapidly converted to a toxic metabolite that is quickly detoxified, such as epoxide compounds from butadiene. The whole body burden is not always the correct focus, the brain and other organs receive arterial blood direct from the lungs and may reach high levels in minutes with a high input, well before the remainder of the body. So we must be consider the processes driving the relationship between the target tissue concentration and the exposure.

Measurement problems

The inherently large variability of exposure on many time scales (minutes, hours, days) makes the measurement of peak exposures difficult. In some situations peak exposures can be anticipated because they are associated with specific job activities or operational situations. However, if they are the upper tail of the an extremely broad exposure distribution, geometric standard deviation > 3, the peaks are rare and difficult to characterize. Peaks can also be difficult to measure because of analytical limitations (short duration sample volume is too small) [6].

The development of real-time, personal monitoring offers the possibility of defining exposure distributions on time scales relevant for effects. It is not feasible to collect consecutive 15 min samples with charcoal tubes or filters, for more than a few time intervals. The 15 min interval is relevant for some types of exposure and effects, but not all. For example, with short exposures, the brain has a clearance half time of about 1 min, so peaks of 2-3 min can lead to a high brain concentration by inhalation, and produce headaches. Real-time monitoring for a central nervous system effect should be averaged over 2-3 min intervals to detect relevant conditions. Thus, as noted by Rappaport for long-term effects, the half time of clearance for the agent at the target site is an important determinant of sampling strategy for short-term effects [7].

Similar considerations apply for biological monitoring and the new biomarkers, such as DNA and hemoglobin adducts. Although the slow turnover of biomarker cells is a misleading indicator of the period represented. Hemoglobin adducts in red blood cells (RBC) only leave circulation when the cells are removed after their 120 day life span. However, a fraction of the RBC are removed each day, so the adducts for each day are progressively removed and the total is weighted toward more recent exposures, especially days with very high exposures. The interpretation of biomarker findings requires both knowledge of biological processes forming them and the distribution of exposures, including measurements to capture recent very high exposures.

Research needs

Research is needed in several key areas to develop and define the hazards from peak exposures. Better methods for measuring personal exposures real-time are needed. PBPK models are needed to identify nonlinear distribution and metabolism situations and agents likely to lead to peak effects. Toxicologic research is needed to better identify nonlinear mechanisms of toxicity that could lead to peak effects. Finally risk assessment and management strategies need to be examined to verify that they are adequate.

Conclusions

Concern about peak exposures is a long standing issue. There are many common situations where peak exposures will be common. Our understanding and evaluation tools have not kept up with advances in toxicology. Limited characterizations indicate that PBPK models and real-time monitoring can better determine the nature of the hazards. Professional practice in occupational hygiene has a growing emphasis on legal limits, and the reduction in reliance on professional interpretation, which adds to the importance of having strong scientific support for peak exposure limits.

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A new tool for assessing psychosocial work environment factors: The Copenhagen Psychosocial Questionnaire

Kristensen TS.

National Institute of Occupational Health, Copenhagen, Denmark, e-mail: tsk@ami.dk

Introduction

The need for valid and reliable instruments for assessment of exposures applies to the psychosocial field as well as to other fields of work environment research and practice. At the National Institute of Occupational Health (NIOH) in Denmark the Copenhagen Psychosocial Questionnaire (COPSOQ) for assessing psychosocial work environment factors has been developed in three versions: A long version for researchers, a medium size version to be used by work environment professionals, and a short version for the workplaces. The whole concept has been labelled "the three-level concept".

By developing the COPSOQ, we have tried to reach a number of goals:

1. To develop valid instruments for use at different levels.
2. To improve communication between researchers, work environment professionals, and the workplaces.
3. To make national and international comparisons possible.
4. To improve surveys of the psychosocial work environment.
5. To improve and facilitate evaluations of interventions at the workplaces
6. To make it easier to operationalize complicated theories and concepts.

Methods

The whole project has consisted of a number of phases. During the first phase psychosocial questionnaires from a number of countries were collected in order to study the different models, concepts, and questions. Sixteen questionnaires from Finland, Sweden, UK, USA, Denmark, and the Netherlands were included in this process. We found several of the questionnaires inspiring and of good quality but concluded that we could not use any of them for our purpose. During the second phase we selected 145 questions from the 16 questionnaires and added 20 new questions of our own. These 165 questions were tested empirically in a survey of a representative sample of 1858 adult Danish employees (20-60 years of age, 49% women, response rate 62%). During the next phase the responses were analysed for internal consistency, factorial validity, missing values, and response patterns. Our purpose was to develop a number of scales, each based on several questions in order to improve reliability and validity of the assessments. In this way the research questionnaire was developed with 141 questions comprising 30 different dimensions (scales). (See figure 1, next page).

During the following phase the length of the scales was reduced so that the maximum number of questions in each scale was 4 (in a few cases: 5). Also, a number of scales on individual characteristics were excluded. In this way the medium size questionnaire with 95 questions and 26 dimensions was developed. In the long and the medium size versions of COPSOQ all scales go from 0 to 100 points.

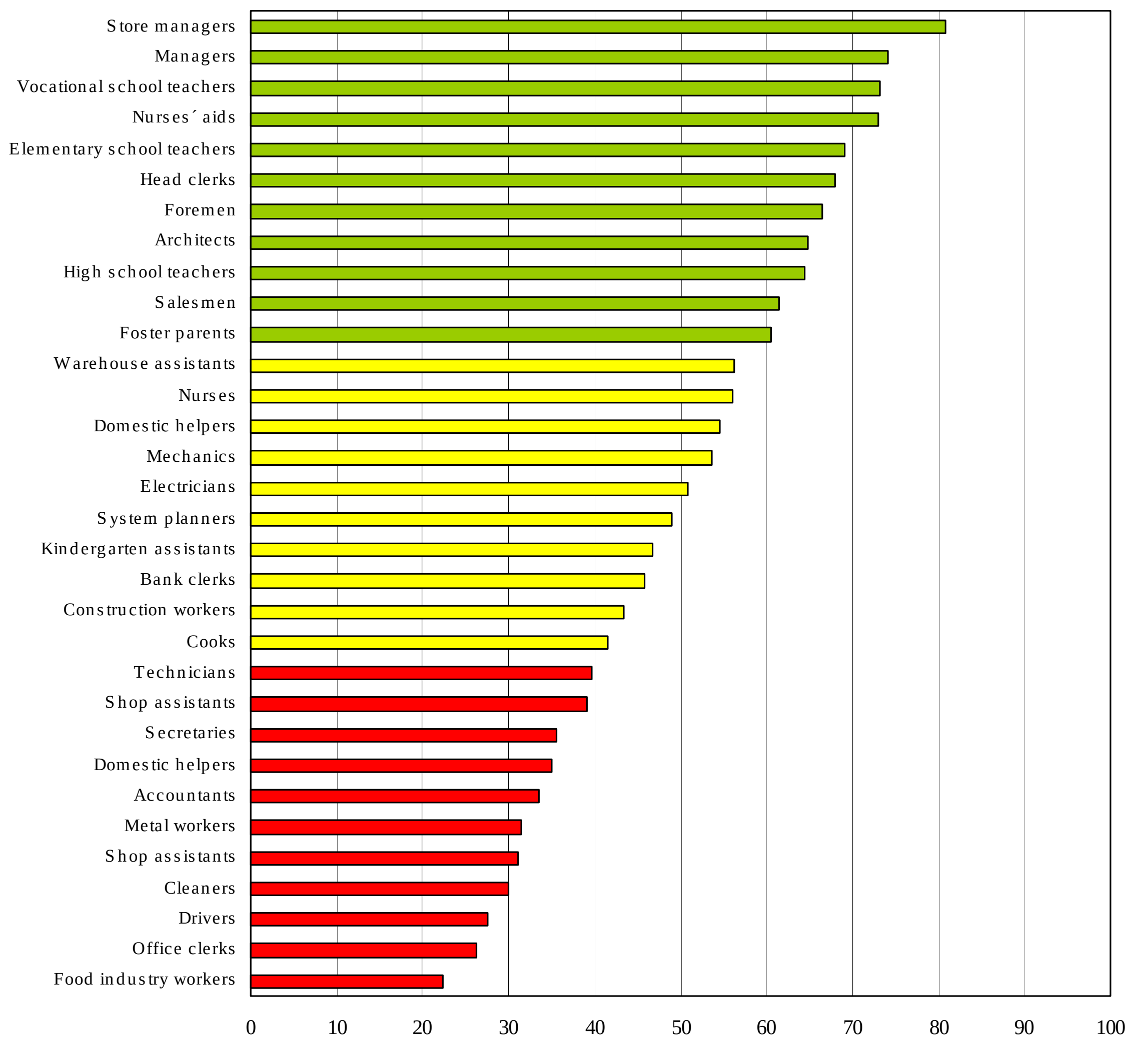
Finally, the short questionnaire was developed by reducing the number of dimensions as well as questions. The short questionnaire comprises 44 questions and only 8 dimensions. Some of these dimensions include several of the dimensions of the longer versions of COPSOQ (see figure 1).

Figure 1. The dimensions and number of questions of the Copenhagen Psychosocial Questionnaire in all three versions: long, medium, and short.

	Number of questions:			
Dimensions	Research questionnaire	Middle questionnaire	Short questionnaire	
Quantitative demands	7	4	3	
Cognitive demands	8	4		
Emotional demands	3	3	2	6
Demands for hiding emotions	2	2	1	
Sensorial demands	5	4		
Influence at work	10	4	3	
Possibilities for development	7	4	2	
Degree of freedom at work	4	4	1	10
Meaning of work	3	3	2	
Commitment to the workplace	4	4	2	
Predictability	2	2	2	
Role-clarity	4	4		
Role-conflicts	4	4		
Quality of leadership	8	4	2	10
Social support	4	4	2	
Feedback at work	2	2	2	
Social relations	2	2		
Sense of community	3	3	2	
Insecurity at work	4	4		4
Job satisfaction	7	4		4
General health	5	5		1
Mental health	5	5		5
Vitality	4	4		4
Behavioural stress	8	4		
Somatic stress	7	4		
Cognitive stress	4	4		
Sense of coherence	9			
Problem focused coping	2			
Selective coping	2			
Resigning coping	2			
Number of questions	141	95		44
Number of scales	30	26		8

The medium size questionnaire for work environment professionals has been developed in a computerized model in which all dimensions have a national average of 50. Values above 60 and below 40 are considered statistically different from the national average. Average results are presented in yellow. Results better than the national average are presented in green, while negative deviations from the average are shown with red bars. When the questionnaire is used for assessing the psychosocial work environment of a workplace it is possible to compare each department as well as the whole workplace with the national average on all 26 dimensions. It is also possible to compare jobs, age groups, wage systems etc. This work is being done by the occupational health services (OHS), the clinics of occupational health or by private consultants. All these professionals have been able to acquire the system (including computer software) for a moderate price of $150. Figure 2 shows the distribution of jobs in the national sample on one of the key dimensions: Influence at work.

Figure 2. An example of the distribution on jobs of one of the COPSOQ dimensions: Influence at work. All the 32 jobs have at least 20 respondents.



The short questionnaire can be used by the workplaces without use of computer or even desk calculator. The points on each of the eight dimensions can be added by hand, and average values for departments or workplaces can then be calculated. A small pamphlet makes it easy to compare with national average values. If a better evaluation is wanted, the workplace is encouraged to contact work environment professionals for further assistance. In this connection the medium size questionnaire can be used in order to give a more detailed picture of the work environment.

Results

The three questionnaires how have been used for about two years. Almost all OHSs and many other work environment professionals in Denmark are now using the system. The short questionnaire has been distributed free of charge in more than 5,000 copies and has been copied from the Internet by hundreds of users. We do not collect the data and we have no surveillance system of users. The philosophy of the concept has been that the users could use the system as a tool for dialogue and development at the workplaces.

The National Institute in Copenhagen receives reactions, comments and questions concerning the concept almost every day, and many of the users have developed the system further for specific workplaces. It is our clear impression that this system has been an unprecedented success. Researchers at the Danish NIOH and other institutions in Denmark have used the COPSOQ dimensions for many studies, which facilitates comparisons between different investigations.

The database for national comparison values will be updated in 2002 on the basis of a new national survey in order to keep the system valid and reliable. In this connection we will look into the possibility of developing reference values for specific industries and branches.

The questions of the COPSOQ have been translated into English, and some of the questions also into Japanese.

Conclusions

The three-level concept of the COPSOQ has been successful in improving communication between researchers, work environment professionals, and the workplaces. The questionnaire seems to provide valid assessments of a broad range of psychosocial work environment factors. In Denmark the NIOH has plans for developing similar instruments for other fields of research.

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Cross-shift decline in FEV_1 among wood dust exposed workers - the importance of repeated measurements in the exposure assessment

Schlünssen V [(1)], Vinzents PS [(2)], Schaumburg I [(1)]

[1.] *Department of Occupational and Environmental Medicine, Skive Hospital, 7800 Skive, Denmark, e-mail: vivi_schlunssen@dadlnet.dk*
[2.] *Department of Indoor Air, National Institute of Occupational Health, Lersø Parkallé 105, 2100 København Ø, Denmark.*

Introduction

In epidemiological studies the validity of the dose-response relationship between exposure and health effects is essential. The dose-response relationship between exposure and effect is highly dependent on the exposure variability (1). Exposure-response relationships may be underestimated, if the exposure is characterised by large within-worker variability relative to variation between individuals.

An epidemiological cross-sectional study in the Danish furniture industry among 2,381 woodworkers has been carried out, in order to study the relation between wood dust exposure and respiratory diseases. In this abstract we present data concerning cross-shift chance in FEV_1 among woodworkers processing or handling pine wood.

Methods

A total of 54 furniture factories were included in the study, and the base study population was defined as all 2,381 workers employed in wood working departments, assembly departments, and stock departments of these factories. The factories were visited between October 1997 and April 1998.

Personal dust sampling was carried out with passive dust monitors. The method is based on measurement of light extinction before and after sampling on transparent foils. The light extinction increase was reported as dust covered foil area, converted into equivalent inhalable and total dust concentration by linear regression models, based on earlier and present calibration measurements (2).

A total of 1,685 valid wood dust measurements were performed in a first measuring round. Totally, 371 randomly selected persons participated in a second measuring round. From this group 341 persons participated in the third measuring round. The time lag between two rounds was one week.

Pulmonary function was tested using a dry spirometer, and both pre- and post-shift measurements were performed. Forced expiratory volume in the first second (FEV_1) and forced vital capacity (FVC) were measured. Predicted values of FEV_1 and FVC were calculated. The cross-shift values for FEV_1 were calculated as pre-shift minus post-shift. The change in volume was reported as percentage change. All together 492 pine workers had a valid cross-shift value.

A total of 443 woodworkers had both a valid cross-shift value and a valid dust measurement in first measuring round, and 114 pine workers had a valid cross-shift value as well as 3 valid repeated measurements.

Results

The geometric mean (GM) equivalent inhalable dust concentration for the 1,685 measurements was 0.94 mg/m^3, geometric standard deviation (GSD) 2.1.

In Table 1, parameters for three linear regression models of cross-shift change in FEV_1 by inhalable dust concentration are given. All three regression models were controlled for potential confounding parameters as gender, age, height, smoking.

The first model includes the 443 pine workers with one dust measurement pr person. The second model includes the 114 pine workers with 3 repeated dust measurements, but only the first measurement was used in the analysis. The third model as well includes the 114 pine workers, but the arithmetic mean of the 3 repeated measurements was used as exposure parameter.

Table 1. Parameters for three linear regression models of cross-shift change in FEV_1 (percentage %) by inhalable dust concentration and confounders.

	number of pine workers [1)]	number of repeated measurements	slope	test of slope (p-value)	R^2
model 1	399	1	1.6	0.042	0.033
model 2	111	1	3.0	0.063	0.072
model 3	111	3	5.3	0.016	0.092

1) The numbers of persons is lower than stated in the text, due to missing values for included potential confounding parameters.

The smallest but significant slope, 1.6, was found in model 1. In model 2, the slope was 3.0, but not significantly different from zero. Model 3 had the highest slope, 5.3, significantly different from zero. R^2 was highest in model 3 and lowest in model 1.

Discussion

In assessing exposure, the between person variability as well as within-person variability has to be taken into consideration. The results from this study underline the importance of assessing the individual exposure not only from one measurement, but from repeated measurements, in order to reduce the attenuation introduced from the within worker variability.

Scheeper et al. (3) assessed the ratio of within- and between-worker variability among woodworkers. The exposure was assessed for two randomly selected days, and the within-worker variance was 1.11 times the between-worker variance, which is in concordance with our results (4).

The difference in slope between one and 3 repeated measurements, e.g. model 2 versus model 3, is in concordance with the expected difference, given a unity ratio of within-worker to between-worker variance (5).

The subjects in model 2 is a random sample from the population in model 1. As expected, the larger study population in model 1 makes it possibly to identify weaker relationships compared to the smaller population in model 2.

Conclusion

The results from this study underline the importance of repeated measurements in assessing relationships between exposure and effects.

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A comparison of exposure grouping methods to reduce attenuation in exposure-response – An analysis of wood dust exposure and lung function

Teschke K [1,2], Spierings J [2,3], Demers PA[2,1], Kennedy SM [2,1], Marion SA [1], Davies HW [2]

[1] *Department of Health Care and Epidemiology, University of British Columbia, Vancouver, BC, Canada, email: teschke@interchange.ubc.ca*
[2] *School of Occupational and Environmental Hygiene, University of British Columbia, Vancouver, BC, Canada*
[3] *Department of Epidemiology, Maastricht University, Maastricht, The Netherlands*

Introduction

In 1996, we conducted a cross-sectional study examining the relationship between wood dust exposure and respiratory disease in a sawmill cutting spruce (*Picea englemanii*, *Picea glauca*, and a hybrid of the two), pine (*Pinus contorta*), and alpine fir (*Abies lasiocarpa*)[(1)]. The study population included 106 sawmill employees with 37 different jobs. Wood dust exposures ranged from below 0.03 mg/m^3 to 15 mg/m^3 (mean=1.0 mg/m^3, n=211). An unexposed comparison group of 486 marine transport workers and bus mechanics was included to stabilize the analyses. Associations were observed between elevated wood dust exposure levels and cough, dyspnea, low FEV_1, and low FVC. In this paper, we explore the effect of different exposure metrics on the strength of the exposure-response relationship between wood dust and FEV_1.

Methods

The wood dust exposure measurements were assigned to subjects in 6 ways. Three involved either no or very little grouping. Each sawmill subject was assigned:

1. the average of their own exposure measurements;
2. the average exposure for their job; and
3. the exposure predicted by a determinants of exposure model[(2)].

Three additional assignments were made by grouping the sawmill subjects into exposure quartiles, and assigning each subject the mean exposure of the quartile. Quartiles were based on the three exposure assignment methods described above:

4. individual subject averages;
5. job averages; and
6. model-predicted exposures.

For all analyses, controls were assigned an exposure level of one-tenth the wood dust detection limit (LOD=0.03 mg/m^3).

Multiple linear regression was used to examine the association between the airborne wood dust concentration and FEV_1, after adjusting for height, age, sex, race, pediatric asthma, and pack-years of smoking, for current and ex-smokers separately.

Results

Table 1 lists the coefficients of the exposure-response relationships estimated for each of the six exposure metrics.

Table 1. Change in FEV_1 per unit wood dust exposure – a comparison of exposure-response relationships, by exposure metric

Method of assigning wood dust exposure to subject	Coefficient, *litres of FEV_1 per mg/m^3 wood dust* (p-value)
No/little grouping	
i. Mean exposure of subject	-0.034 (p=0.13)
ii. Mean exposure of subject's job	-0.072 (p=0.01)
iii. Exposure predicted by determinants model	-0.104 (p=0.03)
Grouping	
iv. Quartiles based on mean exposure of subject	-0.067 (p=0.07)
v. Quartiles based on mean exposure of subject's job	-0.086 (p=0.02)
vi. Quartiles based on exposure predicted by determinants model	-0.133 (p=0.01)

Stronger relationships were observed with each increasing level of grouping. The strongest relationships were observed when exposures were estimated using a determinants of exposure model based on such factors as tasks, jobs, equipment, department, outdoor or indoor location of work, wood condition, and work in booth enclosures. These results support the theoretical benefit (postulated for the Berkson error model[(3)]) of assigning subjects the average exposure of their group: reduction in attenuation of exposure-response relationships.

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Repeated individual exposure measurements: a method to improve the accuracy

Michael Schäper, Christoph van Thriel, Michaela Zupanic & Andreas Seeber

Institute for Occupational Physiology at the University of Dortmund,
e-mail: schaeper@arb-phys.uni-dortmund.de

Problem

Investigating a possible exposure - response relationship in epidemiological studies we need accurate information about the individual exposure. Analysing chemical exposure by repeated personal air sampling is often expensive and time consuming. So efforts were taken to find other solutions to the problem. Exposure depends on the time structure of daily activities, on workareas and on technological parameters. Using such additional information it is possible to increase statistically the precision of individual exposure assessments (1,2).

Method

In a study on health effects of toluene among workers in rotogravure printing plants personal air sampling (mean value for a workshift) were used to assess the individual toluene exposure. Additionally, every person gave protocols on his daily activities at the sampling day (5 categories: regular printing, cleaning, taking a break, disruption of printing, equipping the machine) and on his workarea. Besides, they gave such protocols for 10 consecutive days without personal air sampling. Based on these information three steps were performed:
(1) A statistical multiple linear regression model was computed for the dependent variable log(toluene) using the time protocols [minutes spent on every activity] and the workarea as a dummy variable [0/1] at the days of individual exposure sampling. Log transformed exposure levels were used to standardise variance and to obtain normal distribution.
(2) This statistical model was used to estimate additional individual exposures for every worker leaned on the protocols (For details see: 3,4).
(3) The real and estimated individual exposure information for every worker were combined calculating a mean value and afterwards used for further calculations as the individual exposure assessment (according to: 1,6).

Results

Ad (1): In this model 1115 air samplings of 188 workers of 13 rotogravure printing plants with similar working conditions were included leading to a mean value and a standard deviation of 2.81 ± 1.02 [log(toluene)]. About 7500 protocols of daily activities [times in minutes] were available, including 967 protocols for the respective sampling day. Due to missing values 930 observations (air sampling with corresponding time protocol) could be used to develop the statistical exposure model. The method of stepwise regression provided for the dependent variable log(toluene) an explained variance (R^2) of 17 % leaning on 10 independent variables. These were the 5 variables of the time protocols and 5 of 39 dummy variables indicating a workarea. A group of 7 variables (5 protocol variables and the workareas 'paper supply/feeding' and 'rotogravure machines generally') explained the main proportion, 16%, of the explained variance.

Table 1: Results of stepwise regression for the prediction of log-transformed individual exposure: log(toluene) , R^2 in percent

independent Variable	partial R^2	Model R^2	F-value	p-value
regular printing	5.42	5.42	52.37	< 0.0001
area for paper supply/feeding	3.79	9.21	38.03	< 0.0001
break	3.76	12.97	39.32	< 0.0001
equipping	1.07	14.03	11.30	0.0008
disruption of printing process	1.05	15.08	11.36	0.0008
area of rotogravure machines	0.57	15.65	6.06	0.014
cleaning	0.43	16.08	4.6	0.0323
rotogravure, other areas	0.034	16.42	3.64	0.0567
areas of material transport	0.029	16.71	3.15	0.0764
area of manager's office	0.002	16.91	2.22	0.1362

Further regressions were calculated for stratas of plants depending on the exposure levels of their workers. It resulted in higher portions of explained variance for plants with higher average concentrations of toluene and in lower portions in those plants where lower concentrations of toluene had been found.

The results in the Table agree to the results obtained in an earlier stage of the study with a reduced amount of observations (n = 319), where 6 independent variables explained 16% of the variance of the transformed variable.

In an earlier study with 15 consecutive days of data collection among 31 workers of two plants explained variances of $R^2 = 0.73$ and $R^2 = 0.55$ were found for the same dependent variable (5,3).

Obviously, the level of exposure and the strategy to collect the protocols and the air samples influence the proportions of explained variance.

Ad (2): The regresson model was used to estimate individual exposures [log(toluene)] for every worker based on their protocols and led to more than 6000 additional exposure values.

Ad (3): Using both the real and estimated exposures we found nearly the same overall mean value of 2.89 for the combined exposures vs. 2.87 for the real measurements but a substantial reduction of the overall standard deviation of 0.54 vs. 0.98.

In Table 2 the components of intra- and interindividual variance are presented estimated by a one-way random effect analysis of variance for measured and combined (mean of individual measured and predicted) exposure.

Table 2: Measured and modeled log(exposure) of 188 printing plant workers with estimated variance components and attenuation ratios (see: 1)

	obs.	mean ± sd	Var_t	Var_w	Var_b	Attenuation ratio
measured	930	2,87 ± 0,98	0,9561	0,6171	0,3390	0.77
combined	7209	2,89 ± 0,54	0,2900	0,1997	0,0904	0.96

Var_t , Var_w , Var_b : estimators of total, within, between variance

Conclusions

The proposed concept of collecting easy-to-obtain self reported information about the daily activities established as very effective for our purposes. The variables of the protocols of daily activities were in the main group of explanatory variables for log(exposure). In consequence of that the variance of information on individual exposures in the epidemiological study was reduced.

The gain of the approach may be characterised by the increase of the attenuation ratios of measured vs.combined exposure assessment (0.77 vs. 0.96). The value of 0.96 incicates that further estimations of regressions for dose – response relationships will be nearly unbiased.

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Exploring the correlation structure between repeated measurements for exposure assessment

Peretz C [(1)] , Heederik D [(2)]

[1] *Department of Epidemiology, Sackler School of Medicine, Tel Aviv University, Israel , e-mail:* ***cperetz@post.tau.ac.il*** *;*
[2] *Environmental and Occupational health Group, Institute for Risk Assessment Sciences,Utrecht University, The Netherlands.*

Introduction

In Industrial Hygiene (IH) groups, repeated measures are performed on the same workers through time and recently 2 variance components are evaluated: the variance between workers (var-b) and the variance within worker (var-w), for exposure assessment purposes. The relationship between the variance components enables to calculate the correlation between repeated measurements of the same worker no matter the time interval, namely r = var-b/ (var-b + var-w).

If the hypothesis that r = zero is statistically rejected, this correlation should be taken into account when modeling the relationship between group mean exposure and exposure determinants, to draw valid scientific inferences. Therefore, the aim of this study was to explore the correlation structure between repeated exposure measures in IH groups.

Methods

Sample: Four hundred and forty personal air measurements were carried out on 54 workers, employed in the main processes in six different factories (6-13 in each). Potential exposure was to lead, benzene and dust. Ten randomly repeated hygiene surveys were carried out over one year and each worker underwent 6-10 exposure measurements (unbalanced design). The year was divided into 2 periods: 1^{st} period included the first 5 surveys and 2^{nd} period the 5 last surveys.

Statistics: We estimated the variance components of exposure along time and consequently the correlation by using mixed models for the logged exposure data.

Thus for each IH group and for the whole cohort, with regard to the period factor.

Results

Table 1 presents the estimated variance components and correlations between any 2 repetitions (no matter the time interval) for the factory-based IH groups and for the whole cohort, based on different assumptions. The variance components (var-b and var-w) were assumed to have equal or different values in the 2 periods (homogeneity or heterogeneity respectively); in addition, the period was assumed to either have or not have influence on the group mean exposure (included or not included as a fixed factor in the model). The estimation was performed by using 3 different mixed models with the following assumptions:
Model 1: Homogeneity and period included as a fixed factor ;
Model 2: Heterogeneity and period included as a fixed factor ;
Model 3: Heterogeneity and period not included as a fixed factor.

Table: Estimators of variance components (var-b, var-w) and correlation (r) between repeated measures , using 3 models (n = 440; k=54)

	Model 1			Model 2 **Model 3**				
IH group	Var-b	Var-w	r	Var-b		Var-w	R	
				Period-1	Period-2		Period-1	Period-2
Factory 1	0.23	0.54	.30	0.00	0.52	0.52	.00	.50 (+.50)*
				0.00	0.47	0.52	.00	.48
Factory 2	0.29	1.64	.15	0.00	0.94	1.51	.00	.38 (+.38)
				0.00	0.84	1.50	.00	.36
Factory 3	1.56	1.46	.52	2.54	0.71	1.42	.64	.33 (-.31)
				2.20	0.66	1.42	.61	.32
Factory 4	2.30	2.21	.51	2.66	1.72	2.33	.43	.43 (.00)
				2.49	1.63	2.33	.52	.41
Factory 5	0.45	0.64	.41	0.40	0.51	0.62	.39	.45 (+.06)
				0.38	0.49	0.62	.38	.44
Factory 6	0.07	1.33	.05	0.24	0.74	0.98	.19	.43(+.24)
				0.17	0.69	0.99	.14	.41
ALL	1.05	1.26	.45	1.16	1.10	1.21	.49	.48
				1.15	1.09	1.21	.49	.47

n= No. of measurements; k= No. of workers
Var-b = Variance between workers; Var-w=Variance within worker; r= Correlation
* r change between periods, according to model 2

All estimated variance components, except the zero ones, are statistically different from zero ($p<.01$) and according to model 1, in 4 IH groups out of the 6 r>=. 30. Consequently r cannot assume to be zero.

According to model 2, the correlation between repeated measures is different in the 2 periods; in 4 IH groups the r-change is >absolute(0.23). Consequently heterogeneity in the variance should be assumed. Model 2 and model 3 result in almost the same r estimation. The slight reduction in the var-b from model 2 to model 3 is due to inclusion of the period factor, which seems to have a minor influence on the variability between workers and consequently on the r estimation.

Conclusions

For this data set, common regression models are inadequate for exposure determinants modeling since a correlation seems to exist between repeated measures; furthermore, the variance components (var-b and var-w) were found to have different values in the 2 periods indicating that variance-heterogeneity should be taken into account in the modeling procedure.

Comparison of exposure measurement strategies for cross-sectional studies in occupational health

Sauleau EA (1) Wild P (2) Hours M (3) Leplay A (1) Desprès B (1) Bergeret A (3)

1. *Rhodia, Décines, France, e-mail: sauleauea@sdv.fr*
2. *Department of Epidemiology, INRS, Vandoeuvre, France, e-mail: wild@inrs.fr*
3. *University Institute of Occupational Medicine, Lyon, France*

Introduction

Our objective is to compare different strategies for exposure measurement in the workplaces of industrial sites in view of future cross-sectional study. We suppose that in this industrial site different Homogeneous Exposure Groups (HEG) with respect to a single chemical substance, each characterising a series of tasks, coexist. A strategy consists of allocating a fixed total number of measurements to the different HEGs. A theoretically optimal but non operational solution to this problem was obtained by Ashford (1). We compare this strategy and simpler other strategies using simulations of exposure, sampling strategies and the health effect under the assumption of a linear effect of the cumulative exposure.

Methods

Exposure simulation

Table 1: Characteristics of an industrial population.

Job	Operator 1		Operator 2		Operator 3		Foreman
Number of workers	15		15		20		8
Mean age	38		38		38		38
Age range	23-60		23-60		23-60		23-60
Annual job rotation	8 %		8 %		8 %		4 %
HEG	1	2	3	2	4	2	5
Number of workers	5	10	5	10	7	13	8
Geometric mean (in ppm)	0.2	0.2	2	0.2	1	0.2	2
Geometric standard deviation	2	1.2	2.5	1.2	3.5	1.2	3
Arithmetic mean (in ppm)	0.25	0.20	3.04	0.20	2.19	0.20	3.66

The basis of our simulations was a quantitative description of seven real sites of the chemical industry. This was obtained by a workgroup comprising industrial hygienists, occupational physicians and epidemiologists. Since the beginning of the exposure to the substance considered, the industrial population is described in terms of jobs held and task performed. Further considerations are the age distribution in each job and the job rotations between them. Each task is described as a lognormal distribution with given geometric mean (gm) and geometric standard deviation (gsd). Table 1 shows the main characteristics of one of these described sites. The daily exposure of each subject was simulated on the basis of these characteristics from date of hired to the date of the study. A "between worker effect" was obtained by multiplying exposure by a factor sampled from a lognormal distribution with gm 1 and gsd 1.2 (3).

Measurement strategies

The different strategies we consider are:

- The **optimal strategy** described by Ashford consists in allocating to each HEG a number of measurements proportional to the square root of the number of subjects in this HEG multiplied by its exposure standard deviation computed from the parameters of the lognormal distribution used for the simulation.

- An approximation of the above strategy allocating to each HEG a number of measurements proportional to the square root of the number of subjects in this HEG multiplied by its gm (**gm.sqrt(n)**). This is equivalent to the preceding assuming identical gsd across HEGs.
- A further approximation allocating to each HEG a number of measurements proportional to the square root of the number of subjects in this HEG (**sqrt(n)**). This is equivalent to the optimal strategy assuming identical gsd and gm.
- A **balanced strategy** assigns the same number of measurements in each HEG.

We estimate exposure in each HEG by the mean of the corresponding measurements. This implies that each HEG is measured at least once.

Health effect simulation

For each subject the cumulative exposure is obtained by summing all the daily exposures (multiplied by the "between worker factor"). The baseline health parameter is obtained by sampling from a normal distribution. This parameter is then decreased linearly with individual cumulative exposure.

As an example we used the motor nerve conduction velocity (MCV) normally distributed with mean 52 m/s and standard deviation 4 m/s for non exposed. The assumed effect of exposure to carbon disulphide (CS_2) is a linear decrease in MCV of 4 m/s per 100 ppm.years (4). This value has been obtained in order to achieve an 80% statistical power in a cross-sectional study among active workers in the population described in table 1 followed up for 20 years in absence of any between worker effect.

Criteria

We use two criteria to compare the strategies: the statistical power to detect an effect of exposure and the mean squared error (MSE) of the individual cumulative exposure. These criteria have been computed in 100 simulations of the sampling strategies nested in 100 simulations of the health effect.

Results

Results are given in table 2. Statistical power is nearly independent of the strategies and even very few measurements achieve near maximal power (73%). Results are more differentiated for the MSEs: MSE decreases with number of measurements and **optimal** strategy is indeed optimal. The **balanced** strategy performs better than the **sqrt(n)** strategy while **mg.sqrt(n)** is nearly as good as the **optimal** strategy. Similar results were obtained with other sites and did not depend on "between worker effect".

Table 2: Statistical power and exposure MSE as a function of measurement strategies.

Number of measurements	10	40	75	150
Statistical power (%)				
Duration of exposure	47			
Balanced	66	70	71	71
sqrt(n)	65	70	71	71
mg.sqrt(n)	67	71	71	71
Optimal	68	71	71	72
Real exposure	73			
MSE (in % of balanced strategy for 150 measurements)				
Balanced	597	200	136	100
sqrt(n)	660	212	144	106
mg.sqrt(n)	383	148	109	88
Optimal	353	136	103	84

Discussion

Epidemiological designs are usually compared with respect to statistical power. In this respect our strategies make no difference and the simplest is the best. But the precision of the exposure estimates can be markedly improved using an optimal design. We show that Ashford's (1) design remains the best although it is theoretically optimal only without job rotation. In order to approach such a design we need at least an estimate of HEG specific geometric means possibly by expert assessment. When these estimates are accurate we showed that MSEs are only slightly worse.

Our method has some limitations as it depends on the assumption of a non-reversible effect of cumulative exposure. Other effects include peak exposure or non-linear effects which may yield other optimal strategies. Further work is needed. Our simulation are based on a quantitative description of the sites. However the similarity of the results through the sites strengthens our conclusions. Finally no simulation can truly represent reality. For a study of exposure assessment strategies based on real data see Heederik (2).

Conclusion

Although the different strategies did not prove very different, a reasonable practical advice is to oversample a priori high exposure groups.

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Dermal exposure assessment in occupational epidemiological research

Roel Vermeulen [1,2], Patricia Stewart [2]

[1] *Institute of Risk Assessment Sciences, Environmental and Occupational Health Group, Utrecht University, Utrecht, The Netherlands, E-mail: VermeulR@mail.nih.gov*
[2] *Division of Cancer Epidemiology and Genetics, National Cancer Institute, Bethesda, USA*

Introduction

The recognition of the importance of skin exposure in industrial and environmental settings has steadily increased over the last few decades, although the importance of this route has seldom been reflected in assessment of exposures in occupational epidemiology studies. This lack of consideration has occurred even when the substance being studied is a recognized dermal hazard, such as pesticides, PAHs, PCBs and solvent exposures or when the disease being studied is a skin disease, such as dermatitis and skin cancer. Ignoring dermal exposure when investigating exposure-disease relationships can result in misclassification of study subjects, which can cause the disease risk estimates to be biased to the null. Thus, it is important for experts performing exposure assessments for epidemiologic studies to correctly evaluate the exposure from dermally absorbed substances.

Methods

An extensive literature survey was conducted to identify dermal exposure assessment methods that have been applied in epidemiological and risk assessment studies. Based on this survey and on industrial hygiene principles, methodologies are postulated that could be applied to assess dermal exposures in occupational epidemiological research.

Results and discussion

Although several qualitative, semi-quantitative and quantitative methods have been used in epidemiological research and risk assessment models, few epidemiologic studies have actually addressed dermal exposures. The methods and models used in these studies were mostly based on three basic exposure determinants: 1) the mass of the contaminant; 2) the location and the surface area of the body exposed; and/or 3) the frequency and duration of exposure.

There are, however, several limitations to estimates obtained from one or more of these components. Differences in measurement methods and strategies make it, for instance, difficult to compare or combine dermal exposure estimates from different studies, as little is known about the accuracy and reproducibility of dermal exposure measurements for different compounds and exposure scenarios. Furthermore, only a few studies have addressed day-to-day and between worker variability in dermal exposure, hampering the evaluation of the accuracy and validity of reported quantitative dermal exposure estimates. Use of personal protective equipment and personal hygienic behavior has also been shown to influence dermal exposure and uptake. However, the effectiveness of these measures has been shown to be highly variable. In the end the validity of the exposure estimates depends, at least in the case of systemic exposure, on the relation with the actual dermally absorbed dose. However, several factors have been shown to influence dermal uptake between and within subjects, such as the body location where the uptake is occurring, occlusion and adverse skin conditions. The significance of several of these factors could, however, be limited as some cancel each other out or because the more permeable body parts are also less likely to be exposed.

In epidemiological analyses concerning systemic effects it is desirable to have a single value that represents the total absorbed dose from all routes of exposure. One approach to obtaining this single value is to use biological markers to estimate the internal dose received from all exposure routes. For most chemical exposures, however, no estimates of the internal dose are available. Thus, the exposure assessment of substances absorbed dermally will require developing separate exposure estimates for airborne and dermal exposure that can subsequently be used in an analysis with the health outcome of interest. One set of estimates can then be used to stratify the other set to evaluate the effect of each route of exposure on the disease.

Summary

Assessment of dermal exposure in epidemiologic studies is still in its infancy. Recently, initiatives have, however, been taken to validate existing protocols in occupational hygiene practice and to develop data driven dermal exposure measurement strategies. These efforts should result in more standardized measurement methods and strategies, which will eventually enable quantitative dermal exposure assessment in epidemiological research. Until then assessment of dermal exposure in epidemiological research probably will (and should) be performed by occupational hygienists or other specialists in the field on a qualitative or semi-quantitative basis.

Semi-quantitative dermal exposure assessment: dream or reality? - A first validation step

Van Wendel de Joode BN [(1,2)], Kromhout H [(2)], Vermeulen R [(2,3)], Hilhorst SKM [(2)], van Hemmen JJ [(1)]

[1] *Department of Chemical Exposure Assessment, TNO Chemistry, Zeist, The Netherlands, e-mail: vanwendel@chemie.tno.nl*
[2] *Environmental and Occupational Health Group, Institute for Risk Assessment Sciences (IRAS), Utrecht University, Utrecht, e-mail: b.vanwendel@vet.uu.nl*
[3] *Occupational Epidemiology Branch, National Cancer Institute, Bethesda, Maryland, USA.*

Introduction

Prior to quantitative dermal exposure assessment it is informative to estimate dermal exposure semi-quantitatively. However, validated methods to assess dermal exposure semi-quantitatively are non-existent. We are currently developing a DerRmal Exposure Assessment Method (DREAM) that, amongst others, determines pathways contributing to dermal exposure such as ‘dermal contact with a contaminated working environment ’. Within this scope, the degree of contamination of surfaces present in the working environment is estimated. The aim of our study was to investigate whether contamination scores obtained by DREAM for surfaces present in the working environment, corresponded with the measured contamination levels at these surfaces. In a medical centre, semi-quantitative surface contamination scores were assessed for anti-neoplastic drugs by applying DREAM, and compared with measured cyclophosphamide (an anti-neoplastic drug) levels.

Methods

At five departments of a Dutch medical centre, two occupational hygienists identified surfaces possibly contaminated with anti-neoplastic drugs by hospital personnel during working activities. Consequently, per department, for each surface a DREAM-contamination score was determined by summing the contamination-scores of all tasks carried out at within a department. The contamination score at task level was formed by the product of the estimated ‘probability-of-contamination-value’ (no=0/possibly=1/yes=3) and the ‘intensity-of contamination-value’ (= the concentration of anti-neoplastic drugs containing the agent handled) (residue=1/mixture=3/pure=10)’.

Subsequently, at every department a number of surfaces were wiped with 20 ml 0.03 M NaOH-solution and two tissues. In addition, samples of bed sheets used by patients receiving cyclophoshamide treatment were taken. Samples were stored at –20ºC, extracted with 120-140 ml NaOH-solution (0.03M), and cyclophosphamide concentrations were determined using GC-MS analysis.

De DREAM-scores were plotted against measured contamination levels (ng/cm2) and the Spearman correlation coefficient was calculated. In addition, surfaces were divided into four categories on basis of their DREAM scores: 0= no; 0-10=very low; >10-30=low; >30-100=moderate contamination. High contamination, a DREAM score of more than 100, did not occur.

Results

Figure 1 shows the DREAM-scores of surfaces present in the working environment compared with measured cyclophosphamide values on these surfaces. In general, surfaces with a higher DREAM-score corresponded with higher cyclophosphamide contamination levels. However, due to large variations in actual measured contamination per DREAM contamination score, the correlation was moderate (Spearman correlation coefficient r=0.48, p=0.0001). The DREAM category 'moderate contamination', had statistically significant higher cyclophosphamide levels than other categories (p<0.01) (Table 1). In addition, the 'low contamination' category differed significantly from 'no contamination' (p<0.01).

Figure 1: DREAM contamination scores versus measurements (ng/cm2).

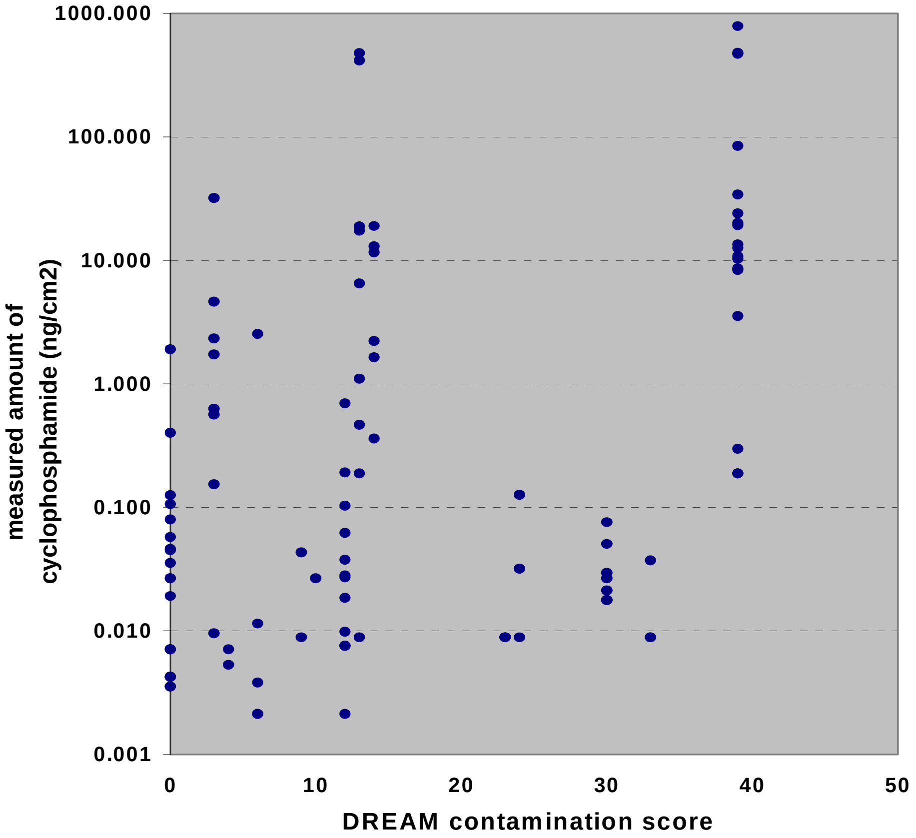

Table 1. DREAM contamination categories compared with measurements (ng/cm2)

DREAM contamination category	GM	95%CI	Groups differ? P-values			
			No	Very Low	Low	Moderate
No (n=22)	0.02	0.01 – 0.04	.	0.15	<0.01	<0.01
Very low (n=21)	0.07	0.04 – 0.13		.	0.28	<0.01
Low (n=44)	0.16	0.10 – 0.25			.	<0.01
Moderate (n=22)	3.81	2.01 – 7.20				.

Discussion

A moderate correlation was observed between DREAM contamination scores and measured cyclophosphamide contamination levels. This may be explained by the method used to estimate the semi-quantitative scores, which were task-based only including contamination due to workers' activities. However, they did not include contamination of the work environment through none-task-related factors such as contamination caused by patients (excreta). In addition, the semi-quantitative scores concerned contamination by anti-neoplastic agents in general where the quantitative assessment only concerned cyclophoshamide.

Conclusion

The results suggest that semi-quantitative assessment of contamination of the working environment may provide useful information. However, inventories should go beyond a task-based approach and consider additional sources of contamination. The approach applied to DREAM will be developed further.

Assessment of dermal exposure to industrial chemicals

Van Hemmen Joop J.

Project coordinator, TNO Chemistry, Dept. Chemical Exposure Assessment, Zeist, the Netherlands (vanhemmen@chemie.tno.nl)

Introduction

In a large project funded by the European Commission (RISKOFDERM, QLKA4-1999-01107), scientists from 15 Institutions from 10 European countries work together with the following aims:
- To develop a validated predictive model for estimating dermal exposure for use in generic risk assessment for single chemicals.
- To develop a practical dermal exposure risk assessment and management toolkit for use by small and medium-sized enterprises (SMEs) and others, in actual workplace situations.

Research goals

To achieve the above-mentioned aims, a research programme comprising four interrelated work parts was formulated:
1) A qualitative survey in European workplaces to obtain an overview of tasks, processes and determinants relevant for dermal exposure.
2) A quantitative survey to obtain detailed data on dermal exposure and determinants in the most relevant tasks and processes.
3) Exposure model building to create a predictive dermal exposure model (set) using all relevant variables.
4) Development of a risk assessment and management toolkit from relevant data on hazard, dermal absorption, dermal exposure and effectiveness of control measures for direct use in workplaces.

Methodology

The project started early 2000 and is to run for four years. The four work parts are carried out independently, but many very important interactions are required to obtain optimal input and output data, as well as results.

In work part 1, the various relevant scenario’s are defined and fragmented to standard operation units for dermal exposure assessment. These will be surveyed in ten European countries by centrally trained observers.

In work part 2, the main scenario’s and operation units will be assessed with the most appropriate (scenario-dependent) quantitative methodology for dermal exposure assessment.

In work part 3, the results of work part 1 and 2 will be integrated in a model or models. These will be tested in practice for two compounds (a liquid and a solid) for which so detailed pharmacokinetic knowledge is available. Biomonitoring in the workplace will be carried out together with dermal exposure monitoring and interpreted. In this way benchmarking of the model results is possible.

In work part 4, the available approaches for other exposure routes in risk assessment are considered in detail as well as available data on hazard, exposure, absorption and control. A practical toolkit on CD-Rom will be developed that can be used by non-experts and experts at different levels of detail.

Results

The first deliverables of the project, which will be discussed in the light of the project development, are currently practically finished:
- A list of dermal occupational exposure units, describing the major scenario's and tasks.
- A description of the tasks and processes that will be studied quantitatively in pilot and main studies and with which methodology.
- Analysis of relevant dermal exposure determinants, based on literature, non-published studies and models.
- A draft toolkit with approaches taken for hazard identification and exposure assessment, leading to risk identification and offering information on actions to be taken. The draft will be assessed in work parts 1 and 2 for further development, and will in the end incorporate the results of work part 3.

Discussion

After about one year in a complex four year project, the results cannot yet be discussed in any detail in the light of the project aims. At this point in time, it is clear that the numerous partners from distinct parts of Europe (Finland, Sweden, England and Scotland, the Netherlands, Germany, France, Austria, Portugal, Spain and Italy) are well-committed and that the project is on schedule. The presentation will enlarge on this and describe the progress made in relation to the ambitious goals presented.

Validating in vitro percutaneous absorption methods

Dellarco M [(1)] , Zendzian, R P [(2)]

[1.] *U.S. Environmental Protection Agency, National Center for Environmental Assessment Washington, DC, USA, dellarco.mike@epa.gov*
[2.] *U.S. Environmental Protection Agency, Office of Pesticide Programs Washington, DC, USA, zendzian.robert@epa.gov*

Introduction

The understanding that dermal penetration of a chemical is a passive process of solution into and diffusion through the stratum corneum has led to the development of a variety of in vitro procedures to estimate dermal penetration. Compared to in vivo studies, these procedures are fast, efficient, and economical. Furthermore, they offer a safe way to test dangerous chemicals on human skin. Consequently, there is considerable interest to use these vitro tests to estimate the percutaneous absorption of pesticides, industrial chemicals, and chemicals found at hazardous waste sites to assess their hazard potential. However, questions have been raised about the validity of in vitro procedures to estimate dermal penetration such that their use has been limited for regulatory purposes. The purpose of this investigation was to construct criteria that would satisfy concerns about validation and apply them to in vitro methods being advocated for use in regulatory investigations.

Methods

We examined matched in vivo and in vitro dermal absorption studies of specific pesticides submitted by manufacturers to the U.S. EPA Office of Pesticides Programs (OPP) for pesticide registration. These studies were conducted according to the Guideline for Dermal Absorption of Pesticides (2). This Guideline requires a minimum of three doses at log intervals be applied to rats for durations of 0.5, 1, 2, 4, 10, and 24 hours and reporting in considerable detail about the experimental design, identity and properties of the test compound, dose preparation and application to experimental animals, sample collection and analysis procedures, and submission of the raw data. This information was evaluated to develop criteria that would provide sufficient evidence of validation. Next, we applied these criteria to a series of published studies selected by the OECD Chemicals Committee in their review of the validity of in vitro percutaneous absorption testing procedures (1).

Results

Examination of the dermal absorption studies submitted to OPP permitted us to develop the criteria for method validation (figure 1). Criteria for a validation study consisted of the presence of both in vivo and in vitro data, use of the same formulation and application procedures, and a comparison of all in vivo and in vitro results.

We tested these criteria against the published studies selected by OECD and to matched in vivo and in vitro dermal absorption studies of acetochlor submitted to OPP. We found that validation was achieved only to a very limited extent in all of the OECD selected studies examined, such that the comparability between in vivo and in vitro procedures was not demonstrated (figure 2). Only one study (#2) contained all of the criteria we require to validate these procedures. However, in this case, only a few doses were studied, thus limiting the comparison. All of the other studies examined were missing validation criteria. One study (#4) did not contain any of the criteria. The most common omissions in these studies were the failure to present all of the numeric data collected and to compare all of the in vivo and the in vitro results. In three of these studies, the formulations tested were not identical, and in two studies, the applied doses were not similar, thus limiting the ability to compare these procedures. In the matched acetochlor studies, we found that the percent of absorbed acetochlor increased over time in all doses tested in both the in vivo and the in vitro procedure (table 1). However, when we compared the two procedures, we found that they were not comparable. Percent absorption in the in vitro procedure consistently exceed that of the in vivo procedure by as much as six times, especially at the lower doses. Morever, the ratio of percent dermal absorption varies inconsistently with dose and duration of exposure.

Table 1. Acetochlor rat in vivo and in vitro dermal absorption study results

Dose	Exposure Duration (hours)					
ug/cm^2	0.5	1.0	2.0	4.0	10.0	24.0
				in vivo		
3.0	3.8	4.3	7.3	9.9	19.5	31.3
42.5	4.0	6.0	4.4	9.2	23.1	29.6
270	4.8	5.6	3.0	4.8	9.3	17.5
2934	1.4	5.2	3.4	2.7	4.5	12.6
				in vitro		
3.03	13.7	27.1	37.8	45.2	71.2	70.1
47.3	4.2	8.2	21.7	33.8	43.8	60.7
318	2.1	6.7	10.5	25.4	57.2	77.3
3095	---	0.5	3.4	4.4	8.5	24.5

Figure 1. Validation criteria for dermal absorption

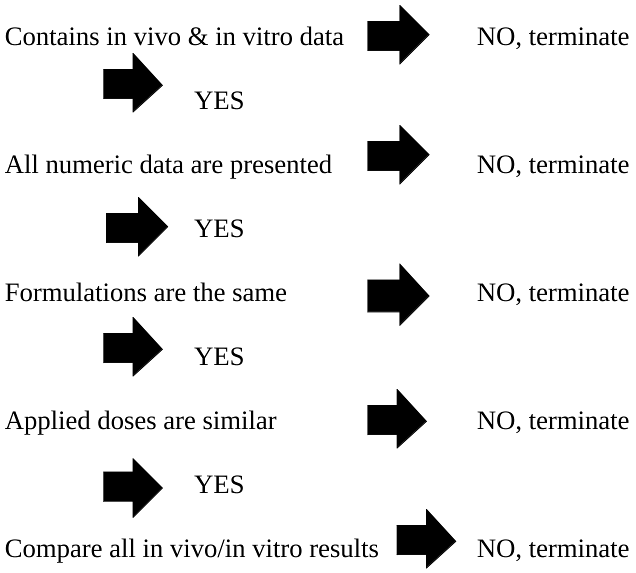

Figure 2. Analysis of OECD in vitro dermal absorption validation studies.

ALGORITHM	EXTERNAL REVIEW PANEL SELECTED STUDIES									
	1	2	3	4	5	6	7 ND	8	9	10
Contains in vivo & in vitro data	X	X	X		X			X	X	X
All numeric data are presented		X				X				
Formulations are the same		X	X		X	X		X	X	
Applied doses are similar	X	X	X		X	X		X	X	
Compare all in vivo/in vitro results		X								

Discussion

In this investigation, we developed criteria to validate in vitro dermal absorption procedures. Our results show that there is a critical need for this kind of more rigorous criteria. In our examination of dermal absorption validation studies, selected by the OECD as the best examples of validation studies, all but one study failed to contain sufficient information for effective comparison. The benefits of this kind of rigorous criteria can be seen in our analysis of matched in vivo and in vitro dermal absorption studies conducted for acetochlor according to EPA's Guideline for Dermal Absorption of Pesticides. The results showed that the in vitro procedure overestimated dermal absorption in the majority of doses and exposure intervals. The ratio of percent absorption between the in vitro and the in vivo test varied inconsistently over the range of doses and exposure intervals tested. This indicates that there is not some kind of consistent difference or error between the two approaches that could be accounted for or corrected with an adjustment factor.

We suggest that these criteria be adopted and applied to efforts to demonstrate the ability of in vitro procedures to estimate in vivo percutaneous absorption. Current efforts by the OECD and the U.S. EPA to develop standard in vitro methods to estimate percutaneous absorption have not been successful. In our view, acceptance will be difficult to attain, unless more rigorous validation studies are conducted as shown here to demonstrate that in vitro procedures are comparable to in vivo methods.

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Dermal uptake index and skin notation

Isaksson T S [(1)], Boman A [(2)], Johanson G [(1)]

[1]*Toxicology and Risk Assessment, National Institute for Working Life, Stockholm, Sweden, e-mail:tina.isaksson@niwl.se,*
[2]*Department of Occupational Dermatology, Norrbacka, Stockholm, Sweden*

Introduction

When establishing occupational exposure limits (OELs) for chemical substances it is common practice to also assess the potential for systemic exposure via the skin. Thus, substances for which dermal exposure is considered to contribute significantly to the overall exposure (1) or that are easily absorbed by the skin (2) are assigned a "skin notation". Unfortunately, skin notations are mostly based on insufficient scientific data. There is often a lack of comparable dermal data and when available, they are often expressed in terms (*e.g.* as percent absorbed dose or LD_{50}), that are dificult to interpret quantitatively. An additional shortcoming with the skin notation is that it is merely qualitative (yes/no) and does not reflect the wide range of dermal absorption rates among chemical substances. To address the latter problem, Johanson *et al.* (3) have proposed a simple procedure to quantitatively describe the importance of dermal uptake in relation to respiratory uptake. Similar approaches have been taken by other researchers, *e.g.* by Fiserova-Bergerova *et al.* (4).

The aims of this study were to: (a) update and extend the previous study (3) by including recent dermal absorption studies and more substances, and (b) compare the results with regards to existing skin notations.

Method

The dermal uptake index (DI) was calculated as:

DI = Dermal uptake rate (nmol /min) / Inhalation uptake rate (nmol/min) (3).

The dermal uptake rate was obtained from published experimental data using neat substances and steady-state conditions. The rates were recalculated for an exposed skin area of 100 cm^2. When several experimental data sets were available, human and *in vivo* data were preferred over animal and *in vitro* data, respectively. The inhalation uptake rate was calculated assuming exposure at the Swedish OEL (2) (8-h TWA), a pulmonary ventilation of 10 L/min and a retention of 60%.

Results and discussion

Overall 55 substances were analyzed. Of these, 37 were assigned a skin notation in Sweden (1), the Netherlands (5) and/or by the US ACGIH (2). Notably, for 19 of these 37 substances the skin notation differed between the three lists.

The dermal uptake rate varied by more than 8 orders of magnitude between the 37 substances, from 6 µmol/min/cm^2 for methanol to 0.00005 nmol/min/cm^2 for chromates. Similarly, the DI varied even more by about 7 orders of magnitude, from 15 000 for ethylene glycol dinitrate to 0.002 for chromates. This suggests that the skin notation *per se* gives limited information about the potential contribution of dermal uptake to total absorption. Moreover, some substances, like ethylene dichloride, methyl isobutylketone, formaldehyde, and ethyl benzene, with relatively high DI values lack a skin notation in at least two lists.

One problem with the DI approach is that the importance of dermal uptake may be overestimated for substances like formaldehyde where the OEL is based on a local effect such as mucosal irritation. However, for substances with irritation as the critical effect systemic effects are generally seen at slightly higher exposure levels.

One factor that contributes to the enormous variability in dermal uptake rates is that different techniques have been used to measure the uptake rate. In addition, the skin samples have been collected from different species and from different parts of the body. For example, extremes of 3300 and 0.1 nmol/cm^2/min have been reported for toluene, using human skin *in vivo* and rat skin *in vitro* respectively (6, 7). There is also a large variability in dermal uptake rate for several other substances. This variability points towards the need for a standardized assessment of dermal uptake rate.

In conclusion, our survey suggests several inconsistencies in the assignment of skin notations. This is mainly due to lack of solid scientific data. Further, we suggest that the use of dermal uptake index or similar approaches would give additional, valuable information about the importance of the dermal route.

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The United States environmental protection agency's dermal exposure research program in support of the food quality protection act

Cohen Hubal EA, Sheldon LS

United States Environmental Protection Agency
National Exposure Research Laboratory
Research Triangle Park, NC 27711 USA
hubal.elaine@epa.gov

Introduction

The Food Quality Protection Act of 1996 (FQPA) requires that children's risks to pesticide exposures be considered during the tolerance-setting process. FQPA requires exposure assessments to be conducted for all pesticides sources, not just food sources. It also requires that assessments use high quality and high quantity exposure data or models based on exposure factors generated from existing, reliable data.

Currently, data on children's exposures and activities are very limited and insufficient to support quantitative assessments that do not rely heavily on major default assumptions as substitutes for missing information (1,2). Results derived from an initial assessment of critical exposure pathways and factors for assessing children's residential exposures to pesticides (1) indicate that dermal exposure and nondietary ingestion may result in high residential exposures for children. However, there are so few data associated with these pathways that exposure estimates may vary by orders of magnitude, depending upon the assumptions and exposure factors selected. Studies across all ages of children, but especially for very young children, are required to characterize activities that contribute to dermal exposure in important microenvironments. Studies are also needed to characterize contact and transfer factors for non-dietary ingestion.

The goal of the U.S. EPA National Exposure Research Laboratory program in support of FQPA is to develop and evaluate protocols for assessing children's aggregate exposure to pesticides, and to conduct fields studies to collect data required to reduce the reliance on default assumptions in development of quantitative exposure assessments. The specific aim of the work described in this presentation is to evaluate the approaches available for assessing dermal exposure resulting from contact with residue contaminated residential surfaces.

Methods

Two main approaches are currently used to assess residential dermal and non-dietary ingestion exposure. In the macroactivity approach, dermal exposure is estimated using empirically-derived transfer coefficients to aggregate the mass transfer associated with a series of contacts with a contaminated medium. The macroactivity approach affords the possibility of developing screening level exposure assessments with relatively limited resources. However, because this approach was developed to assess occupational exposure in an agricultural setting, the feasibility of applying this approach to assess children's dermal exposures in a residential environment needs to be evaluated.

In the microactivity approach, exposure is explicitly modeled as a series of discrete transfers resulting from each contact with a contaminated medium. This approach requires a high level of detail (i.e., "microactivity data") to characterize people's dermal contact with chemical residues in their environments and quantify subsequent dermal absorption and non-dietary ingestion. Because of the age dependencies and labor-intensive nature (i.e., high expense) of gathering microactivity data, few data sets relevant to exposure assessments currently exist. Before micoractivity data can be effectively collected and evaluated, knowledge is required on important activities and contact parameters.

Targeted laboratory and fields studies have been initiated to: (a) collect preliminary data required to use these approaches to assess dermal and non-dietary exposure, (b) evaluate these two approaches for assessing dermal exposure, and (c) develop methods and protocols for conducting field studies.

Study to Test the Feasibility of Using the Macroactivity Approach to Assess Dermal Exposure

To assess the feasibility of using the macroactivity approach for assessing children's exposure to pesticides, a screening-level study was conducted with young children in a daycare center where a known pesticide application had occurred. Four or five children from each of two different age groups were monitored for short time periods while involved in selected macroactivities (e.g., storytime, playtime indoors). To measure dermal loading, the children were clothed in full-body dosimeters. To measure the pesticide concentration in the exposure medium, transferable residues were sampled in the areas where the children spent time during each monitoring event. These measurements were then used to calculate dermal transfer coefficients for each monitoring event. Development of an aggregate surface sampling method is also being developed in this study

Additional field studies to test the feasibility of using the macroactivity approach and to develop additional transfer coefficients are currently being conducted. Several of these studies are collaborative studies with other US EPA researchers or external organizations that are conducting aggregate exposure studies following a known pesticide application. These studies have been enhanced to collect limited dosimeter data and the associated transferable residue and activity data.

Study to Identify Important Parameters for Characterizing Pesticide Residue Transfer

Prior to conducting exhaustive studies to collect the residue transfer data needed to apply the microactivity approach, a screening study to identify the important parameters for characterizing these transfers was conducted. In this study, parameters that affect residue transfer from surface-to-skin, skin-to-other objects, skin-to-mouth, and object-to-mouth, were evaluated using a fluorescent tracer as a surrogate for pesticide residues. A fluorescent tracer was applied as a residue at levels typical of residential pesticide applications to surfaces of interest. Controlled transfer experiments were conducted by varying contact parameters with each trial. The mass of a tracer transferred was measured and the contact surface area estimated using video imaging techniques. In addition, laboratory evaluations were conducted to relate transfer of a tracer to transfer of pesticides. Parameters evaluated included: surface type, surface loading, contact motion, pressure, duration, and skin condition. Transfers onto and off of the hand were measured.

Results and discussion

Preliminary results from the studies being conducted to test the feasibility of the macroactivity approach indicate that this approach shows promise for assessing dermal exposure to children in a residential setting. These results are also being compared with the default transfer coefficients currently being used in residential exposure assessments. More research is required to relate the residues measured using dosimeters and the residues available for absorption.

Results of the study to identify important parameters for characterizing residue transfers in the microactivity approach show that surface type and skin condition are among the important parameters. In addition, the direction of residue transfer (on or off skin) with repetitive contact will vary with skin condition. This data is being used to determine what additional residue transfer data should be collected and what type of microactivity data are needed to estimate dermal and non-dietary ingestion exposure. Despite the limitations associated with collecting and using microactivity data, the microactivity approach may be the only viable approach for estimating non-dietary ingestion.

In general, there is a need for developing field protocols that will facilitate dermal exposure assessments by both approaches. In doing so, it is critical that the sampling methods used in the field to measure surface residues be the same methods used to develop transfer coefficient and transfer efficiency data. Surface sampling methods do not need to act as surrogates for skin. Rather the relationship between transfer of residues from surface to sampling media and surface to skin need to be characterized in the lab. In this way, the surface sampling methods can be applied more generally and field monitoring made more efficient.

Completion of protocol development and key exposure measurement studies will strengthen current databases used for assessing risks to children from exposure to environmental contaminants.

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Design of efficient measurement strategies in ergonomic intervention studies on the basis of exposure variability data

Mathiassen SE [1,2], van der Beek AJ [3]

[(1)] *Div. Production Ergonomics, Fac. Technology and Society, Malmö University, Malmö, Sweden, e-mail: svend.erik.mathiassen@ts.mah.se;*
[(2)] *National Institute for Working Life, Sweden;*
[(3)] *Institute for Research in Extramural Medicine, Vrije Universiteit Medical Centre, Amsterdam, The Netherlands*

Introduction

A large body of ergonomic literature have been devoted to the design of proper data collection strategies. Studies have concentrated on, e.g. conceptual issues, the relevancy of different exposure variables, and the validity of different measurement instruments. The efficiency of the data collection strategy, i.e. its ability to produce precise information at low resource investments, has received much less attention although it is of great importance to the design and interpretation of intervention studies.

The present paper aims at giving a short introduction of how to determine and optimise precision and use this information for designing sensitive intervention studies.

Exposure variability and statistical power

Two major classes of intervention study designs can be distinguished in ergonomics focusing on primary prevention of musculoskeletal disorders: those comparing conditions by collecting data from independent groups of subjects (e.g. different companies), and those investigating matched data (e.g. by using subjects as their own controls in a 'before-after' design). Often, the magnitude of the intervention effect may be expected *a priori*, or at least a lower limit may be set on the effect size which is considered interesting from an ergonomic point of view. In the simple case of comparing two conditions, the detectable difference depends on exposure variability in a straight-forward manner:

$\Delta = SD_\Delta \cdot n_S^{-½} \cdot (t_{\nu,(1-\beta)} + t_{\nu,(1-\alpha/2)})$ {1}, with Δ: difference between conditions; SD_Δ: standard deviation of the difference between conditions; n_S: number of observed subjects in each condition (assumed to be equal in both); $t_{\nu,f}$: f-percentile of the t-distribution with ν degrees of freedom; $(1-\beta)$: power; α: two-tailed significance level. ν equals (n_S-1) and $2(n_S-1)$ in the case of paired and independent data, respectively.

The standard deviation of the difference between conditions, SD_Δ, can be determined according to the equation:

$SD_\Delta = SD_S \cdot [2 \cdot (1-\rho)]^{½}$ {2}, with SD_S: standard deviation between subjects in each condition (assumed to be equal in both); ρ: correlation coefficient between pairs of data in the two conditions. The relationship between study size and detectable effect in fractions of the exposure variability is illustrated in table 1.

Table 1. Number of subjects required to obtain a power of 0.80 in a study aiming at detecting an intervention effect of size Δ (measured in fractions of the standard deviation between subjects) at a (two-tailed) significance level of 0.05. Numbers refer to the group size in each of the two compared conditions, and they are presented for comparisons of independent data, as well as for two paired design cases (cf. equation {2}).

	Independent data (ρ = 0)	ρ = 0.4	ρ = 0.8
$\Delta = 0.25 \cdot SD_S$	252	152	53
$\Delta = 0.5 \cdot SD_S$	64	40	15
$\Delta = 1 \cdot SD_S$	17	12	6
$\Delta = 2 \cdot SD_S$	5	5	3

The sensitivity of ergonomic intervention studies

Table 1 can be used in combination with data on exposure variability to estimate the sensitivity of a planned ergonomic intervention study. For instance, the standard deviation of the 50-percentile of trapezius EMG amplitude among subjects performing a specific task may typically be in the order of 5 % of maximal activation. Thus, a study aiming at detecting a difference of 5 %MVE between two independent groups will have to engage 17 subjects in either group. In a paired design with ρ=0.4, 12 subjects will be needed, all measured twice.

Some reference input data for equations {1} and {2}, relevant to ergonomic intervention studies, can be found in the literature, and an important effort would be to summarise it in a format useful for study design guidance. This includes the influence of exposure variable, of personal factors in the study population, and of data collection instrument on exposure variability. The effectiveness trade-offs of different ways of increasing study sensitivity is also a challenging area of research.

Allocation of measurements

Equation {1} applies to the case of equal numbers of subjects in two compared conditions, but it may be adjusted to accommodate also unbalanced designs. Unbalanced allocation of subjects will almost always lead to less sensitive studies than a balanced allocation of the same total number of subjects. However, if the ergonomic intervention is expensive or difficult to realise, it may be sensible to include more subjects in the reference group than in the experimental group.

The precision of a group mean exposure, $SD_S \cdot n_S^{-½}$, and hence the sensitivity of an intervention study involving that group, will improve, both if the number of subjects is increased and if more data is collected from each subject. According to analytical equations, a certain total number of measurements (subjects *times* measurements-per-subject) will always result in better precision if more subjects are preferred to more data per subject. The performance of different allocation principles may also be explored using modern distribution-free techniques, e.g. bootstrapping. It has been suggested to periodically evaluate exposure data during data collection using these techniques in order to adjust on-line the allocation of measurements (2).

Hoozemans et al. (1) have given one of the first examples of measurement allocation trade-off in a procedure for mechanical exposure assessment. In the future, models including considerations to resource consumption at different levels of data collection could contribute greatly to the optimisation of studies.

Task-based strategies

As a general principle, the efficiency of exposure assessment may be enhanced if known exposure determinants are utilised, either to stratify data collection or to indirectly estimate exposures. Thus, a number of ergonomic studies have assessed job exposures on basis of known tasks in the job. It is then assumed that tasks discriminate between exposures. In order to be efficient, however, a task-based strategy must meet a number of additional requirements, including that tasks must occur for substantial proportions of the job, and that correct data must be available of task occurrences as well as task exposures.

The efficiency of task-based exposure assessment in ergonomic intervention studies was explored recently by Svendsen and colleagues (3). They conclude that job exposure estimation on basis of task diaries combined with a task exposure database may, indeed, be an attractive and efficient strategy, in particular in some types of intervention studies. The need for research on resource consumption in task-based strategies as compared to other methods of obtaining job exposures is also stressed.

A ‘best practice’ for using exposure variability data in study design

Following the considerations above, a minimal ‘best practice’ of how to use exposure variability information in the design of ergonomic intervention studies includes the following steps: (1) obtain variability information from a pilot study, the literature or by educated guessing, (2) analyse the sensitivity and size of the planned study and contemplate the result in relation to available resources, (3) consider the option of using a task-based strategy in this particular case, (4) if the study is considered feasible, determine an efficient measurement allocation.

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The precision of group mean exposure explored by bootstrapping

Hoozemans MJM (1) Burdorf A (2) Van der Beek AJ (1)
Frings-Dresen MHW (1) Mathiassen SE (3,4)

1. Coronel Institute for Occupational and Environmental Health, AmCOGG Amsterdam Centre for Research into Health and Health Care, Academic Medical Centre / University of Amsterdam, P.O. box 22700, 1100 DE Amsterdam, The Netherlands.
2. Department of Public Health, Erasmus University Rotterdam, P.O. box 1738, 3000 DR Rotterdam, The Netherlands.
3. Division of Production Ergonomics, Faculty of Technology and Society, Malmö University, SE – 20506 Malmö, Sweden.
4. National Institute for Working Life, Sweden.

Introduction

An effective data collection strategy succeeds in obtaining an estimate of, for instance, a group mean exposure with a sufficient accuracy (small bias) and precision (small random error) at the expense of a minimised resource investment. The precision depends on the collected number of measurements, including their allocation between and within subjects. A proper planning of studies includes considerations as to the data collection effort needed to produce results of a desired precision without being excessive. The present study examined the precision of the group mean exposure to pushing among train stewards, using various combinations of numbers of workers and measurements per worker.

Methods

A group of 15 train stewards (mean age 33.7 years (SD 8.6)) was continuously observed for a whole 8 hour working day using TRAC (Task Recording and Analysis on Computer (1)). A major task was to push a 135 kg cart to provide train passengers with food and drinks. The observational data of each worker was subdivided into consecutive periods of 30 minutes. Thus, a working day of 8 hours consisted of 16 observational periods, providing 16 repeated measurements per worker. The influence of the number of workers and the number of observational periods on the precision of the mean frequency of pushing in a group of workers was studied using bootstrapping (2). The bootstrap method estimates the empirical distribution of a variable through a large number of simulated ‘experiments’, based on sampling with replacement from the original observational data. A nested bootstrapping procedure was performed. First, a predetermined number of workers was drawn with replacement and, second, for each of the selected workers a predetermined number of periods was drawn with replacement. 1000 replicates of this whole procedure generated the distribution of the group mean exposure for 1 through 15 workers, combined with 2, 4, 8, and 16 periods per worker. The range between the 5th and 95th percentile was calculated as a measure of precision.

Results

A mean pushing frequency of 13.4 times per 30 min for a total of 235 periods of 30 min (SD 8.8) was observed. The SD was 3.2 when the 15 workers' means were averaged. This indicates that a reasonable part of the variance can be explained by the within worker variance.

Results of the bootstrap procedures indicate that the gain in precision obtained by increasing the number of workers was considerable when observing just a few workers (figure 1). Beyond about 10 workers, the inclusion of an additional worker would not considerably improve precision. Furthermore, observing randomly 2 periods of 30 minutes yielded the largest 5th-95th percentile interval. Using 4 periods resulted in more precise estimates of the group mean and also the observation of 8 periods per worker resulted in improvement of the precision. In comparison to the random observation of 8 periods per worker, little was gained by observing 16 periods of 30 min (full working day).

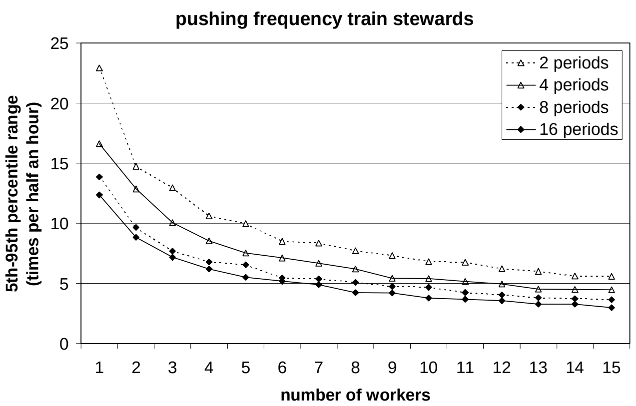

Figure 1. The 5th-95th percentile ranges of the group mean exposure, resulting from using different numbers of subjects (x-axis) and periods per subject (family of curves).

Table 1. The number of workers that has to be observed to arrive at a specific value of the 5th-95th percentile range (10, 7.5, and 5) per 30 min period.

	5th-95th percentile range		
	10.0	7.5	5.0
Number of 30 min periods	Number of workers		
2 periods	5	9	>15
4 periods	3	5	12
8 periods	2	3	8
16 periods	2	3	7

The number of workers required to obtain a specified level of precision may be derived from figure 1. This data appears in table 1. For instance, to reach a 5th-95th percentile range of 10, 5 workers have to be observed for 2 random periods of 30 min each. To reach the same level of precision, only 2 workers would have to be observed for 8 random periods of 30 min. Table 2 is derived from table 1 and shows the total number of 30 min periods that has to be observed to arrive at a specific value of the 5th-95th percentile range. The general message of table 2 is that it is favourable to observe more workers for a short period of time (a small number of repeated measurements).

Table 2. The number of 30 min periods that has to be observed to arrive at a specific value of the 5th-95th percentile range (10, 7.5, and 5) per 30 min period.

	5th-95th percentile range		
	10.0	7.5	5.0
Number of 30 min periods	Total number of 30 min periods		
2 periods	10	18	>30
4 periods	12	20	48
8 periods	16	24	64
16 periods	32	48	112

Discussion

The bootstrap procedure considers the collected data sample as a true representation of a population. It is crucial that this assumption of representativeness is met if results are used to establish an efficient measurement strategy for additional studies. In this study, workers were selected using a stratified sampling procedure in order to take into account a priori the most important sources of variation in exposure between individuals. Although these sources of variance were not further studied, we believe that the sample of workers were representative to a population of train stewards.

Observing more workers for a short period of time implied that a smaller total number of periods were required to obtain a certain precision. Appearently, in this study increasing the number of workers reduced variation of the group mean more effective compared to increasing the number of repeated measurements per worker. This suggests that the group mean is largely determined by between worker variation. Furthermore, this measurement strategy would have reduced costs and measurement efforts. However, the allocation of measurements is also influenced by practical considerations. For instance, it is convenient to switch between workers on the day of observation. However, in the present study, this was impossible because only one train steward worked at a time on a specific train.

In conclusion, the results of the present study illustrate the relationship between the measurement effort (number of workers and periods per worker) and the resulting precision of the group mean exposure. A measurement strategy prioritizing more workers rather than more periods per worker reduces the total number of periods necessary to obtain a certain precision.

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Can the ergonomic analysis of non-routinized work really be efficient?

Paquet, V [(1)], Punnett, L [(2)] Woskie, S [(2)]

[1.] *Department of Industrial Engineering, University at Buffalo, State University of New York, Buffalo, NY, USA, email: vpaquet@eng.buffalo.edu*

[2.] *Department of Work Environment, University of Massachusetts Lowell, Lowell, MA, USA, email: Laura_Punnett@uml.edu, Susan_Woskie@uml.edu*

Introduction

Reliable information about the physical requirements of work is needed for both epidemiologic study of ergonomic stressors and evaluation of ergonomic controls. While the ideal exposure assessments provide reliable and detailed exposure information for each participant in the study over a representative set of tasks, such assessments are rarely feasible due to financial and logistical considerations.

One way to reduce the amount of work associated with exposure assessment is to classify study participants into homogeneous exposure groups. Obtaining reliable measures of group exposures within occupations or tasks requires knowledge about how exposures vary across tasks, over time and among workers within a particular group. For jobs or tasks in which the sources of exposure variance are low, reliable exposure assessment may be achieved fairly quickly. However, in non-routinized work, for which the distribution of tasks performed by individuals of a particular occupation, as well as distribution of ergonomic exposures within task may be highly variable, multiple workers over long measurement periods may be necessary for reliable exposure measures.

Efficient data collection strategies are those that minimize the time and effort in data collection and analysis without jeopardizing the reliability of the data. The aim of this paper is to provide recommendations for the efficient assessment of physical ergonomic exposures in non-routinized work.

Methods

The results and discussion of this paper are based primarily on exposure data collected at large highway and tunnel construction project in which approximately 5800 observations were made with a discrete-interval observational sampling method known as PATH. This method requires observers to code the task, body postures, activities, loads handled and tool used (if any) for a single worker at specific instant in time over short but discrete time intervals (1). Exposure data were collected for 10 construction tasks performed by three trades (concrete reinforcement workers, carpenters and general laborers). For each task, measurements were made on multiple workers across multiple days to allow an evaluation of the inter- and intra-worker exposure variability across multiple exposures.

Data analysis included an analysis of exposure variability across tasks within trade, an evaluation of between-worker and within-worker exposure variability within task and simulation methods (i.e., bootstrapping) to evaluate the number of observation days required of a reliable estimate of exposure. A more detailed description of the methods has been reported previously (Paquet et al. 2000).

Results

Statistically significant differences in exposure frequency among tasks within were found in over one-half of the ergonomic exposures evaluated. The between-worker component of exposure variance was generally small when compared to the with-in worker (day-to-day) variance in exposure. These results demonstrate the value of using the task-based, rather than occupation-based exposure characterizations for non-routinized work settings.

As expected, the required observation time for a reliable group estimate of exposure depended on the day-to-day variability of exposure. Some tasks had little variability in exposure across days, but most were associated with a high degree of day-to-day variability. Simulations demonstrated that observation periods of at least 6 and as much as 10 days could greatly improve the reliability of the assessment in the "high" between day exposure variability cases (figure 1).

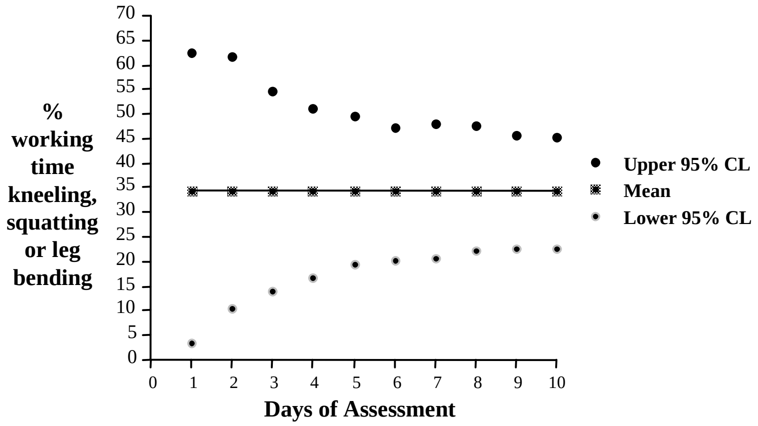

Figure 1. Group exposure frequency estimates for different observation periods. Results generated with a bootstrap analysis based on 1000 "resamples" of an exposure frequency estimate for a laborers' task (manual excavation) in which a total of 10 different workers were observed repeatedly on 10 different days.

This exposure had high day-to-day variability.

Discussion

Gathering reliable exposure information for multiple ergonomic stressors for a job or tasks within a job is a serious undertaking when there is great variability in exposure among people and over time. When these sources of variability are prominent, use of one-time observational checklists will be of little use unless used repeatedly on multiple workers across multiple days. Even when used repeatedly, observational checklists may not have enough sensitivity to detect small changes in exposure frequency or magnitude. Use of direct measurement instrumentation (e.g., accelerometry, electrogoniometry) under such circumstances may also be difficult to use when measuring large groups of workers over long time periods.

The use of discrete-interval observation methods allows a systematic characterization of exposure frequencies for different exposures across multiple workers over periods of days or weeks with very little interference with the work.

The advantage of measuring multiple exposures simultaneously, while efficient in some respects, is not in others. In order to obtain reliable estimates of exposure for all of the variables, the assessments should be designed to assess the exposure with the greatest variability and therefore exposures with little variability across workers and days are over-sampled.

Will ergonomic job analysis of non-routinized work ever be quick and easy? No, probably not. *However*, there are practical ways to enhance the efficiency of exposure assessment without jeopardizing the reliability of the analysis:

1) Carefully consider the exposures that could impact the health outcome of interest and limit the exposure assessment effort to only those exposures. When using "proven" methods of assessment, it may still be necessary to customize the method for the job of interest by adding or dropping exposure variables.
2) Evaluate exposure data periodically during data collection and drop the low exposure variability variables for which reliable estimates of exposure are obtained. With the increasing power of hand-held computers that can be used in exposure assessment, software can automatically evaluate the variability in exposure and drop variables with low exposure variability.
3) Because of the great time and effort required when evaluating ergonomic exposures in non-routinized work, it is critical to ensure that the assessment tool has sufficient sensitivity and that the evaluation strategy has enough precision to measure the desired effects before beginning the study. For epidemiologic research, this will require estimating the strength of association between the exposure and health outcome. For intervention research, this will require estimating the change in exposure frequency, duration and/or magnitude associated with the workplace change.

Acknowledgements

This work was supported by the National Institute for Occupational Safety and Health (NIOSH) through the Center to Protect Workers' Rights (CPWR) (Grant #s: UO2/CCU308771 and U02/CCU312014).

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Task-based estimation of exposure to work with elevated arms among car mechanics

Svendsen SW [(1)] Mathiassen SE [(2,3)] Bonde JP [(1)]

(1) Department of Occupational Medicine, Aarhus University Hospital, Denmark, e-mail: SWSVE.MAIL.AKH@aaa.dk,
[(2)] Division of Production Ergonomics, Faculty of Technology and Society, Malmö University, Sweden,
[(3)] National Institute for Working Life, Sweden

Introduction

It has been proposed that the efficiency and generalizability of job exposure assessment may be increased by combining information on the distribution of job tasks with estimates of corresponding task exposures (1). So far the performance of this approach has hardly been explored. The aim of the present investigation was to estimate the precision and accuracy of task-based assessment of exposure to work with elevated arms.

Methods

Upper arm elevation was measured during a whole working week for 23 subjects, randomly selected among 692 male car mechanics. Postural data were collected with a data logger and processed to give the percentage of worktime with the arms elevated more than 90^{o}. During the measurements the subjects filled in a diary with 12 pre-printed task categories. The task classification was based on expected arm postures according to four experienced car mechanics. Task exposures were determined as the mean of the individual weekly exposures within each task. Between-subjects and between-days variance components were assessed using a general linear model. Individual job exposures were estimated as the product of the relative task durations according to the diary and the corresponding task exposures. The accuracy and precision of the estimates were assessed by linear regression of estimated on ‘true’ weekly job exposures.

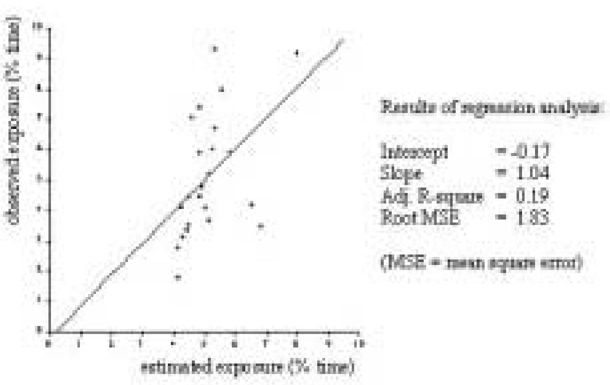
Results

Essential descriptive statistics for the most prevalent tasks and for the job are shown in table 1. At the group level, the accuracy of the task-based estimation was good as indicated by the fact that the regression line against ‘true’ exposures coincides with the identity line (figure 1). The task-based approach increased the precision of the exposure assessment by 9.9%, since it reduced the overall standard deviation between subjects from 2.03% to 1.83%.

Table 1. Data material, mean exposure and exposure variability in the job and for the most prevalent tasks among car mechanics. Var_{BS}, Var_{BD}: variance between subjects and between days (within subject), respectively.

Task	Subjects (days)	Minutes (fraction of total)	Proportion of time (%) with right arm elevated more than 90°		
			Mean	Var_{BS}	Var_{BD}
Suspension	16 (29)	3634 (0.08)	9.2	30.0	12.5
Brake pipes	18 (40)	3250 (0.07)	6.9	0.0	43.8
Brakes	20 (45)	4480 (0.10)	5.6	1.4	164.9
Engine room	23 (80)	9477 (0.20)	4.0	2.0	19.0
Wheels, tyres	19 (50)	3125 (0.07)	3.3	3.7	11.7
Break, test run	23 (105)	8776 (0.19)	2.7	0.0	188.7
Job	23 (107)	46791	5.2	2.9	5.3

Figure 1. Estimated versus observed weekly exposure to arm elevation above 90°. Scatterplot with regression line and results of regression analysis (n=23).



Discussion

Task-based exposure assessment requires exposure contrast between tasks, and each task must occur for a considerable part of the total working time. In this study the diaries were successfully constructed to meet these criteria (table 1). Additionally, it is required that the individuals have different task distributions. The dispersion of estimated job exposures shows that task distributions did vary among the car mechanics (figure 1). Considering costs, it may be favourable to obtain exposure estimates from external databases. In ergonomic intervention studies, the use of job exposure matrices is not an option because changes in exposure within a job must be detected. If the aim is to modify job exposures of individuals by altering their task distribution, it seems particularly attractive to link diary data with a task exposure data base. If task exposures are also affected, a combination of new direct measurements and diaries might be the most efficient strategy. Evidently, the optimal allocation of resources between direct measurements and diaries depends on the relative costs of the methods.

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Convergence of subjective and expert rating of demand and decision latitude at the work place – results from the Swedish WOLF study

HM Hasselhorn[1*], T Theorell[2,3], N Hammar[4,5], L Alfredsson[5], Westerholm P[6]
and the WOLF-Study Group

1) Department of Occupational Health, Univ. Wuppertal, Germany
2) Division of Psychosocial Fact. and Health, Karolinska Institutet, Sweden
3) National Institute for Psychosocial Factors and Health, Sweden
4) Inst. of Environmental Medicine, Karolinska Institutet, Sweden
5) Dept. of Epidemiology, Karolinska Hospital, Sweden
6) National Institute for Working Life, Stockholm, Sweden

Hans-Martin Hasselhorn, MD,
FB 14 - Department of Occupational Medicine; University of Wuppertal; Gauss-Str. 20; D - 42097 Wuppertal; Germany; email: hans-martin.hasselhorn@arbmed.uni-wuppertal.de

Introduction

In recent years the call for 'objective' assessment methods in work stress research has increased. By this the problem of self-report biases should be avoided. In addition, 'objective' assessment should help to disentangle whether the 'real working condition' or merely its 'perception' is associated with ill health.

Aim

In this investigation it was examined to which extent the expertise of occupational health personnel could be used to evaluate psychological demands and decision latitude (the central components of the job strain model) among blue and white collar workers. The study was carried out within the frame of the Swedish WOLF Study which investigates the relationship of psychosocial job characteristics to risk factors of coronary heart disease.

Materials and Methods

Psychological demands and decision latitude were assessed for 3807 work places in 16 companies in the Stockholm area by the workers themselves (self-report questionnaire) and by occupational health personnel (questionnaire). Convergence was calculated on individual as well as aggregated level.

Results

While experts rated higher scores for demands than for decision latitude the opposite was the case for subjective ratings. Experts tended to use a wider range of possible answers. A high degree of convergence was found for decision latitude, especially for male blue collar workers. For demands, however, convergence was low or absent.

Table 1: Bivariate correlation coefficients (r) for subjective and external ratings of demands and decision latitude (p<.05 if not marked otherwise, ns = not significant)

	R age 19-44	R age 45-54	r age 55-66	r all
Demands				
Men, all	.14	.23	.30	.19
Blue collar	.08	.25	.29	.17
White collar	.10	.10	.17	.11
Women, all	.12	.19	.16	.14
Blue collar	.20	.14 (ns)	.28 (ns)	.17
White collar	.06 (ns)	.11	.24	.10
Decision latitude				
Men, all	.58	.53	.51	.56
Blue collar	.56	.45	.51	.53
White collar	.29	.13	.07 (ns)	.22
Women, all	.47	.47	.45	.47
Blue collar	.35	.37	-.20 (ns)	.35
White collar	.20	.24	.28	.22

Discussion

This study suggests that expert rating by local occupational health personnel might be an applicable method of assessing certain psychosocial job characteristics (such as decision latitude) but not for others (demands). The strong correlation for external and subjective decision latitude scores particularly for blue collar workers indicates the potential importance of improving objective conditions since this is likely to improve perceived conditions as well. In further investigations the external evaluation method using occupational health personnel should be refined. Furthermore, objective health outcomes should be investigated in relation to subjective and ‘objective’ assessments.

Occupation-specific versus general self-report measures to assess psychosocial workplace exposures — dilemmas and potential solutions to bridge the gap

Karen Belkić [1]

[1] *M.D., PhD, Adjunct Associate Professor of Preventive Medicine Institute for Health Promotion and Disease Prevention Research, University of Southern California School of Medicine and The Center for Social Epidemiology, Santa Monica, California*

It is indisputable that etiologic research demonstrating the relationship between psychosocial workplace stressors, most notably, Job Strain and its major dimensions, and a number of key health outcomes, would not have been possible without generic instruments to measure these exposures. The very success of this line of research, coupled with the global trends towards a deterioration in working conditions, obliges us to sharpen our tools, so that efforts to protect working people against these deleterious job exposures are maximally effective. Complementary to constructs such as the Job Strain Model (JSM) and Effort-Reward Imbalance, that are based heavily upon sociological theory, are approaches derived from cognitive ergonomics and brain research. These help describe, in more quantitative terms, the burden of work processes upon the central nervous system (CNS). Thus, e.g., when speaking of psychologically demanding work, we can go far beyond queries about "working hard" and "working fast", to analyze tasks in terms of allocation of mental resources. As formulated in many of the most widely used psychometric instruments, the dimension of psychologically demanding work has often been mired with problems of report bias (both over-report and denial), and insufficient internal consistency. The psychological demand dimension of the JSM has not proven to be as robust a predictor of cardiovascular disease (CVD) outcomes as the control dimension. On that basis, some have even called into question the validity of the JSM itself. However, from the vantage point of cognitive ergonomics, the indelible coupling between these two dimensions becomes eminently clear: with sufficient decision-latitude, or control, a worker can modulate even a fairly onerous, ***though not overwhelming***, psychological workload to meet his or her moment-to-moment needs and capacities. Within this framework, the imperative to define and guard against exposure to overwhelming psychological demands becomes that much greater.

In the Occupational Stress Index (OSI), an additive burden model, we have sought to delineate work stressors relevant to the CV system, including psychological demands, in terms of how the CNS receives and processes information. Thus, we consider objective factors such as the nature and temporal density of incoming signals, the complexity and speed with which these are processed, *inter alia*, as well as how much control the worker has in modulating these, and other, demanding factors. Taking this approach, the demand dimension of the generic OSI has shown excellent psychometric properties (Cronbach α=0.80).

However, generic questionnaires have a common weakness in their remoteness from actual work experiences, and therefore, are often not helpful for assessing ***within-occupation*** variance, the very level at which intervention strategies are developed, in practice. The generic or General OSI is no exception. On the other hand, the General OSI, having been designed identify objective features of work, can be a bridge to the next step in the application of the OSI. Namely, General OSI data from workers in a single occupation can be used as the first phase for developing an occupation-specific questionnaire. Qualitative data from workers willing to put in the extra time to comment and explain their answers to the General OSI in relation to their actual work environment proves to be invaluable. This process is facilitated by a number of open-ended questions. Expert observers can also be of great help. Once developed, these occupation-specific OSI allow us to omit questions about the fixed aspects of a given line of work and to concentrate upon the variable features. The specific OSI's would all be compatible with the General OSI, allowing between-occupation comparisons, but would be far more operationalized and streamlined. Specific OSI are being designed for a broad range of occupational endeavor—from industrial, transport, to clerical and other white-collar sectors. Thus far, the OSI for professional drivers has been validated and widely tested, OSI for physicians and for those who work daily with computers are in the final phase of piloting, and OSI for teachers, production workers, clerical workers, air traffic controllers and for airline pilots are being developed.

Our experience with the OSI for professional drivers (OSI-PD), a group at very high risk for hypertension and CVD, illustrates these points. The OSI-PD is about half the length of the General OSI, and the questions are concrete and germane to this occupational group. We first identified the constant features, e.g. the need to make and carry out rapid, non-deferrable, but somewhat automatic decisions (a combination of decision-making under-load and high demand), no possibility of ignoring incoming signals (strictness on the input level), no chance to influence the rate at which new signals are received (extrinsic time pressure on the input level). These and other factors contribute to the high demand and low control of PD, but because they are invariant, queries in this regard would be superfluous. Furthermore, PD epitomizes threat-avoidant vigilant activity, with potentially fatal consequences from a momentary lapse or even slight judgment error. Again, no need to ask about this. We then operationalized the variable features in relation to the traffic environment: road and vehicle conditions, type of routes, passengers, accidents, as well as work schedules, time table stringency, rest breaks, etc. These queries are presented in a neutral way, to minimize reporting bias. Here are some examples how this was done for elements of input high demand versus under-load: Frequency of incoming signals is scored by where driving predominantly takes place--within the city signifies rapid incoming signal speed (high demand), while driving mainly on long, inter-city routes is scored as low frequency of incoming signals (under-load). Heterogeneous signals (high demand) are encountered when driving on various routes, while with driving on the same route day after day, relatively homogeneous signals are seen (under-load). The OSI-PD has now been completed by 327 professional drivers. PD tell us that the questionnaire is easy to fill out, and it takes only a few minutes for them to do so. The Cronbach alpha for the total OSI-PD (variable features only) is 0.84. Between-group analyses reveal that PD have approximately twice the mean total OSI scores compared to heterogeneous groups of workers of similar socio-economic status ($p<0.001$). In contrast to non-significant results obtained using the Demand-Control Questionnaire, the total psychological demand scores using OSI-PD were nearly three times higher ($p<0.001$) compared to the referents. The total demand levels of various PD sub-groups were also clearly distinguished (city bus > truck drivers, $p<0.001$), and the nature of these demands could be delineated for each sub-group. The total OSI-PD scores significantly and independently predicted smoking intensity, indicating within-occupation criterion validity of this instrument. Pressure to stay on schedule and long work hours were identified as key modifiable stressors.

The OSI for physicians (OSI-MD) has been applied among 12 of our colleagues from various clinical specialties. Initial analyses suggest adequate variance and good face validity. Mean total OSI-MD scores are high (approximately at the levels of PD), and the demand levels about 1.5 times > than among PD. We contextualized the OSI-MD as "by physicians for physicians" within the framework of a "participatory action research" approach. This point is emphasized here because of the pivotal position of physicians with respect to the work environment and health outcomes. Namely, physicians are often called upon to make decisions about fitness for work, and can potentially have an impact upon patients' working conditions by making informed recommendations. At the same time, physicians increasingly face an infringement of decision-making latitude, increased demands, etc., especially within the context of managed care. The underlying burden of the work of physicians is a heavy one. Documenting and quantifying this burden is important for many reasons. As an empowerment tool for physicians, we hope this will help efforts to improve the working conditions of our own profession. We also hope that this process can be translated into better insight by physicians into the working conditions of patients. The response of our colleagues during pilot testing has been very positive and we are grateful for the time they have taken to provide invaluable insights into their working life, and how it might be improved.

It is a great and labor-intensive challenge to develop a set of occupation-specific instruments to assess work stressors, within a theory-based framework, and from which between-group, as well as within-group, analyses can be made. Many dilemmas remain. A major limitation of the current application of the OSI has been the linear nature of the analyses that have been performed. There is a need to explore possibilities for multiplicative interactions and higher-level terms, especially in relation to well-established models, such as the JSM. Eventually, weighting factors might be developed to reflect the relative contribution of the various factors to the total burden. Integration could be performed with work-site measurements (part of triangulation). For example, for city bus drivers there could be finer gradations to the scoring of high frequency of incoming signals based upon traffic density measures, and data on average number of passengers could improve quantification of the burden of communicating with the public. Information obtained from expert-observer assessment of job characteristics, could be very well integrated with the OSI. On the other hand, the OSI could detect areas for which in-depth observational analysis is needed, especially with the view to practical improvements in the work environment.

Objective and subjective assessments of the psychosocial work environment

Töres Theorell

National Institute for Psychosocial Factors and Health and Department of Public Health Sciences, Karolinska Institutet, Stockholm

The debate regarding the relative importance of subjective and objective aspects of the psychosocial work environment has important implications for policy. If it is the individual´s perception that is more important, the individuals´ ways of handling difficulties will be the target of action whereas if the objective condition is more important, it should be the external conditions that ought to be the target. Neither objective nor subjective assessments can be said to represent the "truth". Both represent different parts of reality and both are plagued by assessment problems. Evidence indicates that combinations of self reports and more objective assessments may be particularly useful in predictions of health related outcomes (1).

Problems with self reports are for instance that denial and alexithymia individually or collectively may lead to underestimation of the importance of a factor. Negative affectivity and similar person characteristics, on the other hand, may lead to overestimation of the importance of a factor.

The more objective assessments rely either on experts who observe the work sites by means of standardised methods or on occupation subgroup means (defined by means of occupation, gender, age and duration in occupation) based upon surveys of subjects in a variety of occupations. There will always be conditions specific to the environment of the individual worker that such assessments will not be able to assess. This leads to meaurement error that could be systematic (causing bias in results) or random (decreasing the power of the predictions).

For global standard dimensions the concordance between self reported, imputed and expert rated psychosocial conditions are quite different for different kinds of dimensions. For instance, psychological demands show a very low concordance between self ratings on one hand and imputed scores and expert ratings on the other hand (2). For decision latitude the concordance between these three methods of assessment is much better and similar excess levels of morbidity have been shown regardless of whether self reports or more objective measures are used (Whitehall and SHEEP studies).

That denial in self reports could be a serious assessment problem has been shown in bus drivers – a correlation has been shown between objectively assessed psychosocial working conditions on one hand and elevated blood pressure on the other hand (5) whereas correlations between self rated conditions and blood pressure levels have been in the opposite direction in the same study groups (6).

As will be shown by Belkic there is also another aspect of the objective/subjective discussion. Several aspects of the psychosocial environment not discussed so far could be addressed by means of self reports. In the measurement system, OSI, introduced by Belkic, more detailed aspects of the objective psychosocial environment are explored such as number of incoming inputs, noise level and availability of resources. These measures are integrated in a model of stressors which include both objective and subjective aspects.

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An overview of analytical and sampling approaches for bioaerosols

Burge H[(1)]

[(1)] *Harvard School of Public Health, Boston MA, USA, hburge@hsph.harvard.edu*

Bioaerosols have become of increasing interest to the public health community. Existing measurement data remain difficult to interpret because a multitude of sampling and analytical approaches are used, and data are interpreted subjectively. This workshop is designed to assess the latest approaches and to stimulate discussion about their advantages and disadvantages. This short introduction is meant to provide a structural framework for our discussions.

General categories of the types of analyses that are commonly used include assays for living organisms, recognizable particles, allergens, structural components, and DNA sequences. Some of these measure actual agents of disease (immunoassays, toxin assays, culture of pathogens); others are indicator measurements (Table 1)

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Table 1:	Living organisms	Recognized particles	Assays for toxins or allergens	Structural components	DNA sequences	Biosensors
Indicators for :	Infective potential	Specific and groups of large organisms	Specific agents of disease	Biomass of large fungal groups	Presence, absence of very specific organisms or small groups	Presence, absence of specific indicator compounds
Best sampling approach for air	Culture plate impactors	Microscopy slide or tape impactors	Filtration	Filtration	Filtration	Real time sensors, flow cytometry

Sampling approaches are usually chosen based on compatibility with analytical method, and on available equipment. However the following are considerations that should be made for each sampling project:

(1) A focus on the disease agent of concern is essential. Disease agent assays that are commonly used are the immunoassays used for allergen analysis. These assays are usually applied to dust and need to be improved for greater sensitivity to allow air sampling.

(2) Upper and lower limits of detection coupled with estimates of environmental concentration must be considered. The Andersen culture plate impactor is often used in situations where concentrations are either too low to allow collection of enough units to accurately represent the aerosol (i.e., >10 colonies per plate), or where concentrations are too high (e.g., >50-100 colonies per plate depending on organisms).

(3) A decision needs to be made whether continuous or grab samples will best test the hypothesis. If peak exposures are of interest, then time-descriminating continuous sampling (as is possible with the Hirst-type spore traps) may be appropriate. If exposures over a finite period of time are important, then a series of grab samples may work. If 24 hour averages are adequate, then filtration sampling may best approximate exposure. However, each of these approaches needs to be balanced with points 1 and 2 above.

(4) Often ignored is an initial consideration of the numbers of samples to be collected and level of effort required for analysis. In case studies, only one or two samples may be collected, resulting in inadequate data for interpretation. In large epidemiological

studies, very large numbers of samples requiring thousands of hours of skilled technician time may become a significant problem.

(5) Finally, and most important, data are not useful if they cannot be interpreted. For research, experimental design should always include data interpretation plans. For case studies, either the study design must match that required for research, or methods should be used for which good baseline data are available.

(6) In research situations, samples collected by methods for which no baseline data exist may be impossible to interpret.

We are often tempted to think that a new analytical approach will solve the problems inherent in bioaerosol exposure assessment. However, it should be obvious that no one sampling or analytical approach will ever be appropriate for "bioaerosol" monitoring. It is our task to make this clear to the air quality community, and to continue to refine existing methods as well as to develop new ones. Development of new methods must not focus simply on ease and repeatability. Hypothesis testing should be the emphasis for exposure assessment, and method development should focus on providing data to most accurately test these hypotheses.

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Efficacy of measurement methods for airborne levels of non-infectious micro-organisms in uncovering exposure-response associations in epidemiological studies – a review

Wijnand Eduard

Department of Occupational Hygiene, National Institute of Occupational Health, Oslo, Norway, e-mail: wijnand.eduard@stami.no

Introduction

Airborne levels micro-organisms have traditionally been measured by culture-based methods although light microscopy has been used to some extend. Culture-based methods are suitable for the detection of infectious agents as species can be identified and only viable organisms are detected. For infectious agents type and viability is crucial.

In studies of non-infectious effects of micro-organisms such as chronic bronchitis, asthma, and inhalation fever, culture-based methods are probably less useful. Non-infectious effects can develop after exposure to nonviable micro-organisms, and these organisms, which may represent a major part of the exposure, are not detected by culture-based methods. As the proportion of culturable micro-organisms is also highly variable, culture-based methods are assumed to give poor estimates of relevant exposure to non-infectious micro-organisms (4).

During the last 15 years several non-cultural methods have been developed for the quantification of airborne micro-organisms. Micro-organisms have been counted by fluorescence microscopy (8), scanning electron microscopy (3) and flow cytometry (6). Markers of micro-organisms have been determined by enzyme immuno-assays (10) and gas-chromatography-mass spectrometry (7).

Although these methods should be expected to provide more valid exposure estimates than culture-based methods, their validity may also depend the ability to differentiate between species. For specific responses as atopic astma and rhinitis, and hypersensitivity pneumonitis, the species of micro-organism is important. For non-specific responses as non-atopic astma and bronchitis and inhalation fever, however, this is less clear. Experimental studies have shown that species may have different toxicity (2,9,1,5), but this still has to be shown in human studies. It is therefore not certain that nonculture-based methods should be preferred to culture-based methods, especially when specific effects are involved.

The literature will be searched for epidemiological studies where exposure-response associations have been demonstrated for airborne micro-organisms.

The results will be presented at the conference.

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Development and application of advanced measurement and modelling techniques to assess the exposure of patients and health workers to hospital acquired infection

Beswick, A J [(1)], Crook, B [(1)], Stagg, S [(1)], Biegon, D [(1)]

[(1)] *The Health and Safety Laboratory, Broad Lane, Sheffield, S3 7HQ, UK,*
email: alan.beswick@hsl.gov.uk

Introduction

Recent data indicated that the incidence of hospital acquired infection (HAI) in nineteen UK hospitals was between 1 and 7.2% (1), with 5,000 people affected each year in the UK (2). Total HAI in England alone costs the National Health Service ~£1 billion for every 100,000 cases treated (2). HAI is therefore an issue of increasing concern for both the NHS and Government departments such as the Health and Safety Executive. HAI affects patients and also places clinical staff at risk. To reduce risks, methods are needed to identify and control the hazards posed by HAI. This study aims to apply occupational hygiene assessment, advanced microbiological detection techniques and mathematical modelling of bioaerosol transportation to study the airborne route of infection. Hospital bronchoscopy suites have been chosen as a model system to evaluate these techniques.

The core aim of the project is to identify practical methods by which identified risks of airborne infection can be reduced, both by analysing scientific data and by analysis of working practise reports compiled by an occupational hygienist.

Materials and methods

Occupational hygiene (OH) data is being used to complement scientific data generated from computational fluid dynamics (CFD) and aerobiology. The OH information is collected during discussion with key personnel in the surveyed units and by observations of their working practices. Key considerations include:

- Determination of likelihood of exposure, i.e. where are people in relation to any contaminant and what are they doing?
- Extent of exposure, i.e. residence time, length of exposure time, frequency, methods of work, pattern of work
- Assessment of the control measures, including management, working practices, engineering controls and use of personal protective equipment.

For bioaerosol sampling, unobtrusive equipment is necessary for sampling of the hospital environment and for personal sampling of staff involved in procedures. Six IOM personal samplers, an RCS sampler and a Burkard Cyclone sampler were chosen to provide material for culture-based microbial characterisation and for DNA-based detection. The DNA-based work includes microbial detection using the polymerase chain reaction (PCR). Samples will ultimately be obtained from several hospital locations prior to and during procedural activity. Exposure comparisons of microbial levels will then be possible between different hospital facilities.

A commercial CFD code is being used to construct a model of flow and contaminant paths throughout the spaces of interest. These typically comprise treatment areas and interconnecting spaces such as preparation/waiting rooms. The space are subdivided into a large (some hundreds of thousands) number of grid cells which will resolve the main geometrical features, such as treatment tables and fixed items of equipment. The presence of staff and patients can also be included, but these will be represented as stationary elements. Following the analysis of routes for airborne contamination identified above, the validated CFD model will then be used as a predictive tool to examine alternative working methods aimed at improving the general control of infectious agents.

Results and discussion

Air samples, OH assessment and ventilation measurements were obtained from one hospital site just prior to a major ventilation overhaul. Sampling and ventilation measurements were then repeated after maintenance completion to allow comparison and the assessment of any effect following maintenance ‘intervention’. Airflow measurements taken prior to maintenance established that the bronchoscopy room was at positive pressure compared with all surrounding areas. This increases the likelihood of microbial spread from any infective patients to nearby public corridors. A nearby toilet is also at positive pressure compared with an adjacent public corridor, and since that this problem has been identified it is under review by hospital engineers.

The range of total airborne bacteria counted by direct microscopy was in the order of 10^5 – 10^6 m^{-3} air for personal IOM samples, with a similar range for background samples obtained with static IOM samplers. The highest individual count (6×10^6 microorganisms m^{-3} air) was obtained from a personal sampler. A background Burkard sampler gave total direct counts of between 10^3 and 10^4 microorganisms m^{-3} air. Colonies grown on either Nutrient Agar or Blood Agar have included *Staphylococcus epidermidis*, *Staphylococcus caprae*, *Acinetobacter* spp. and *Streptococcus bovis*. Staff exposure during procedures has varied considerably between the clinics so far assessed. Short clinics have lasted for as little as 1 hour, with longer exposure times of 3.5 hours for a busy clinic. DNA was extracted from a number of representative samples obtained over 4 clinics and will be subjected to PCR amplification to target the bacterial 16S rRNA gene, with PCR-cloning of the products allowing culture independent identification of bacterial populations within hospital samples. This detection approach includes those species which may not grow on artificial media (3).

This study demonstrates the potential value of supplementing conventional bioaerosol measurement and microbiological analysis with more recently developed DNA-based methods. The study provides a valuable combination of aerobiology along side OH assessment and workspace modelling.

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Characteristics of a new personal sampler for collection of airborne spores

Reponen T, Grinshpun S A, Górny R L, Aizenberg V A, Wang Z, Willeke K

Department of Environmental Health, University of Cincinnati, Cincinnati, USA,
e-mail: Tiina.Reponen@uc.edu

Introduction

Most of the commercially available bioaerosol samplers have been developed as stationary devices (not as personal samplers). The Button Aerosol Sampler (SKC Inc., Eighty-Four, PA, USA) has previously been evaluated for stationary and personal sampling. The tests conducted with non-biological particles have shown that its sampling efficiency follows closely the inhalability convention (1). It has also been shown to feature low transmission losses and low sensitivity to the wind direction and velocity. In this study, the performance of the Button Sampler was tested for the total and viable enumeration of airborne microorganisms and compared to that of the standard 37-mm filter cassette, the Burkard sampler, and the Air-O-Cell sampler.

Methods

Test particles included inert PSL particles (aerodynamic diameter, da = 0.44-5.10 µm), fungal spores (*Cladosporium cladosporioides,* d_a = 1.78 µm; *Aspergillus versicolor,* d_a = 2.40 µm; *Penicillium brevicompactum,* d_a = 2.34 µm; *Penicillium melinii,* d_a = 3.07 µm), bacterial spores (*Streptomyces albus,* d_a = 0.84 µm *Bacillus subtilis,* d_a = 0.90 µm), and bacterial vegetative cells (*Pseudomonas fluorescens,* d_a = 0.80 µm; *Serratia marcescens,* d_a = 1.0 µm). Test particles were aerosolized under controlled laboratory conditions using the experimental facility described by Aizenberg et al. (2). The aerodynamic size of the test particles was measured with an aerodynamic particle size spectrometer (Aerosizer, model API Mach II; TSI-Amherst Process Instruments, Inc., Hadley, MA, USA).

The Burkard and Air-O-Cell are glass-slide impactors, whereas the Button Sampler and the 37-mm cassette collect particles on filters. Most of the tests with the two filter samplers were performed using polycarbonate filters (0.2 µm pore size; Millipore Co., MA, USA). Selected tests were conducted using gelatin filters (2 µm pore size, Sartorius, Germany). A Grimm optical particle counter (model 1.108; Grimm Technologies Inc., Douglasville, GA) was used to determine the physical collection efficiency of the Button, the Burkard, and the Air-O-Cell samplers by measuring the concentration of particles upstream and downstream of the samplers.

The culturability of microorganisms was tested at two relative humidities, RH=30% and 85% using the Button Sampler and the 37-mm cassette. After challenging the filters with microorganisms, air was drawn through the samplers for a period ranging from 2 minutes to 8 hours. Then, microorganisms were analyzed according to a modified CAMNEA method, involving extraction of microorganisms by vortexing and ultrasonic agitation of the filters. This method was found to extract the microorganisms with 96-98% efficiency. The extraction suspension was analyzed by cultivating to get the culturable count, and by epifluorescence microscopic counting to get the total count of microorganisms. The relative culturability was calculated by dividing the culturability (culturable count/total count) of microorganisms in the extraction suspension by the original culturability of microorganisms before aerosolization.

Results and discussion

The physical collection efficiency of the Button Sampler was close to 100% for the entire tested particle size range (0.44 – 5.10 µm). The cut-off size of the Burkard and the Air-O-Cell samplers was 2.3-2.4 µm. This difference in the physical collection efficiency affected the total count results: the filter sampling gave higher total counts for smaller microorganisms (*B. subtilis, S. albus, C. cladosporioides*) than the two impactors. For larger microorganisms (*P. brevicompactum* and *P. melinii)* all the samplers gave comparable results. The uniformity of particle deposit on the collection surface was highest for the Button Sampler, see Table 1.

Table 1. The ratios of highest-to-lowest average microscopic counts and coefficients of variation of microscopic counts obtained at specific locations on sampling surfaces of the Button, Burkard, and the Air-O-Cell samplers.

Sampler	Ratio of highest-to-lowest counts	CV, %
Button	1.42	9.5
Burkard	5.36	31
Air-O-Cell	13.41	19

There was no significant difference in the microbial culturability collected with the Button Sampler and the 37-mm cassette. The culturability varied from 89 to 40% for *P. melinii* and from 94 to 63% for *A. versicolor* when sampling for 30 minutes to 8 hours (see Figure 1A). No significant difference in relative culturability was found for these species when the humidity increased from 30% to 85%. *P. fluorescens* and *S. marcescens* vegetative cells were culturable only at RH=85%, when the sampling time did not exceed 10 minutes. Their culturability in this case was about 3%. The culturability of *B. subtilis* decreased from 17% to 5% when the sampling time was increased from 2 minutes to 4 hours at RH=30% (see Figure 1B). At RH=85%, the culturability of *B. subtilis* increased by about 15% compared to that at RH=30%. Selected tests with *B. subtilis* spores were conducted to compare the culturability after collection on polycarbonate and gelatin filters. When *B. subtilis* spores were collected for 30 min at RH=30%, the relative culturability was 10% with polycarbonate filters and increased to 55% with gelatin filters.

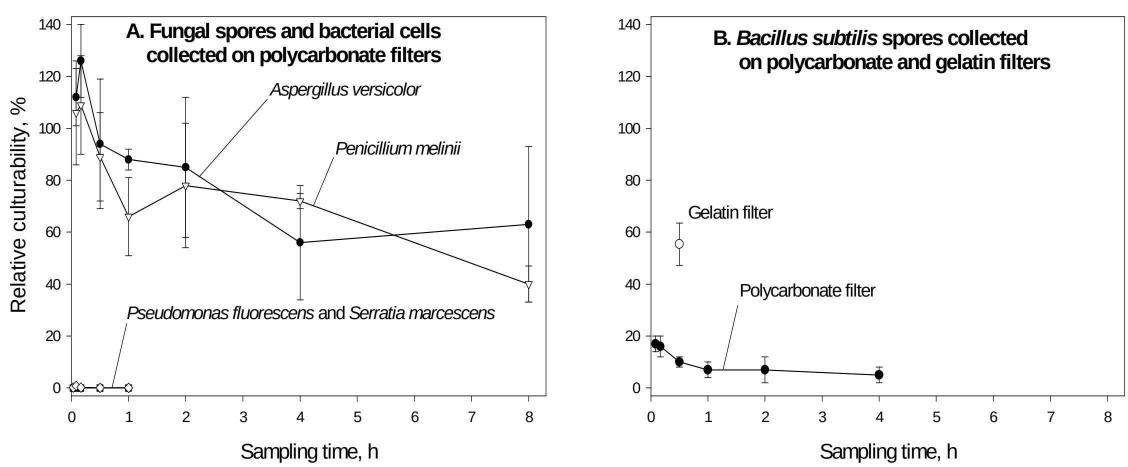

Figure 1. Effect of sampling time on the relative culturability of microorganisms when collected with the Button Sampler at a relative humidity of 30%.

Conclusions

In contrast to impactors, high physical sampling efficiency is achievable with the filter sampling for wide size range of microorganisms if an appropriate filter is used. The uniformity of particle deposit on the collection surface among the tested samplers is highest for the Button Sampler. This is especially advantageous when performing direct microscopic counting from the collection surface.

The type of microorganism is the most important factor influencing the bioefficiency of filter samplers. Vegetative cells lose their culturability during traditional filter sampling due to desiccation of the cells. The Button Sampler was found to be suitable for the total enumeration of airborne microorganisms and for viable enumeration of resistant spores.

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Can exposure be assessed? Guidance to evaluating feasibility from a multi-country cancer mortality study

Rice, C [(1)], Rosenman, K [(2)]

(1) Department of Environmental Health, University of Cincinnati, Cincinnati OH, USA, e-mail alerdilr@uc.edu
(2) Kenneth Rosenman, Department of Medicine, College of Human Medicine,Michigan State University, East Lansing, MI, USA, e-mail rosenman@pilot.msu.edu

Introduction

In order to evaluate the possible approaches to exposure assessment in occupational epidemiology, feasibility studies are often undertaken. This involves a review of available resources to understand plant processes over time, materials changes, implementation of various exposure control strategies and results of often-variable air sampling and analysis methods. The accumulation and evaluation of such information is even more challenging when multiple plant sites are involved; in the global market place, multiple plant sites will increasingly be located in different countries. The experience gained conducting one such multi-country feasibility study is reviewed, and general guidelines offered for the types of resources that should be evaluated.

Methods

The work was undertaken to evaluate the feasibility of conducting a mortality study of workers at four manufacturing sites—two in the United States, one in a European country with English was the major language, and one in a country where English was spoken by few production or management personnel. Prior to site visits at each location, plant personnel were asked to prepare materials to introduce the study team to the operational history of the facility, arrange for key personnel from various functions to be available (e.g., human resources, worker representative, health and safety, medical, production management, research/development, maintenance), identify the location of air sampling records and retrieve representative reports, and invite long-term workers to a discussion session.

Structured record forms were developed to record the information obtained during the interviews of various personnel. Management representatives were asked about record content and retention schedules, air sampling protocols and records, and implementation of capital improvements which may have altered production or emissions; production employees were asked out physical layout, staffing at each work station, job titles, tasks, perceived exposure intensity, engineering controls and product changes. Whenever possible, applicable years were recorded.

The results of the information collected were summarized, and reviewed for similarities and completeness.

Results

Production started at the facilities in 1942, 1960, 1966 and 1969. During the site visits substantial information on exposure was located. The average duration between plant start-up and exposure measurements was 6 years (range 0-11). In the early years, reports indicated that more samples had been collected than could now be documented; for example, the annual report summarizing quarterly sampling was found, but the individual reports were not retrievable. No only were paper records lost; at one facility, years of computerized data were no longer retrievable, although a hard copy printout of some years had been retained. Loss of industrial hygiene data was documented at three of the four facilities. The complete retention of measurement data was initiated in 1975 t 1986, depending upon the location. In addition to the plant location, other potential sources of historical information included corporate headquarters (U.S. and European) and the U.S. Archives, as one facility was in operation during WWII; these leads were not followed as part of the feasibility evaluation.

At one location, production had ceased, and the equipment was slated to be dismantled and removed. Strong recommendation was made to photograph the interior and exterior, showing the layout of the equipment and control systems. Retention of engineering drawings and production records was also recommended pending decision on the mortality study.

Long-term employees were willing to provide insights into plant operation over time at each location. At three facilities, multiple workers were interviewed separately; at the facility where a translator was needed, only one worker was interviewed. All recalled specifics of the jobs held at the facility; those who were asked to draw the layout of the plant during early operations were able to show where equipment was placed and to list the number of workers at specific workstations. The tasks included in jobs were easily listed and the frequency or duration of the task in the work shift was recalled. Several workers were asked to rate the intensity of exposure for the various tasks; across facilities, the same tasks were identified as associated with the most intense exposure. Changes in product formulation were also reported during the interviews; when asked to rank the perceived hazard of working with the various products, the reported "most pungent" material was consistently identified.

Discussion

The use of standardized tools for the recording of information was essential in order to compare the quality and extent of available resources. By listing the types of information on sampling data forms, and the rate at which each element was completed, differences in sampling instrumentation or analytical method could be documented. We recognized the need to identify long-term employees with good recall of a number of aspects of operations throughout the history of the facility, namely plant layout and staffing, production process, product types, job descriptions and component tasks, exposure surveillance, implementation of exposure controls, use of exposure controls and perceptions of exposure intensity. In a feasibility study it is not possible to ask all questions of each participant; however, by interviewing several workers and covering two or more of the issues, we were able to collect sufficient information to describe each plant and evaluate the consistency of the reports. In the full study, substantial emphasis could be placed on evaluating the accuracy and reliability of elements included in the institutional history. Where engineering plans are not available, multiple, independent interviews can be used to evaluate reliability.

Sampling data at three of the facilities included at least one other possible carcinogen. Because these exposures could contribute independently or as a mixture to the overall mortality, these data were reviewed. Potential methods to extend this more limited data set could be considered. For example, one could develop criteria to evaluate the applicability of data at one plant to exposures at another facility; the relation between the concentration of the main exposure of interest and a second carcinogen could be investigated and if found to be consistent for a number of situations, the ratio could be used to impute exposure estimates.

The quality of demographic, life-style and work history information has not been described here, but was included in the feasibility study. In addition, the ability to trace previous employees and determine cause of death was also determined. The final decision on feasibility of the study encompasses all of these data elements.

Conclusions

The collection of plant history and process information in a standardized format allows investigators to elicit necessary information and evaluate the feasibility of assessing exposure in an occupational epidemiology study. General guidelines for data collection/review in multiple-location studies are developed from this effort. The quality and quantity of exposure measurements can then be considered in order to determine the type(s) of exposure metrics that can be calculated; these range from exposed/unexposed to quantitative estimates of exposure.

Validity of empirical models of exposure in asphalt paving

Burstyn I [1,2], Boffetta P [2], Burr G [3], Cenni A [4], Knecht U [5], Sciarra G [4], Kromhout H [1]

(1) Environmental and Occupational Health Group, Institute for Risk Assessment Sciences, Utrecht University, Wageningen, The Netherlands, e-mail: I.Burstyn@vet.uu.nl;
(2) Unit of Environmental Cancer Epidemiology, International Agency for Research on Cancer, Lyon, France;
(3) The National Institute for Occupational Safety and Health, Ohio, USA;
(4) Operative Unit of Industrial Hygiene -- National Health Service, Sienna, Italy;
(5) Institute of Occupational and Social Medicine, Giessen, Germany.

Introduction

The International Agency for Research on Cancer is co-ordinating a multicentric investigation of cancer among asphalt workers in order to address the controversy surrounding carcinogenicity of bitumen, binder used in asphalt mixes. The study is an industry-based historical cohort assembled in Denmark, Finland, France, Germany, the Netherlands, Norway, Sweden and Israel. Coal tar use has been progressively discontinued in Western Europe, resulting in the possibility to disentangle any effects of its exposure from that of bitumen. In occupational epidemiology the quality of studies and their subsequent usefulness for risk assessors and regulators increasingly depends on the validity of their exposure assessment. This study focused on the issue of validation of exposure models for asphalt paving workers, the most numerous bitumen-exposed group in the historical cohort study of bitumen.

Methods

The mixed effects models evaluated in this paper have been described in detail elsewhere (1). They revealed a declining (6 to 14 percent per year) trend in exposures to bitumen fume, organic vapour and benzo(a)pyrene with time. Furthermore, differences in exposure levels were observed between different methods of paving. Coal tar use was demonstrated to be the most important predictor of benzo(a)pyrene exposure, but the magnitude of this effect was somewhat less than that expected on the basis of laboratory studies. The differences in sampling and analytical methods were accounted for. There were no differences between comparable paving operations among countries.

Internal validity of the models was assessed in a cross-validation procedure. This was accomplished by evaluating the models' parameters on random subsets of 50 percent of the data. At each evaluation, predictions of the models were compared to the remaining 50 percent of the data by estimating bias and precision of the models. Bias was defined as the mean difference between predicted and measured values on logarithmic scale; precision was defined as the standard deviation of bias. Relative bias was estimated as ((predicted value-measured value)/measured value)×100%. In cross-validation, both bias and precision were estimated on a logarithmic scale, since they appeared to follow log-normal distribution in histograms (i.e. natural logarithms of predicted and observed values were compared). We ran 300 evaluations for each model.

In addition, two of the models were validated against external data on bitumen fume exposure obtained from the United States (n=98), and benzo(a)pyrene exposure measurements obtained Germany and Italy (n=339). These data were made available to us after the original statistical models were constructed. Bias and precision were re-estimated in a manner similar to that used for the internal validation, newly acquired data providing measured values that were compared to model-based predictions.

Results

In cross-validation, most point estimates of the parameters of the three models were similar to those estimated by modelling the entire data set. The exceptions to this pattern were the estimates of the models' intercepts. This suggested that even though the estimates of relative differences between identified determinants were stable, one could expect a greater uncertainty in the absolute value of predictions generated by the models. All models showed negligible negative average relative bias (-1 to -3 percent). However, relative bias ranged from -37 to 45 percent, implying individual predictions can be biased. Precision tended to be a factor of 1.1 to 1.4 greater than the within-worker standard deviation in all three models. However, the estimated ranges of the two statistics overlapped, except in the case of the bitumen fume model. This indicates that the imprecision in all three models is comparable to that which we predicted would arise from day-to-day fluctuations in exposure levels.

In external validation, bitumen fume and benzo(a)pyrene models showed negative relative bias, -70 and -51 percent respectively in external validation. Predicted bitumen fume exposures tended to be lower (average factor of three) than concentrations found during paving in the USA. Evaluation of external validity of the benzo(a)pyrene exposure model revealed a similar to expected effect of re-paving and a larger than expected effect of tar use. This disagreement between predicted and measured values tended to be greater for exposure circumstances associated with elevated exposure levels and those occurring further in the past.

Discussion

An investigation of the models' internal validity revealed that most parameters of models for bitumen fume, organic vapour and benzo(a)pyrene we developed earlier had little average bias. This gives us some assurance that the models adequately described the data. Therefore, if the data is representative of exposures experienced by asphalt workers, then the application of these models in an epidemiological study will result in valid estimates of exposure intensity. However, the models had relatively poor precision, probably resulting from large day-to-day exposure variability. This was adequate because our goal was to model between-worker differences in exposure, that are related to the variables used in the calculation of exposure intensity estimates for the epidemiological analyses. Precision of the bitumen fume and benzo(a)pyrene models, when evaluated against external data, was of the same order of magnitude as those observed in cross-validation.

Bias estimates derived from internal cross-validation were lower than those seen in the external comparisons, which indicated that our models can underestimate bitumen fume and benzo(a)pyrene concentrations by a factor of two to three. This underestimation of exposures, if it were differential as suggested by our results, may lead to overestimate of dose-response relationships based on quantitative indices of exposure. The apparent bias for bitumen fume exposures might be attributed to differences between Western European and USA paving practices. If that is the case, than models' applicability to European pavers is not undermined by our results. The observed underestimation of benzo(a)pyrene exposures by our model may stem from incomplete modelling of (a) the effects of analytical methods and (b) variability of coal tar concentration in asphalt mixes. The principal shortcoming of external validation was the lack, in validation data sets, of the diversity of exposure scenarios needed for a more comprehensive evaluation.

Conclusion

Estimates derived from previously elaborated models can be expected to be imprecise but with small average bias. This indicates that the models are most suitable for group-based exposure predictions in which all members of a group are assigned the same average exposure, instead of individual-based exposure predictions. Possible bias due to underestimation of the impact of coal tar on benzo(a)pyrene exposure levels must be explored in sensitivity analysis of the exposure-response relationships. Validation of the models, albeit limited, increased our confidence in their applicability to exposure assessment in the historical cohort study of cancer risk among asphalt workers.

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An icon-calendar-based questionnaire for assessment of parental occupational pesticide exposure to evaluate cancer in the offspring

Monge, P [1], Wesseling, C [1], Engel, L [2], Keifer, M [3]

[1] *Central American Institute for Studies on Toxic Substances, Universidad Nacional, Costa Rica (IRET),*
[2] *National Cancer Institute, Bethesda, WA.*
[3] *Occupational Medicine Program, Department of Medicine and Environmental Health, University of Washington, Seattle.*
e-mail: pmonge@una.ac.cr

Introduction

Ascertainment of a person's work history is a critical component in studies of health effects of occupational and environmental exposures. Traditional questionnaires do not deal adequately with difficulties to recall past exposures. An icon-calendar-based questionnaire (ICB) uses icons related to distinct life events to prompt recall about exposures during certain periods. This method was previously developed for migrant agricultural workers in the United States by two co-authors (MK and LE). We present now an adaptation for use in a developing country with different cultural, educational, and occupational exposures characteristics.

Questionnaire development

The questionnaire will be used in a population based case-control study of childhood leukemia and brain cancer in Costa Rica in relation to parental occupational pesticide exposure. The IBC will be applied to parents with agricultural occupations and assess exposures during the period of two years before birth until the time of diagnosis for the cases and until current age or age fourteen for the controls.

Modifications of the original calendar include new icons for regions of the country, special life events, crops, jobtitles and non-agriculture occupations. New aspects regarding the pesticide exposure include washing of hands before eating, time in the field after spraying, and practices for storage and washing of clothes. Previously developed list of the most frequently used pesticides (by specific crops, geographical regions and time periods) will be used as an additional aid for prompting memory and the answers collected in the calendar. All items are made of paper materials. The icons for especial events, country regions, crops and jobtitles are developed in stickers. The icons of personal protective equipment and application techniques are developed as list of drawings. All the drawings and pictures were designed to be familiar to the Costa Rican population. Interviewers will be trained by the authors (PM and CW).

Each icon will have a code to help the keying of the information. Data entry in a computerized database will be done with the help of a bar code reader pen.

This ICB is in the phase of last modifications and will be tested in early February. Data collection in the case control study will start in March. Besides exposure data for the case control study on childhood cancer, we plan to use these data to develop a job exposure matrix.

A theory of human chemical exposure and its implications for measurement

Cherrie JW [(1)(3)], Burstyn I [(2)], Ritchie P [(3)]

1. University of Aberdeen, Department of Environmental and Occupational Medicine, Foresterhill Road, Aberdeen AB25 2ZP, UK.
2. Utrecht University, Rizema Bosweg 23A, 6703 AZ Wageningen, The Netherlands.
3. Institute of Occupational Medicine, 8 Roxburgh Place, Edinburgh EH8 9SU, UK.
e-mail: john.cherrie@abdn.ac.uk

Introduction

In science there is a close relationship between theory and measurement, with the dominant theoretical model dictating the measurements that are to be made. Precise, clearly formulated theories are a necessary prerequisite for precise measurements. In exposure assessment, the absence of an explicitly articulated theory hampers accurate assessment of human exposure.

The aim of this paper is to briefly outline a theoretical model of human inhalation and dermal exposure for hazardous substances and explore its implications for measurement.

Uptake

The model uses uptake as an alternative to the more conventional cumulative exposure as a measure of external exposure by inhalation and skin contact. Uptake by inhalation (U_I) is defined as:

$$U_I = \int_{t=t_1}^{t_2} C(t).B(t).dt$$

where *B(t)* is the breathing rate of the person and *C(t)* the exposure level, both at time *t*. Uptake by inhalation corresponds to the mass of contaminant entering the respiratory tract or a specific region of the lung over a period of exposure. Assuming the exposure duration may be subdivided into a number of tasks and that *C(t)* and *B(t)* are independent then:

$$U_I = \sum_{n=1}^{N} C_n.B_n.t_n$$

Uptake by dermal contact (U_{sk}) is defined as:

$$U_{sk} = k_p \int_{t=t_1}^{t_2} \oint C_{sk}.ds.dt$$

where k_p is the permeability constant and C_{sk} is the concentration of the contaminant in the skin contaminant layer. For the situation where the contaminant concentration is constant over the exposed skin surface (*S*) and unchanging over the duration of exposure (*t*), then the estimate of dermal uptake can be simplified to:

$$U_{sk} = k_p.C_{sk}.S.t$$

Dermal uptake is a measure of the mass of contaminant passing through the stratum corneum.

Inhalation exposure

For the inhalation exposure level (*C(t)*) the model comprises terms for the emission from sources, airborne dispersion and the subsequent interactions between the person and the pollutant. This model has been previously described by Cherrie et al (1) and Cherrie and Schneider (2). It is hypothesised that emission is described by three independent multiplicative factors: *intrinsic emission, the handling of the substance and the effectiveness of any local controls.* Intrinsic emission is the innate potential of a material to release contaminant and, for example, is dependent on the saturated vapour pressure for a liquid or dustiness for a solid material. The handling term is assumed to be dependent on the amount of energy input to the system, e.g. the temperature at which a liquid is used or the height through which a powder is dropped.

Dispersion of the contaminant is accounted for by dividing the environment into a *near-field*, i.e. close to the person, and a *far-field*. In this model the near-field is centred on the individual and moves with them. Sources of exposure may either be within the near or far-field. Emission in the far-field is generally diluted by general ventilation. Emission in the near-field may also be affected by general ventilation, but only in small poorly-ventilated rooms (3). Further allowance is made in the model for the time sources are active and the efficiency of any respiratory protection. The pattern of interaction between the worker and the pollutant is accounted for by subdividing the exposure time according to their work tasks, if necessary allowing for inter-individual variation. From this information the exposure can be related to the persons activities and the environment. The total exposure level throughout the day is then given as the weighted sum of near and far-field exposure components.

Cherrie and Schneider (2) and Semple et al (in preparation) have shown that this method can be used to produce exposure estimates that are well correlated with actual measurements, although with a positive bias. We conclude that the model encompasses much of the variation in human exposure that determines the inhalation exposure.

Dermal Exposure

For dermal exposure the theoretical model is less well developed, although recent work by Schneider et al (5) have proposed a conceptual model for such exposures. This model contains descriptor of the main environmental compartments where contaminants may reside and the exchange process between compartments, including the anatomical location of the exposure. Semple et al (7) have developed the conceptual model to provide a more detailed model for one exposure process and this has been used to reconstruct exposure in a semi-experimental study involving spray painters. Again, allowance can be made for inter-individual variation. We consider that the key descriptive information for dermal exposure may also be deduced from this model.

Implications for measurement of chemical exposure

The model further suggests a limited set of data groups that are necessary to fully describe the exposure environment. Focusing on uptake rather than cumulative exposure highlights the importance of recording information about breathing rate for inhalation and the contaminant concentration on the skin so that exposure of subjects may be more validly described. This is not commonly done.

For inhalation exposure these include information about the materials being handled, the way they are handled, the effectiveness of local controls, the time people spend in the vicinity of sources. For dermal exposure this will include details of the source, the contamination of surfaces, the behaviour of people in the environment and the anatomical locations exposed. Recommendations can be made for standardising the data elements that should be collected along with measurements of exposure, i.e. a “core” set of data.

We suggest that publication of studies involving human exposure data be reliant on the authors having collected the core set of exposure data to enable a clear interpretation of the measurements.

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Integrating qualitative and quantitative methods to assess occupational exposures

Loomis D (1), McDonald MA (2), Lipscomb H (3), Dement J (4)

(1) University of North Carolina, Chapel Hill NC, USA (Dana.Loomis@unc.edu)
(2) University of North Carolina, Chapel Hill NC, USA (mcdon055@mc.duke.edu)
(3) Duke University, Durham NC, USA (hester.lipscomb@duke.edu)
(4) Duke University, Durham NC, USA (demen001@mc.duke.edu)

Introduction

Standard occupational hygiene methods for assessing exposure originated with studies of workers concentrated in large plants where repetitive tasks are performed in relatively controlled environments. With employer cooperation, such work settings facilitate application of statistical sampling designs, direct observation of the work by researchers and quantitative measurement of exposure levels. These approaches are not always feasible, however. Modern, decentralized operations disperse workers in a larger number of smaller sites, complicating both sampling and the logistics of observation and measurement. New, flexible production strategies mean that work activities are less routine and predictable, requiring longer periods of observation and more measurements in order to characterize exposures. Similar problems may be encountered in studies of rural and traditional, artisanal workers, whose activities are not governed by production lines and may be conducted outdoors.

Methods

The use of qualitative research methods can help to address some of the preceding challenges. Qualitative research uses methodology originating in anthropology and includes diverse data collection techniques and a range of guiding theories. Qualitative research is characterized by an emphasis on context; a holistic approach with attention to the viewpoints of those under study; and using the natural setting; the research and analysis process is reciprocal and iterative and relies on inductive reasoning (1).

In research on occupational health, qualitative methods help researchers draw on workers' own experience to understand jobs in their true complexity. Hazards of the job can then be seen in the context of larger processes of working and making a living. In practical terms, involving workers as a primary data source can solve logistical problems of observing workers who may be preforming highly-varied tasks in dispersed or shifting locations.

Results

To illustrate, we are using ethnographic methods to assess safety hazards in a study of injuries among commercial fishermen, traditional workers whose time is spent outdoors, and often alone. In detailed, ethnographic interviews, fishermen describe how they fish, identifying key tasks and gear. These interviews are taped and transcribed, then entered into text-analysis software. The results of the analysis can be used to construct a matrix, similar to a quantitative job-exposure matrix, that describes each type of fishing operation in terms of work process, equipment, and potential hazards. This matrix can then be linked to epidemiologic data on injury occurrence and analyzed using standard statistical methods, thus producing a unique integration of quantitative and qualitative approaches.

The matrix resulting from the qualitative work in this study resembles that which might be produced by an occupational hygienist in a worksite assessment, but with critical differences. First, ethnography is a rigorous, well-defined methodology based on a large body of anthropological theory, whereas qualitative work done by hygienists is often informal and developed ad hoc. Second, ethnography allows the work to be understood from the fishermen's perspectives, rather than imposing a structure developed by outsiders. In addition, fishermen's perceptions of risk and ideas about improving safety can be heard and used to inform the research and any recommendations for prevention.

Qualitative methods can also have valuable applications in situations where employer cooperation is lacking. We are using this approach to assess exposure to ergonomic hazards in a study of musculoskeletal disorders among poultry processing workers. Our work is being carried out in partnership with a workers' organization and the industry has been unwilling to allow researchers to enter production facilities. Instead, our approach engages workers as data collectors to characterize operations inside the plant. In group interviews, workers produce a "risk map," showing the plant layout, the work process, the equipment, and the associated hazards. As in the fishing study, the risk map can be used to produce a matrix linkable to epidemiologic data that can be analyzed with statistical methods. While information obtained through qualitative methods will enable this study to provide epidemiologic estimates of exposure-response association, the qualitative approach also empowers workers and legitimizes their experience by involving them in the research process.

Discussion

Qualitative approaches to exposure assessment can facilitate research on workers' health and safety in situations where standard, quantitative approaches are not possible or would not be appropriate. The results of epidemiologic studies that integrate such qualitative information may look similar to those produced with quantitative approaches alone, but there are important differences of interpretation and meaning. Qualitative data are generally seen as less objective, repeatable and generalizeable than quantitative, but each approach has strengths that complement the other's weaknesses (2). A strength of qualitative methods is that, in addition to serving the pragmatic goal of providing data that could not be obtained otherwise, it allows work and its hazards to be understood from workers' point of view. Both of the studies described here adopt this approach.

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A consideration of dose-response relationships for vibration-induced white finger

Griffin MJ [(1)], Bovenzi M [(2)], Nelson CM [(3)]

[1.] Human Factors Research Unit, Institute of Sound and Vibration Research, University of Southampton, Southampton SO17 1BJ, England, e-mail: mjg@isvr.soton.ac.uk
[2.] Department of Public Health Sciences, Clinical Unit of Occupational Medicine, University of Trieste, Centro Tumori, Via della Pieta' 19, 1-34129 Trieste, Italy, e-mail: bovenzi@univ.trieste.it
[3.] Health and Safety Executive, DST E4, 316 Magdalen House, Stanley Precinct, Bootle, Merseyside L20 3QZL, England, e-mail: chris.nelson@hse.gsi.gov.uk

Introduction

Occupational exposure to hand-transmitted vibration is associated with various disorders, collectively known as the ‘hand-arm vibration syndrome’. The syndrome includes vascular, neurological and musculoskeletal disorders that may become manifest individually or collectively. The conditions causing each of these disorders are not known. However, for the best known vascular disorder, vibration-induced white finger (VWF), several studies have reported the vibration conditions associated with an observed incidence, or prevalence, of the condition.

This study investigated the relationships between finger blanching and characteristics of exposures to hand-transmitted vibration, specifically the vibration magnitude and lifetime exposure duration. The effects of vibration frequency were investigated by comparing dose-response models constructed with and without the frequency weighting recommended in current standards.

Methods

Three previously published studies of VWF have been reanalysed: a study of dockyard workers (4,5), a study of quarry/stone workers (1), and a study of forestry workers (2). In each of these studies, medical history, employment history, extent, severity and development of vibration-induced white finger, and exposure to vibration were obtained from individual workers during interviews using a structured questionnaire. The three sets of data provided a group of 1557 male subjects in seven occupational subgroups: stone grinders, stone carvers, quarry drillers, dockyard caulkers, dockyard boilermakers, dockyard painters and forest workers.

Subjects were asked to identify the vibrating tools used during their working life. Tool operating time was obtained in hours per day, days per year and total number of years, separately for each period of use of each tool type. The estimated total (i.e. lifetime) operating duration in hours was thus obtained for each subject, for each tool. The total vibration exposure duration for each subject was obtained by the addition of the operating durations for the different tools.

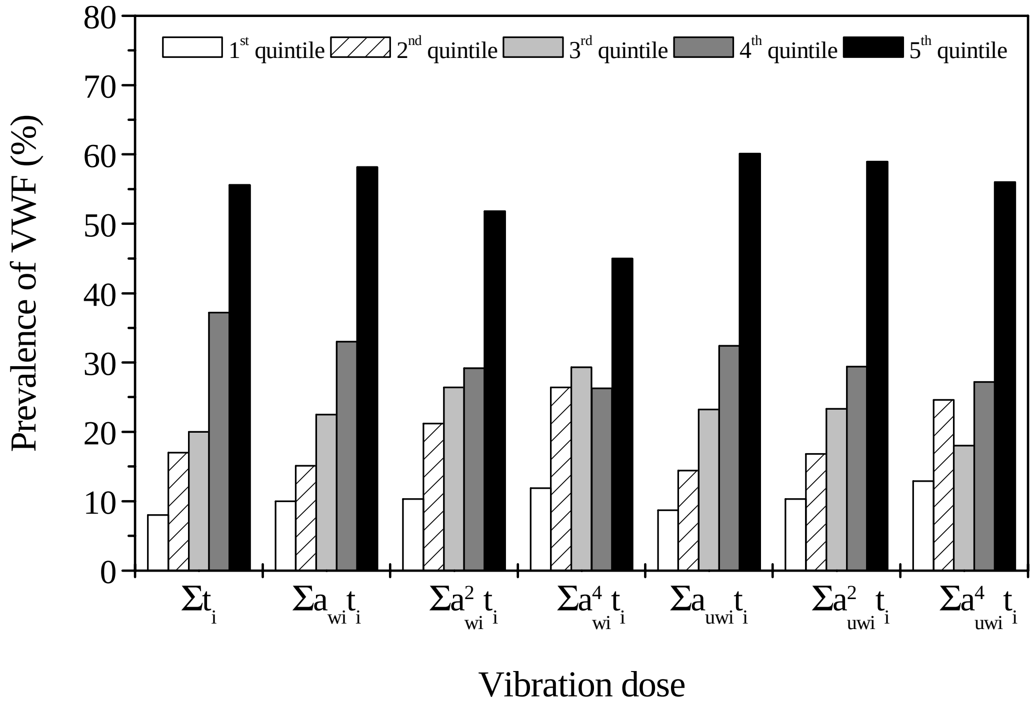

Figure 1 Relation between vibration-induced white finger (VWF) and alternative measures of vibration dose in the vibration exposed workers (n=1557). The prevalence of VWF in each quintile of vibration dose is shown. (a_{wi} = frequency-weighted acceleration; a_{uwi} = unweighted acceleration; t_i = exposure duration)

Vibration was measured on representative samples of the tools. Vibration magnitudes were expressed as root-mean-square acceleration, frequency-weighted in accordance with ISO 5349 (1986). Unweighted acceleration magnitudes were also obtained over the same nominal frequency range (6.3 - 1250 Hz).

From the vibration magnitudes and exposure durations, various alternative vibration 'doses' were calculated for each subject:

$$dose = \sum_i [a_i^m t_i]$$

where a_i and t_i are the acceleration magnitude and the exposure duration, respectively, for tool i, and m = 0, 1, 2 or 4.

Results

For all seven measures of dose, an increase in dose was associated with a significant increase in the occurrence of vibration-induced white finger (Figure 1). However, the strength of the relationship between alternative measures of dose and the occurrence of vibration-induced white finger varied between dose measures. Generally, dose measures with high powers of acceleration (i.e. $m > 1$) faired less well than measures in which the acceleration, a_{wi} or a_{uwi}, and lifetime exposure duration, t, were given equal weight. Indeed, dose determined solely by the duration of exposure (without consideration of the vibration magnitude) tended to give better predictions than measures with values of m greater than unity.

Logistic regression suggested that all measures of dose provided better predictions when the dose was calculated from the unweighted acceleration than from the frequency-weighted acceleration.

Discussion

Current methods for evaluating exposures to hand-transmitted vibration are based on standards that assume a squared relationship between vibration magnitude and exposure duration during the working day (i.e. $m = 2$) and a linear relationship between vibration magnitude and years of exposure (i.e $m = 1$). The data shown here are restricted to the total exposure duration and do not discriminate between exposures accumulated over the day and those accumulated over years. With exposure duration evaluated in this way, it seems that a linear relationship between vibration magnitude and exposure duration is appropriate for predicting the occurrence of vibration-induced white finger.

The predictions were dependent on the frequency weighting, with poorer predictions when the currently recommended frequency weighting was employed. This suggests that more weight should be given in the standards to vibration at some intermediate or high frequencies.

Conclusions

The findings suggest that improvements are possible to both the frequency weighting and the time-dependency in current standards used to predict the development of vibration-induced white finger.

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Vibration load among workers within a heavy engineering production workshop. A ten-year follow-up

Lage Burström [(1)], Ronnie Lundström [(1)], Mats Hagberg [(2)], Tohr Nilsson [(3)]

[(1)] Program for Technical Risk Factors, National Institute for Working Life, Umeå, Sweden, e-mail: lage.burstrom@niwl.se
[(2)] Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Gothenburg, Sweden
[(3)] Sundsvall Hospital, Department of Occupational and Environmental Medicine, Sundsvall, Sweden

Introduction

Manual work involving vibrating power tools could be associated with different symptoms, collectively named as "hand-arm vibration syndrome". These symptoms, which include vascular, neurological, bone, and musculoskeletal disorders, have also been recognised as an important preventable occupational disease. The aim of the present investigation is to follow a group of workers within a heavy engineering production workshop over time and to determine their exposure to vibration.

Methods

The study started in 1987 and has been followed up in 1992 and 1997. The study base was a cohort of workers at a company, which produces paper and pulp-mill machinery. The work task consisted mainly of welding, plating and grinding on iron and stainless steel. The work is very varied and each component is produced in small numbers. In 1987 68 workers listed on the employee rosters were included in the study population. In 1992 the numbers of workers included was 48 and in 1997 40. The assessment of vibration exposure was made under normal working conditions by measuring the intensity of vibration and the exposure time for each of the air powered tools in use. The tool vibration intensity was measured on all types of tools and at all relevant job stations in accordance with ISO 5349 (2). The daily vibration-exposure time was assessed by subjective assessments and by an objective measurement of the time used for each type of hand-held tool. The objective measurements were carried out by observation. The subjective assessments of daily exposure time were collected in three ways, by diary, questionnaire and interview.

For each subject the 4-hour frequency-weighted energy-equivalent acceleration was calculated for the dominant direction, in accordance with ISO 5349, as estimate of the vibration load.

Results

The workers exposure to vibration has its dominating origin in the use of grinders and hammers. These two types of tools correspond to about 90 - 95% of the total daily use of hand-held tools. The results from conducted measurements of the vibration acceleration in the dominant direction for the grinders and hammers are presented in Figure 1.

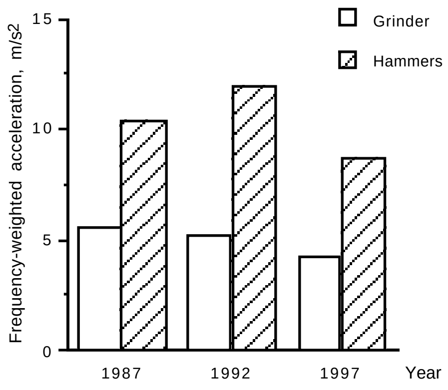

Figure 1. Mean frequency-weighted accelerations for the grinders and hammers measured for different investigation year.

In the figure it can be seen that the average frequency-weighted accelerations have decreased over the investigation period. Since 1987 the acceleration have decreased with about 20 to 25% and during this time about 85% of the tools have be replaced. Figure 2 shows the mean average for the exposure time for different investigation years. The total daily exposure time for vibrating tools have decreased from about 105 minutes in 1987 to about 55 minutes in 1997.

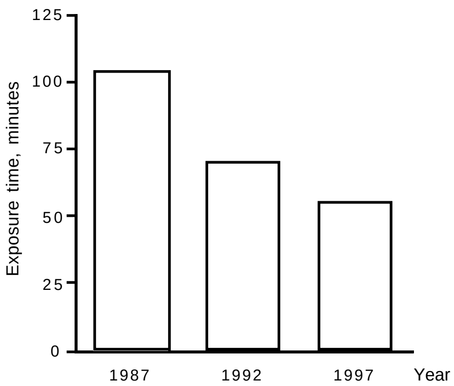

Figure 2. Mean daily exposure time (minutes) for different investigation year.

Figure 3 shows the total frequency-weighted equivalent acceleration for a period of 4 hours, calculated in accordance with ISO 5349. The frequency-weighted energy-equivalent acceleration for a period of 4 hours varies between 4.5 m/s^2 in 1987 to 2.9 m/s^2 in 1997.

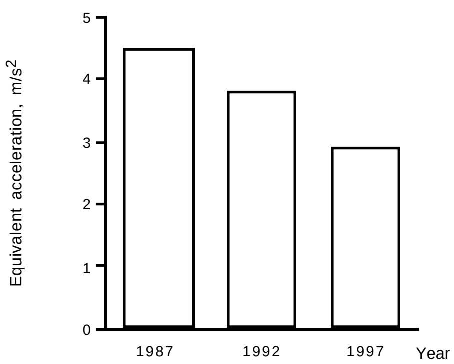

Figure 3. Mean 4 hours energy-equivalent frequency-weighted acceleration for different investigation year.

Discussion

This study clearly shows that the vibration load among studied workers has decreased over a ten-year period time. During this period the workers vibration load has decreased by about 35%, which consequently reduces the risk for vibration injures. The reasons are that both the vibration intensity and the exposure time have decreased over the years. The reduction in vibration exposure time is due to that the workers has received extended work contents including less work with vibrating handheld tools.

A proposal for a physical agent directive has been presented for the European Union (1). For hand-arm vibration two limits have been proposed, one exposure action value and one exposure limit value. These values are normalised to a working day of 8 hours and expressed as the root sum of square for the frequency-weighted acceleration of the three components values (x_h, y_h, z_h). If the action value is exceeded the employer shall establish and implement a programme for technical and/or organisation measures. The aim with the programme should be to reduce the vibration exposure to a minimum. The workers shall in no cases be exposed to vibration above to exposure limit value. For hand-arm vibration the proposed exposure limit value is 5 m/s^2 and the action value is 2.5 m/s^2. For the workers within the actual heavy engineering production workshop the 8-hours energy equivalent value was found to be 3.7 m/s^2.

Conclusions

Notwithstanding that the vibration load among the workers has decreased over the study time, the vibration dosage for the workers is still a risk factor, why more efforts should be spent to decrease the vibration exposure.

Acknowledgement

The financial support of the Swedish Council for Work Life Research (Project 2000-0358) is gratefully acknowledged.

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Characterizing exposure to hand-transmitted impacts

Brammer AJ[(1)], Peterson DR[(2)], Cherniack MG[(2)]

[1] *Institute for Microstructural Sciences, National Research Council, Ottawa, Canada, e-mail: tony.brammer@nrc.ca*
[2] *Division of Occupational and Environmental Medicine, University of Connecticut Health Center, Hartford, U.S.A.*

Introduction

It is well established that occupational exposure of the hand to intense vibration may result in a complex of neurological, vascular and musculo-skeletal symptoms known as the hand-arm vibration syndrome (HAVS). From analyses of epidemiologic studies there appear to be relationships between cumulative exposure to vibration and the development of HAVS for some work practices and some symptoms, with the existence and form of a relationship most developed for the onset of episodic finger blanching.(2,1)

A relationship between the mean years of exposure experienced by a population group, all of whom are engaged in similar work using effectively the same power tools or industrial process whereby vibration enters the hands, and a measure of the magnitude of the daily, energy-equivalent acceleration of a surface in contact with the hands has been incorporated into an international standard (4). The relationship predicts the mean duration of exposure for a 10% prevalence of white fingers to occur in the population group, and is considered applicable to all daily vibration exposures. The broad applicability relies, in part, on the ability to specify accelerations at different frequencies that are equally hazardous. The standard notes that the relationship should be applied with caution to percussive tools for which the magnitude of the daily, energy-equivalent acceleration is dominated by frequency components below 20 Hz. Moreover, all editions of ISO 5349 are only "provisionally applicable" to hand-transmitted impacts.

The purpose of this paper is to employ our current understanding of the origins of deviations from the existing exposure-response model to examine functions that may assist in the formulation of improved models. In this way it is believed that the applicability of models for the development of symptoms of HAVS may be extended to include repeated impacts.

Method and Discussion

There are reasons to believe that exposure of the hand to impacts may require an alternative method of assessment than that contained in the international standard. First, while the ISO exposure-response relationship has the merit of simplicity and can trace its origin to epidemiologic and exposure data, it makes no attempt to model the body burden or dose, and so has no basis in tissue pathology, nor the physiologic nor biodynamic processes responsible for the observed structural changes (9,5). Second, there have been several reports in the literature of symptoms of HAVS from exposure to repeated impacts that deviate from the ISO exposure-response relationship, and contain a broad range of vibration frequencies that may not be appropriately assessment by current methods (6,3). Third, laboratory experiments to elicit subjective or physiologic responses to vibration have demonstrated deviations from an energy-like exposure rate and the weighting to be applied to components at different frequencies in order for them to represent an equal hazard of developing some component of HAVS. Fourth, spinal injury from repeated impacts and neurological damage to the brain from a single impact (including diffuse axonal injury), are assessed by very different exposure rate functions from those currently employed for hand-transmitted vibration (10,7).

A generalized expression for exposure to vibration may be written as:

$$E(a_w, T)_{m,r} = \left(\int_0^T [a_w(t)]^m dt\right)^{1/r} \quad (1)$$

where $E(a_W,T)_{m,r}$ is the exposure occurring during a time T to a stimulus with an instantaneous acceleration at time t which has been frequency-weighted to equate the hazard of vibration at different frequencies, $a_W(t)$, and m and r are constants describing the moment and root of the function, respectively (8). Within this family of functions, only those with even integer values for m, e.g., m = 2, 4, 6, etc., will be considered (i.e., positive integrands) The form of the function applicable to hand-transmitted impacts may be explored by reference to epidemiologic and laboratory data. It should be noted that comparisons may include data from exposures to vibration using the existing method of assessment, as the 8-hour energy equivalent root mean square (rms) acceleration, $(a_{hv})_{eq(8)}$, may be used to construct the exposure function in which $m = r = 2$, i.e.:

$$E(a_w, T_0)_{2,2} = \left(\int_0^{T_0} [a_w(t)]^2 dt\right)^{1/2} = T_0^{\;1/2}\left(\frac{1}{T_0}\int_0^{T_0} [a_w(t)]^2 dt\right)^{1/2} \quad (2)$$

In this expression, T_0 corresponds to 8 hours, and the exposure rate is:

$$\left(\frac{1}{T_0}\int_0^{T_0} [a_w(t)]^2 dt\right)^{1/2} = (a_{hv})_{eq(8)} \quad (3)$$

Corresponding expressions between higher-order root mean value accelerations and higher-order moment and root exposure functions may be derived. Also, relationships between the former and the rms acceleration may be derived for known acceleration waveforms (8).

A strategy of comparing epidemiologic, physiologic, or subjective responses to vibration exposure that permits relationships between the unknown parameters to be proposed has been adopted. For this purpose the relative contributions to the frequency-weighted acceleration at different frequencies are determined by frequency bands, i.e.,

$$(a_{hv})_{m,r} = \left(\Sigma_i [b_i (a_{hi})_{m,r}]^m\right)^{1/m} \quad (4)$$

where $(a_{hi})_{m,r}$ is the acceleration magnitude for the i^{th} frequency band, b_i. The complexity of the analysis increases with the number of variables, and has been set to the minimum number consistent with representing the broad range of frequencies believed to influence health effects. With three frequency bands, the goal is to establish values for the five parameters, m, r, b_1, b_2, and b_3, for different combinations of tool vibration, exposure time and human response.

The large number of parameters to be fitted, together with the need first to specify and then match human responses in order to effect comparisons, limits the formulation of a unique exposure-response relationship. Moreover, while the approach is designed to improve the characterization of exposure to repeated impacts, it does not address the temporal occurrence of the impacts. A biologically plausible model will be required for such purposes, which transforms the (external) exposure into body burden and, ultimately, tissue dose. The essence of such a model is obtained by expressing the total exposure in terms of a sequence of exposure elements, d_1, d_2, d_3, . . d_j, . . d_N. If these are arranged in the reverse order from which they were experienced (i.e., d_N, the most recent exposure, first), then the dose elements may be given inter-related weights that reflect repair and recovery processes since their occurrence, c_j:(8).

$$\Sigma_j [\, d_j)\,]^r = c_0 d^r_N + c_1 d^r_{(N-1)} + c_2 d^r_{(N-2)} + ...etc. \qquad (5)$$

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Daily exposure time to hand-arm vibrations in Swedish car mechanics

Barregård L

Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg, Sweden, e-mail: lars.barregard@ymk.gu.se

Introduction

Car mechanics may be exposed to hand-arm vibrations, nut-runners being the most common vibrating tools used. A survey of vibration-induced white finger (VWF) in Swedish car mechanics revealed that 25% of those who had worked as car mechanics for > 20 years had VWF (1). The vibrations levels of nut-runners used in garages are relatively moderate, but the exposure time has been unknown. The aim of the present study was to examine the daily exposure time in a sample of Swedish car mechanics.

Subjects and methods

Six garages were surveyed. In each garage, 5-10 car mechanics were observed in random order every 30 seconds throughout a number of entire working days. The daily exposure time for each mechanic was estimated from the fraction of the observations that the mechanic was exposed, i.e. having a vibrating tool running in his hand. A total of 51 mechanics were observed, most of them on two different days. At the end of the day, each mechanic was asked to estimate his effective exposure time (in minutes) during that day, and as expressed in percent of the exposure time on 'a normal work day'.

The variability of the daily exposure time for mechanics studied on two work days (in total 88 work days) was partitioned on garages (N=6), mechanics (N=44), and within-worker variability, using a nested analysis of variance. Using the method proposed by Rappaport, the ratio of the 97.5th percentile to the 2.5th percentile of the individual mean exposure times ($R_{0.95,B}$) was calculated.

Results

The median effective exposure time was 10 minutes per day (95% CI 5-15 minutes, arithmetic mean 14 minutes, maximum 80 minutes), and most of the exposure time was attributable to the use of nut-runners. The car mechanics’ self-estimates were: arithmetic mean 17 minutes, and median 7.5 minutes. On average, the mechanics estimated the exposure time on the study day to be 62% of 'a normal day'.

Partitioning of variability showed that within-worker variability constituted about half of the total variability. The $R_{0.95,B}$ was 18, which is a high between-worker variability indicating that the car mechanics do not constitute a 'uniformly exposed group'.

Discussion

The design of studying workers on 100-200 randomly selected occasions during the working day, instead of continuously during 8 hours introduced a random error, but enabled us to survey 95 work days, despite limited resources. We thus sacrificed precision on the individual level, but obtained a reasonably precise estimate of the average exposure time.

The effective daily exposure time was short, median 10 minutes per day. Even so, 25% of car mechanics with > 20 years of exposure had VWF in a survey of mechanics from these six and a number of other garages in Göteborg (1). The survey comprised 900 mechanics of whom more than 300 underwent clinical medical examinations. A previous large study in 26 garages in Sweden, on the same tools as those used by the car mechanics in our study, showed an average weighted acceleration level of 3.5 (SD 0.6) m/s^2 in 286 nut-runners (2). The vibration levels were measured according to ISO-standard 5349, in three directions. We consider this level to be a good estimate of the average vibration levels for the car mechanics we have studied.

The prediction model for prevalence and latency time of VWF in ISO-standard 5349 would predict that only three percent of the car mechanics will suffer from VWF after 20 years of exposure. In contrast, the survey of VWF showed a much higher prevalence (about 25%). In our opinion, the model of the ISO norm is insufficient, at least for the transient vibrations created by nut-runners. The validity of the model has been questioned by others.

Conclusion

Swedish car mechanics use hand-held vibrating nut-runners only for short periods of time, but the exposure is nevertheless sufficient to cause VWF in a considerable fraction of the work force. The model of the ISO-norm is insufficient for the transient vibrations created by nut-runners. The between-worker and within-worker variability in daily exposure time was considerable, but in the present study the latter included also a substantial measurement error. The group average of the self-estimates was surprisingly accurate.

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Role of guidelines in exposure assessment at the workplace

Buckle P [(1)], Kadefors R [(2)], Fallentin N [(3)]

[1]. Robens Centre for Health Ergonomics, EIHMS, University of Surrey, Guildford GU2 7TE
[2.] National Institute for Working Life,-West, Goteborg, Sweden
[3.] National Institute of Occupational Health, Copenhagen, Denmark

Most exposure assessment guidelines have been based upon short-term physiological and psychophysical responses to well-defined characteristics of physical load in laboratory experiments. This roundtable will explore the use and limitations of these guidelines. It will provide an opportunity to explore ideas as to how improved guidelines might be developed.

The three key areas of discussion will be: - a) the use of guidelines in the evaluation of tasks that are composed of various activities, b) the applicability of guidelines to the reality of work systems and c) the establishment of exposure limits and the ability of guidelines to predict the associated musculoskeletal risks. Each of these areas will be introduced by a member of the roundtable panel. This will be followed by general discussion time and a summing-up.

The need for standardised and valid assessment of exposure in work systems is essential for both research and practice. No such standards are currently widely accepted. The resultant difficulties in, for example, comparing research data across studies, providing appropriate tools and training for practitioners and developing and enforcing regulations are all too obvious. The requirement has been recognised for some considerable time and it might be argued that significant research effort has been expended in attempting to achieve suitable guidance. Barriers to realising the goals include the complexity of tasks, interactions between tasks, limited knowledge of how exposures related to such interactions should be treated (e.g. summation, multiplication,) and a limited number of well designed epidemiological studies using good exposure and outcome assessment methods.

Epidemiological studies that have attempted to validate guidelines derived from laboratory data frequently appear to lack the rigour required, usually because of resource limitations or difficulties with obtaining suitable access to study samples of workers. Time requirements (i.e. for prospective studies) have meant that the predictive power of such guidelines with respect to musculoskeletal risk has rarely been tested. In any event, the continuously changing nature of modern work systems and their organisation necessitates repeated estimates of exposure to be made if predictive power is to be validated over a reasonable course of time.

Regulatory guidelines have been subject to many of these criticisms, yet many countries still pursue them. This is, presumably, because they are seen as essential in any “risk assessment” strategy for reducing the size of the problem. The need for simple measures is evidenced by the recent USA initiatives in attempting to develop Threshold Limit Values (TLV’s) for repetitive hand work. The call by practitioners for simple tools to assess risk in the workplace appears to be as strong now as is was a decade ago, and the need to accept a pragmatic approach with, potentially, a reduction in validity may need to be contemplated more widely.

The challenges for this roundtable are immense. Failure to deliver appropriate guidelines for exposure assessment is not an option. Seeking consensus on what ***is*** acceptable is therefore the priority. This roundtable will help to establish whether and how such a consensus might be achieved by both the research and practitioner communities.

Covariation between physical and psychosocial stressors in the workplace: implications for musculoskeletal epidemiology

MacDonald LA [1,2], Karasek RA [2], Punnett L [2], Scharf T [1]

[1] *National Institute for Occupational Safety and Health (NIOSH), Cincinnati, OH, USA, e-mail: LMacDonald@cdc.gov.*
[2] *University of Massachusetts Lowell, Department of Work Environment, Lowell, Massachusetts, USA.*

Introduction

There is increasing interest in distinguishing the effects of physical and psychosocial workplace stressors on the etiology of work-related musculoskeletal disorders (MSDs). Modest associations have been found between psychosocial stressors and MSDs, but interpretation of these results are limited by likely covariation between physical and psychosocial stressors. The aim of is investigation was to examine exposure covariation among blue- and white-collar workers and to perform an exploratory factor analysis to investigate the structure of possible underlying factors linking these conceptually distinct stressors.

Methods

Four hundred and ten (84% participation) workers were enrolled in a epidemiologic study at an appliance manufacturing plant. Over half (54%) of the participants were blue-collar workers assigned to direct production (assembly) and support functions. White-collar workers were employed in management and professional positions, and a small proportion (9%) were clerks and secretaries. All participants completed a detailed questionnaire about exposure to physical and psychosocial workplace stressors. Physical stressor questions were adapted from ergonomic checklists, and composite physical job demand scores were computed for the upper extremity (UE) and for the back/lower extremities (BL) by weighting stressors by intensity and duration criteria according to a proposed regulation (5). As described by Estill et al. (1), quantitative assessments of upper limb motion were obtained from wrist-worn accelerometers (ACC) among 146 (36%) participants: 91 blue-collar and 55 white-collar. Measures of psychological job demands and decision latitude were selected from the Job Content Questionnaire (JCQ) (4). Other psychosocial stressors were selected from the NIOSH Generic Job Stress Questionnaire (3). Correlation coefficients were computed, and orthogonal and oblique rotations were used in an exploratory factor analysis.

Results

Moderately high correlations between selected physical and psychosocial stressors showed evidence of covariation (table 1). Strong inverse relationships were found between the occupational group aggregate measure of decision latitude and aggregate measures of physical stressors: UE (r= -0.91, p=0.001), BL (r= -0.82, p=0.0002) and ACC (r= -0.75, p=0.005). Factor analysis results yielded one factor with bi-polar loadings and substantial clustering of repetition and job control measures, while another showed a strong interrelationship between time (pacing) pressure and social pressure (table 2).

Table 1. Spearman correlations between composite physical job demand scores and accelerometry with workplace psychosocial stressors, by work group.

Psychosocial Stressors	Blue-Collar (N=220)			White-Collar (N=190)		
	UE	BL	ACC[1]	UE	BL	ACC[1]
Job Strain (ratio)	**0.58** [a]	**0.34** [a]	**0.37** [b]	**0.34** [a]	0.14	0.26
Psychological Demands	**0.24** [c]	**0.25** [c]	0.23 [d]	**0.26** [b]	0.09	0.12
Decision Latitude	**-0.61** [a]	**-0.34** [a]	**-0.32** [c]	**-0.24** [c]	-0.09	-0.10
Mental Demands	-0.11	0.02	-0.12	0.19 [d]	0.06	0.20
Poor Work Schedule Control	0.16 [d]	0.17 [d]	0.01	0.06	-0.07	0.14
Lack of Group Cohesion	0.09	0.07	-0.05	-0.15 [d]	0.12	-0.02
Group Pressure	0.21 [d]	0.17 [d]	0.18	0.19 [d]	0.03	0.22
Lack of Supervisor Support	**0.25** [c]	0.11	-0.03	-0.19 [d]	-0.01	0.15
Lack of Co-Worker Support	0.01	-0.03	-0.16	0.03	0.05	-0.12
Opinions not Accepted	0.13	0.05	0.01	0.03	0.05	-0.12

Significance: a ≤0.0001, b≤0.001, c≤0.01, d≤0.05 (bold if significance ≤0.01).

[1.] Sample size: 91 blue-collar and 55 white-collar.

Table 2. Factor loading pattern from principal factor analysis with orthogonal rotation showing the structure of possible underlying factors linking physical and psychosocial stressors in the workplace (N=410).

Stressor Measures (bold if a physical load measure)	Organizational Constraint	Work Pace Pressure
Work Pace Regulation	0.776	0.035
Short Cycle Work	0.774	0.080
Repetition Rating Scale	0.628	0.254
Physical Monotony	0.486	-0.000
Poor Work Schedule Control	0.455	-0.068
Skill Discretion[1]	-0.654	-0.043
Decision Authority[1]	-0.827	0.154
Group Pressure	-0.187	0.602
Mental Demands	-0.527	0.581
Hard*Fast [2]	0.256	0.530
Time Demands [3]	-0.360	0.501
Difficulty Maintaining Pace	0.252	0.493

Loading values >0.30, explaining more than 9% factor variance, underlined.

[1.] Sub-scale component of decision latitude, [2.] Two-items from the psychological job demands scale, [3.] Three-items from the psychological job demands scale.

Discussion

Moderately high correlations between selected physical and psychosocial stressors showed evidence of covariation. The strength of these correlations was especially notable considering that imperfect scale reliability can attenuate empirical relationships (2). Correlations were strongest among blue-collar production and low status (clerks and secretaries) office workers. Factor analysis results showed considerable common variance among selected stressors, suggesting that concomitant exposure to physical and psychosocial stressors arises from organization-level antecedents. While recognizing the conceptual differences between these stressors, the findings call attention to the strong empirical relationships that can exist in the workplace. These associations may explain why the epidemiologic evidence concerning the role of psychosocial stressors in the development of work-related musculoskeletal disorders has been inconsistent. Ecologic understandings of workplace exposure situations are critical to formulating correct inferences about the components of risk as well as effective prevention strategies. Further research is warranted to gain further insight into work organization factors linking physical and psychosocial stressors.

Conclusion

Exposure covariation was found between selected physical and psychosocial stressors and was strongest in blue-collar production and low-status office workers. Factor analysis results suggest that these disparate stressors manifest from common work organization factors that govern the structure of work

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Job demand and control in a triangular perspective; the concordance between self administered questionnaires and expert evaluations of ”factual” versus ”subjectively evaluated” conditions respectively

Ahlberg, G (1), Härenstam, A (1), Scheele, P (2), Waldenström, K (2) and the MOA-research group

(1) *National Institute of Working Life, Stockholm.*
(2) *Department of Occupational Health, Karolinska Hospital, Stockholm, Sweden, E-mail: Gunnel.Ahlberg@niwl.se*

Introduction

Within both epidemiological and psychological scientific research there is an ongoing discussion on how to define and assess concepts like psychological demands and control. One of the most influential model is the job-strain model developed by Karasek and Theorell (1,2). The most common method of measurement is various forms of self administered questionnaires. The reliability of these measurements is sometimes questioned and criticized for being too subjective. During recent years, the relevance of the job strain model in service occupations has been questioned (3). The scientific research on psychosocial work environment that developed during the seventies and eighties was often preoccupied with low skilled blue-collar workers occupations in manufacturing.

Materials and methods

This present study is a part of the MOA-study, *Modern Work and Living Conditions for Women and Men*, a Swedish inter-disciplinary study. In the MOA-study, a triangular design was used to investigate whether a number of often used questionnaire items more reflect a subjective evaluation or a factual description of work conditions. The study group consisted of 102 women and 101 men at 80 work sites in five different counties in Sweden. Three quarters of the study group were matched according to gender, qualification level and type of work (working with people, things or data). If possible the matched pairs were chosen at the same work sites. The remaining fourth mainly consisted of women from female dominated occupations and work sites and men from male dominated ones. Men and women were also equally distributed regarding age, socio-economical groups and family situation in the whole study group.

In Sweden the measurement of work demands and control often is conducted by means of a shorter version of the JCQ-scale consisting of 11 items. In this present study reliability and validity for 8 of these was investigated. Reliability was established through a test-retest procedure and validity through comparisons between questionnaire data and estimations from two different theoretical and methodological perspectives made by researchers. An estimation from an external/descriptive perspective was primarily based on of job analysis through on-site observations and an estimation from an internal/evaluative perspective was based on interviews about the subjective experience of the matter which the item concerned.

Reliability and the concordance between questionnaire data and the two expert estimations were calculated by means of weighted kappa-values and percentage total agreement. In order to investigate if lack of stability was due to any systematic misclassification in any subgroup, Wilcoxon signed rank tests were performed for type of occupation, age-group and educational level separately.

Results

The analyses show that reliability for all the items are acceptable, in some cases excellent. However, reliability for some of the items was not stable for various subgroups, often due to a skewed distribution of responses for some of the groups.

Generally the concordance between questionnaire data and the assessments from the external perspective was lower than the concordance with the assessments from the subjective perspective. The deviation from the assessments based on job analysis was more often lower for the responses among females than for the responses among males.

A systematically higher reporting of possibility to learn new things and the extent to which work requires creativity, was noted in relation to the external perspective among the whole study group. Correspondingly a lower reporting of monotonous work could be noticed. This discrepancy regarding self-reporting of skill utilization was especially attenuated for persons working with things and persons with a low level of education. People working with things, especially men, also tended to report higher levels of decision authority in comparison with the external assessment. In relation to the estimation of the subjective experience, questionnaire data showed a notable deviation regarding psychological demands. In the questionnaire, both men and women reported less psychological demands than later was expressed in the interview.

Discussion

The greater discrepancy between questionnaire data and the external assessment compared with the internal assessment is what could be expected. The psycho-social dimensions derived from the job analysis are based on action regulation theory and therefore not identical to the ones in the demand control model. However the criteria used in the external assessment were equally defined for the whole study group. It could therefor be concluded that the systematic higher differences noted for people working with things and persons with low education regarding skill utilization and decision authority indicate that these groups put a somewhat different meaning into these concepts. A qualitative analysis of the subjective significance of these items shows that people working with things tended to refer to a narrower spectrum of decision authority than for example people working with data.

The relatively small study group naturally limits the possibilities to generalize the results . However, the reflections made are based upon a material of high quality. The results indicate that skill utilization and decision authority may be somewhat overexerted among people working with things and/or low education. This means that the job strain ratio may be underestimated for these categories. The results do not support the assumption that the questions should be less appropriate for women than for men.

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Gender differences and job stress models in an occupational cohort in France

Niedhammer I, David S

INSERM Unit 88, Hopital National de Saint Maurice, France
e-mail: *i.niedhammer@st-maurice.inserm.fr*

Introduction

Occupational epidemiology has provided convincing results supporting predictive effects of psychosocial factors at work on both physical and mental health. As there is a clear gender division of work, and as women are not engaged in the same work activities than men, they may also be exposed to different occupational exposures, especially regarding psychosocial factors at work. The objective of this study was to explore the associations between gender and exposure to psychosocial factors at work in a large occupational cohort.

Population

The study was based on the subjects of the GAZEL cohort established in 1989 and composed at baseline of 20624 workers employed by the French national electric and gas company (EDF-GDF) and followed up since then by means of yearly self-administered questionnaires and by the collection of data provided by the medical and personnel departments of the company. Research on psychosocial factors at work and health has been conducted in this cohort since 1995 (4,5,6). The study was restricted here to the working subjects who responded to the self-administered questionnaire of 1997 and 1998.

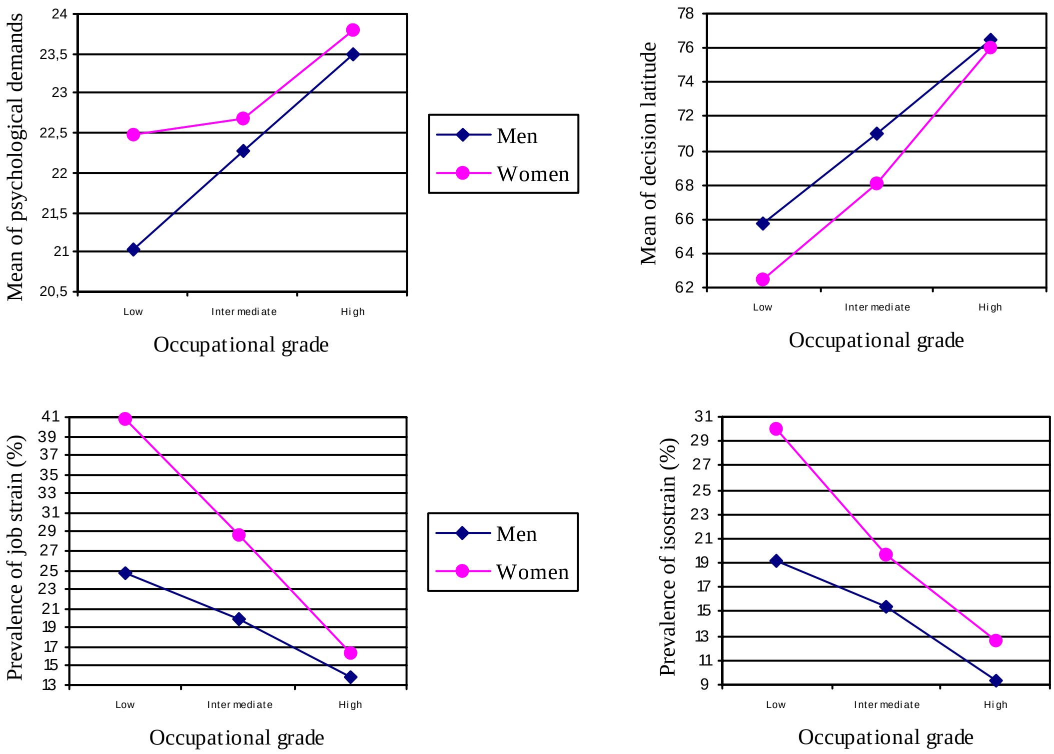
Methods

Two theoretical models were used to evaluate psychosocial factors at work: the Demand-Control (DC) model elaborated by Robert Karasek (1,3) and the Effort-Reward Imbalance (ERI) model elaborated by Johannes Siegrist (8). The Job Content Questionnaire (JCQ) developped by Robert Karasek (2) was used to measure psychological demands, decision latitude and social support, and the French version was introduced in the self-administered questionnaire of 1997. Job strain was defined by the combination of high demands and low latitude (median cut-off). In addition, isostrain was defined by the combination of high demands, low latitude, and low support. The French version of the ERI instrument (9) measuring extrinsic effort and reward was introduced in the questionnaire of 1998 (7). Effort-reward imbalance was defined by a ratio of extrinsic effort to reward higher than 1. Occupational grade was provided by the personnel department of the company. Three categories were defined: low grade (clerks and blue collar workers), intermediate grade (technicians, foremen, and other associated professionals), and high grade (managers, engineers, and other professionals). Analyses were performed using t-test, analysis of variance, Chi-Square test and logistic regression analysis.

Results

In 1997, 11447 working subjects, 8277 men and 3170 women, answered the self-administered questionnaire including JCQ. In 1998, they were 10174, 7251 men and 2923 women, to respond to the ERI questionnaire. Women were more likely to belong to intermediate or low occupational grades than men. They were also more likely to be exposed to lower decision latitude, lower social support and lower levels of reward than men. After adjustment for occupational grade, the exposure to psychological demands was significantly higher and the exposure to decision latitude was lower for women than for men. Futhermore, significant interactions between gender and occupational grade were observed: the gap between men and women increased with low occupational grade for both psychological demands and decision latitude (figures 1 and 2). Regarding extrinsic effort and reward, no significant differences were found between men and women when occupational grade was taken into account. The prevalence of job strain was found to be significantly higher for women (29.1%) than for men (17.7%). In the same way, the prevalence of isostrain was higher for women (20.4%) than for men (13.1%). Using logistic regression analysis, women were more likely to be exposed to job strain and isostrain than men (OR=1.6 and OR=1.4 respectively) after taking into account occupational grade. In addition, an interaction was observed betwen gender and occupational grade for both job strain and isostrain; the difference between men and women increased for low occupational grade (figures 3 and 4). The prevalence of effort-reward imbalance was significantly higher for women (7.0%) than for men (5.6%), but this difference was no longer significant when occupational grade was included in the model.

Figures 1-4



Discussion

This study explored the differences between men and women for two job stress models, the Demand-Control model and the Effort-Reward Imbalance model. First of all, differences were observed between genders for occupational grade, women were more likely to work as low or intermediate grade workers than men. Women were more likely to be exposed to job stress factors than men, but the differences between genders were significant only for psychological demands and decision latitude when occupational grade was taken into account. Futhermore, stronger differences were found between men and women in lower occupational grade for these two psychosocial dimensions, leading to greater difference in prevalence of job strain and isostrain. In conclusion, this study underlines the differences between men and women regarding the prevalence of job stress conditions in a large occupational cohort, and highlights that these differences may be still stronger in lower occupational grades.

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Exposure to job stress factors in a national survey in France: construction of a job-exposure matrix (JEM)

Cohidon C [(1)], Niedhammer I [(2)], Chouaniere D [(1)], Guéguen A [(2)], Bonenfant S [(2)],

[(1)] *Département Epidémiologie en Entreprise, INRS, Avenue de Bourgogne, BP n° 27, F - 54 501 Vandoeuvre, France, E-mail: c.cohidon@inrs.fr*
[(2)] *Inserm Unit 88, Saint-Maurice, France*

Introduction

Occupational stress is a growing epidemiological field in France. Up to now, some surveys have been set up in particular occupations or industries, but the exposure to job stress factors in the general working population in France is not precisely known.

The aim of this study was to develop a job-exposure matrix (JEM), based on a national survey in France, and to describe exposure to various psychosocial, physical, and chemical factors across occupations. Physical and chemical factors were explored in this study as other potential job stress factors. In the present paper, we focused on the method of the JEM construction and we gave preliminary results.

Methods

The study population was based on a French national survey on working conditions from the French Ministry of Labour. The first survey took place in 1978, and was conducted again in 1984 and 1991, each time on a national representative sample of the French working population. In the present study, the data from the 1991 survey were explored, in which 20 868 workers, 11 643 men and 9 225 women, were interviewed by questionnaire.

The first step was to define the occupational exposure from the 77 questions, retained as being pertinent regarding job stress. These items were separated in two groups: psychosocial factors (45 items), and physical or chemical factors (32 items). For each group, a principal component analysis with Varimax rotation was performed to construct scores based on the identified dimensions. For psychosocial factors, the dimensions were interpreted using Karasek's model (2). For physical and chemical factors, factor analysis results were deepened by an expert judgement. Scores were obtained by summing items.

Three other variables were used in this study: sex, age (10-year groups), and occupation. Occupation was coded according to the French occupational classification from the National Institute for Statistics and Economic Studies (INSEE). This classification is composed of 4 hierarchical levels of codes with a maximum of 455 categories.

The CART (Classification And Regression Tree) segmentation was used to construct the JEM. The construction of a segmentation tree is based on successive divisions of the initial sample according to occupational categories, thus providing a partition of the population between homogeneous exposure groups (HEG or terminal nodes) for each exposure studied. HEG are individualized to obtain a maximal between-group variance for exposure and a minimal within-group variance.

Results

For psychosocial factors, 14 scores were constructed based on the results of principal component analysis. For physical and chemical factors, principal component analysis and expert judgement allowed the construction of 9 scores. Table I presents the mean score for each exposure for men and women separately.

Table I: Mean score for each psychosocial and physical/chemical exposure for French working men and women in 1991.

		Men		**Women**	
	No of items	Mean	Standard deviation	Mean	Standard deviation
Psychosocial factors					
Lack of decision authority[a]	7	34.2	27.3	37.5	25.7
Particular working hours[a]	5	22.7	26.1	19.9	24.8
Repetitive work[a]	4	9.7	18.5	11.3	19.1
Relations with public[a]	4	41.7	33.3	45.4	32.3
Lack of material means[a]	3	18.8	28.1	19.7	28.7
Psychological constraints[a]	4	52.4	33.5	35.9	32.1
Concentration/attention[a]	4	20.0	25.7	16.7	23.4
Organizational constraints	4	22.6	25.7	16.8	23.3
Shift work[a]	4	16.6	23.8	14.4	20.3
Polyvalent job[a]	2	39.1	37.0	36.9	36.1
Supervisor role[b]	1	31.1	0.5	14.1	0.4
Isolated work[b]	1	5.4	0.2	5.2	0.2
Lack of work[b]	1	14.2	0.4	15.2	0.4
Lack of cooperation[b]	1	12.7	0.3	17.2	0.4
Physical or chemical factors					
Physical load[a]	6	35.3	29.2	24.4	24.3
Noise[a]	4	21.6	24.4	15.5	21.4
Extreme temperatures[a]	2	24.5	35.9	19.0	30.4
Unhealthy environment[a]	5	31.6	32.2	15.9	23.3
Biological risks[a]	2	9.3	21.0	13.4	24.2
Windowless environment[a]	2	27.3	37.1	28.6	36.0
Immediate physical risks[a]	8	25.6	27.1	9.6	16.6
Chemical risks[a]	2	24.3	34.2	12.6	24.9
Road risks[b]	1	40.2	0.5	11.2	0.4

[a] Mean exposure score from 0 to 100
[b] Percent of exposed people

Two matrices were built for each exposure, separately for men and women. In men, the number of tree terminal nodes or HEG varied according the exposure considered from 5 to 44 (from 2 to 30 in women). Age interfered twice in HEG construction (different levels of exposure according to age, in a same HEG) for both men and women.

Discussion

This study is the first attempt to construct JEM in the area of job stress factors in France. To the best of our knowledge, three other JEM have been developed (4,1,3) in the field of occupational stress. As in our study, they were based on existing survey data, and for one of them on expert judgement.

In these previous studies, evaluation of exposure was based on mean scores calculated by occupational category which do not always allow to have reliable evaluations when there are few people in some categories. The method of construction used in our study has the two following advantages: it provides an exposure assessment for occupational categories in which there are only few people and it takes into account the hierarchical structure of the French occupational classification codes in the HEG construction.

Thus, our results provide evaluation of exposure to job stress factors for all the 455 categories of the French occupational classification for men and women separately.

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Characterisation of the microbial community in indoor environments: a chemical-analytical approach

Sebastian A, Larsson L

Department of Medical Microbiology, Dermatology and Infection,
Division of Bacteriology, Lund University, e-mail: aleksandra.sebastian@mmb.lu.se

Introduction

Assessment of indoor air quality (IAQ) in terms of microbial flora is important since inhalation of air-borne microorganisms has been associated e.g. with asthma and allergy. It is well known that only a small fraction of the total microbial flora in an indoor environment is culturable. Direct microscopy is insufficient as regards specificity. Therefore new, non-culture based analysis methods are required.

Methods

We focus on certain unique microbial markers:

1) muramic acid (MuAc), marker of bacterial peptidoglycan/biomass;
2) 3-hydroxy fatty acids (3-OH FAs) with 10-18 carbon chains, markers of lipopolysaccharide (LPS, endotoxin) of Gram-negative bacteria;
3) branched-chain fatty acids - differ between Gram-positive bacteria;
4) ergosterol, marker of fungal biomass.

An integrated method was developed for the determination of these markers in organic dust. For all these analyses only two dust samples are required, one for muramic acid, 3-OH fatty acids and branched-chain fatty acids, and another for ergosterol.

C^{13}-labelled blue-green algae are used as an internal standard for the first three markers and dehydrocholesterol for ergosterol.

In brief, samples are subjected to acid/alkaline hydrolysis, purified with extractions and derivatized for rendering them suitable for analysis with gas chromatography - ion-trap mass spectrometry (GC-MSMS)(1).

Results

The studied markers can be detected in air-borne and settled house dust samples even when present in amounts of only a few nanograms. Figure 1 shows: muramic acid (a), 3-OH fatty acids (b), branched-chain fatty acids (c) and ergosterol (d) in the studied dust sample.

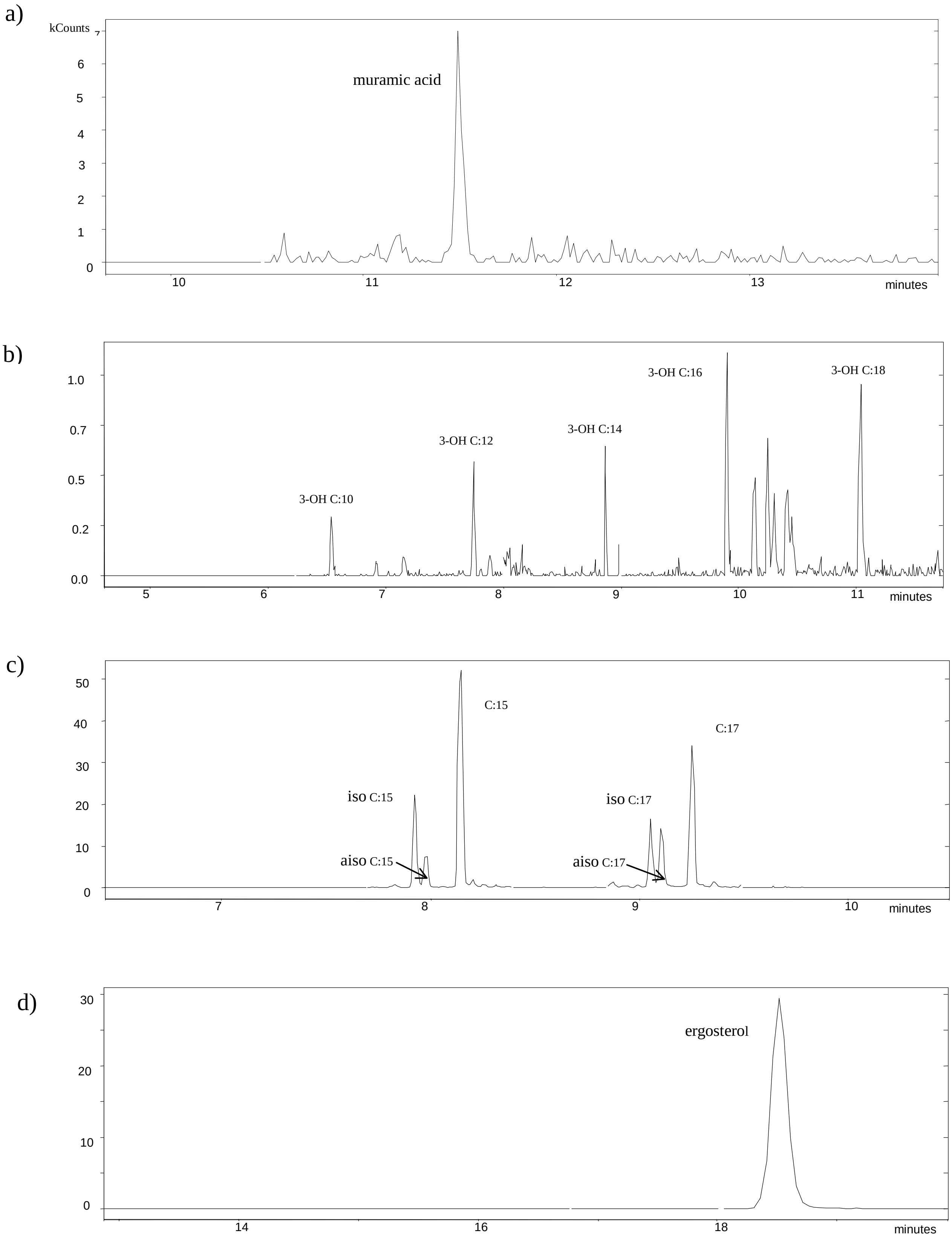

Figure 1. a) muramic acid, b) 3-OH fatty acids, c) branched-chain fatty acids, d) ergosterol, in a house dust sample.

Discussion and conclusion

The described method can be used for characterisation of microbial communities in indoor environments as regards fungal biomass, relative amounts of Gram-negative/Gram-positive bacteria, and information about the bacterial species present (see for example reference 2). Our future research will include studies on the relations between marker patterns, dampness of the buildings and health effects.

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Occupational exposure to blood in health care workers

Krstev S, Vidakovic A.

Clinical Center of Serbia, Institute of Occupational Health, Belgrade, Yugoslavia, e-mail: srmena@EUnet.yu

Introduction

The specific occupational risks in health care workers (HCW) are hepatitis B virus (HBV), hepatitis C virus (HCV) and HIV infections. In the majority of cases occupational transmission occurs by parentheral needlestick inoculation, by other sharp instrument injury or through mucous membranes. We performed an investigation to establish the prevalence of HBV and HCV infections in health care workers, and to see the routine practice while handling blood and other blood products. In this study, the aim was to establish the frequency of exposure to blood and of sharp needlestick injuries and mucous membrane contact, as well as the other risk factors for these injuries.

Methods

A sample of health care workers (HCW) from different hospitals (cardiovascular, orthopedics, psychiatric, occupational health) was selected in order to estimate the prevalence of blood borne hepatitis B (HVB) and hepatitis C (HVC) infections, using self-administered questionnaire. Total of 394 HCW responded with response rate 46.7% (nurses 48.7%; physicians 42.5%). For this study, a sample of HCW occupationally exposed to blood (N = 316) was included. Among them, nurses were more prevalent than physicians (Table 1), as well as females compared to the males. They were engaged in various departments as follows: operating theatre, intensive care, invasive diagnostics, ward, outpatient clinic, etc.

Table 1. Main characteristics of the examined health care workers

	Physicians	Nurses
Number	47	269
Males	36 (76.6)	20 (7.4%)
Females	11 (23.4%)	249 (92.6%)
Age - mean (range) yr.	40.2 (31-65)	34.8 (19-62)
Exposure duration - mean (range) yr.	10.9 (1-35)	12.2 (0-40)

A self administered questionnaire was used to obtain different data regarding possible HVB and HVC infections, as well as frequency of blood contact during the work and frequency of needlestick or mucous membrane exposures, use of protection during the work, HBV vaccination, etc.

Results

Almost the half of the physicians have the blood contact from 1 to 14 times per week (Table 2), compared to 6.5% of nurses. On the other hand, more than a half of nurses are exposed to the patient's blood more than 50 times per week (chi-square = 62.32; p = 0.0000). The average number of blood contact per week is almost 4 times higher in nurses than in physicians (H = 35.363; p = 0.0000).

Less accidental needlestick or mucous membrane exposures per year have been reported by physicians than nurses. One third of all nurses had more than 15 needlesticks per years compared to 15% in physicians (chi-square = 11.56; p = 0.009). Mean number of accidental injuries in nurses is 23.6 per years, more than twice higher than in physicians (H = 7.931; p = 0.0049). When the more frequent and less frequent blood contact were compared, the risk for needlestick injury was higher in both the physicians and nurses when the blood contact is more frequent (RR = 9.43; 95% CI 2.43-36.57 and RR = 3.76; 95% CI 1.35-10.48, respectively).

Table 2.

	Physicians	Nurses
Blood contact		
* 1-14/week	22 (46.8%)	16 (6.5%)
* 15 - 49/week	18 (38.3%)	100 (40.3%)
* > 49/week	7 (14.9%)	132 (53.2%)
–Mean (range) per week	30.1 (4 - 200)	106.9 (4-1000)
Needlestick or mucous membrane blood exposure		
*None	5 (10.6%)	17 (6.3%)
*1 - 4	27 (57.4%)	96 (35.7%)
*5-14	8 (17.0%)	63 (23.4)
*> 14	7 (14.9%)	93 (34.6%)
–Mean (range) per week	9.7 (0 - 72)	23.6 (0 - 144)

While handling blood, protective gloves have not been used regularly. There is a difference between physicians and nurses, in the way that 80% of physicians compared to 35% nurses use them often, while never wear them 15% and 10%, respectively. Risk for more frequent needlestick injuries is not elevated for those that are not wearing protective gloves compared to those who use them often neither in physicians (RR = 0.42; 95% CI 0.06 - 2.70) nor in nurses (RR = 0.91; 95% CI 0.61 - 1.35).

Discussion

Our results show that the needlestick injuries occur more often in nurses than in physicians. Similar has been found in other investigations (1,2,3). More knowledge on modes of transmission of blood borne infections and preventive measures could be an explanation for that. However, we found that risk for needlestick injuries is elevated when the daily contact with blood is more frequent, and that was significant both for physicians and nurses. The average number of incidents in our study is much higher than found in some others (2,4,5). Wearing gloves while handling with blood, was not related to the frequency of injuries.

This study is completely based on the data from the questionnaire. The response rate is low, particularly for physicians. Some answers might be with error, like reporting 144 injuries per year. Questionnaires are not much in use in Yugoslavia, and people are not used on them. We suppose that some subjects do not understand well the questions, so the answers are biased. This has to be changed in the further studies to obtain more reliable data on exposure to blood.

Our data have shown that third of all nurses never wear protective gloves handling blood. Reporting needlestick and other accidental injuries is not mandatory and not regulated.

Conclusions

In spite of all shortcomings our data have found more needlestick injuries in nurses than in physicians, and both are higher than found in other studies. We also noticed that the incidents are more frequent when the blood contact is more frequent. The method of assessing exposure to blood must be improved in order to perform adequate preventive measures and prevent possible occupational blood borne infections in health care workers.

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Assessment of exposure to solvents - a comparison of exposure metrics

Semple S [(1)], Cherrie JW [(1)].

(1) Department of Environmental and Occupational Medicine, University of Aberdeen, Aberdeen, AB25 2ZP, UK. Email: sean.semple@abdn.ac.uk

Introduction

To determine possible chronic health effects from exposure to solvents, it is necessary to be able to characterise lifetime exposure. Exposure misclassification can reduce study power and failure to identify possible causal associations. The aim of this work was to utilise two recently developed subjective exposure assessment techniques to determine both inhalation and dermal solvent exposures and to compare these results with other simpler exposure assessment methods.

Methods

One hundred and twenty men participated in the study. The mean age was 54 years (range 28 to 79). Ninety-two had worked in the paintshop of a local dockyard with a further 28 recruited as non-painters from the local community. Exposure assessment was carried out using two previously developed strategies to estimate both inhalation (1) and dermal (2) exposure to solvents. The exposure reconstruction strategy employed occupational information gathered from all subjects using a self-completed questionnaire and detailed interviews. Data on working practices, processes and control measures was utilised. Data on solvent levels were obtained from a literature review and records of paint types and monitoring data collected in the workplace during the 1980's. Workplace visits were used to help understand the process and current working conditions.

The process of estimating personal exposures in each job code took account of changes over time in work practices and methods. The 25 job codes were subdivided into 89 job code eras. In turn, each was further divided into primary job tasks and a total of 127 job tasks were produced.

Inhalation and dermal exposure estimates for each task were completed and summed according to the time fraction spent on the task to produce a time-weighted average solvent exposure for the 89 job code eras. The job code era exposures were applied to the work history database and the lifetime solvent exposures calculated. A similar procedure was used to evaluate non-occupational exposures. The cumulative exposure was expressed as the equivalent number of years work at the current UK Occupational Exposure Limit (OEL.years) for that particular solvent mixture. The sum of these fractions was used as a cumulative lifetime solvent index.

The final cumulative exposure metric was compared with three simpler metrics used in previous investigations of these painters. This included 'Ever/Never' worked in the dockyard paintshop, years of employment in the paintshop, and finally the subjective exposure assessment carried out purely in terms of occupational inhalation exposure.

Results

Total cumulative solvent exposures ranged from 0 to 64.1 OEL.years with a mean value of

13.5. The ever/never categorical classification of workers' exposure indicated that the group who had never worked in the paintshop typically had very low cumulative exposures (mean 0.53 OEL.years range 0-8.2). However, those classified as having worked in the paintshop had carried out a diverse range of activities for an equally wide range of employment durations and as a result had a wide range of cumulative exposures (mean 17.5 OEL.years range 0-64). Indicating that a large fraction of these workers would be misclassified by this method.

The surrogate metric of years of employment in the dockyard was a similarly poor predictor of lifetime cumulative exposure as indicated by a Pearson correlation coefficient of 0.51 and figure 1.

The assessment of inhalation exposures provided an excellent prediction of lifetime cumulative solvent exposure in OEL.years as shown in figure 2. The Pearson correlation coefficient is 0.99. Such a strategy however fails to identify non-occupational exposures and the solvent dose resulting from dermal uptake. We found that the fraction of additional solvent exposure from non-occupational and dermal sources was, on average, 13% and ranged from 0-70%. This additional fraction may have important repercussions in terms of epidemiological analyses and limit setting.

Conclusions

Simple exposure assessment strategies based on categories such as 'ever' or 'never' employed in an industry or surrogate metrics such as years of employment are likely to create considerable exposure misclassification. When considering cumulative lifetime exposure to a chemical that may be experienced in many occupational and non-occupational settings and where exposure may be received by more than one route, a full characterisation of exposure is necessary. The methodology employed in this study is particularly useful where limited measurement data exist.

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Figure 1: Graph of cumulative solvent exposure against duration of dockyard employment

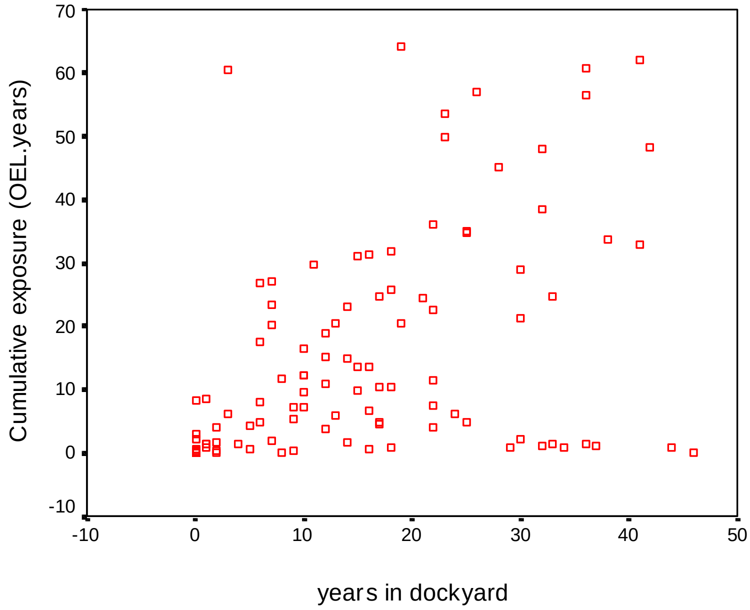
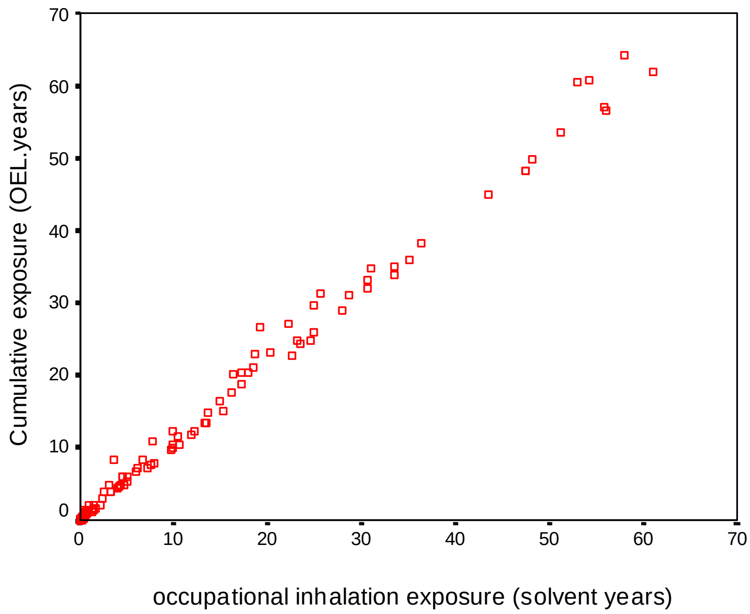


Figure 2: Graph of cumulative solvent exposure against occupational solvent exposure by inhalation only



Peak exposures to styrene in Quebec fibreglass reinforced plastic industry

Vyskocil A [(1)], Thuot R [(1)], Turcot A [(2)], Gérin M [(1)], Viau C [(1)]

[1.] *Department of Environmental and Occupational Health, Université de Montréal, Québec, Canada, e-mail: adolf.vyskocil@umontreal.ca*
[2.] *Department of Public Health Chaudière-Appalaches, Lévis, Canada*

Introduction

The manufacture of fibreglass reinforced plastic products may give rise to substantial occupational exposure to styrene. Using hand lay-up and spray-up techniques, employees work near large styrene emitting surfaces. During these operations, ten to 15 percent of styrene can evaporate into the work place air. Short-term peak exposure is frequently observed in this industry. Such exposure pattern needs further consideration in terms of styrene neurotoxicity. The aim of this pilot study was to examine the exposition profiles in 10 fibreglass reinforced plastic plants and to aid in the selection of industrial cohorts to be included in a future epidemiological study. The emphasis was placed upon the analysis of peak concentrations.

Methods

Exposure data were collected in 10 small, medium-sized and large plants in Quebec, producing boats, showers, baths, parts of truck or bus bodies, balconies and various small objects. In each plant, exposure of workers was monitored during the various tasks. A task is defined as a working cycle during which a lamination of one layer is completed.

The concentration of airborne styrene in the breathing zone was «continuously» recorded with a portable gas chromatograph **(**Varian Chrompack CP-2003) The instrument was calibrated with standard mixtures 21 – 852 mg/m^3 styrene in air. Sample were taken and analysed every 1.2 minutes during entire working cycles, to obtain styrene peaks exposure data. Work practices were recorded simultaneously. A peak concentration was defined as a short-term concentration exceeding at least twice the average of the personal 8-hour TWAs most recently observed in this plant. To assess the average 8-hour exposure in each plant, the data set included 4-hour TWA concentrations measured using passive dosimeters by the local community health hygiene teams.

Results

Presently, 5 of 10 plants have been evaluated : two small plants (2 and 6 directly exposed workers), two medium-sized plants (15 directly exposed workers) and one large plant (45 directly exposed workers). Small plants used between 200 and 800 kg styrene resin/day, the medium plant used 1100 kg/day, and the large plant 3400 kg/day. The styrene content in the resin varied between 20 and 70 percent (by weight). The volumes of the lamination rooms varied from 2500 to 20 000 m^3. The operations were generally much the same in all plants and the two major operations were hand lay-up and spray-up. Two plants used robots for spray-up of some parts.

Big structures were laminated in large, open areas without separation into different sections, i.e spray-up molding was done in an open area of plants. Laminators performed their tasks in many instances in close proximity to the chop gun operators and while the “gunner” was spraying the resin. Gel coaters, always wearing a respirator,were not evaluated. The use of respirators by other workers was not observed. All the plants had both local and/or general exhaust ventilation. In all plants the entire environment was controlled by a central dilution ventilation system consisting of exhaust fans and conditioned make-up air. In some instances, the ventilation system was aided by the use of circular fans which developed directional air flow patterns. There was no large accumulation of styrene at the worksites. In all plants, there were no differences between summer and winter exposures of workers.

Table 1 shows a summary for 5 fibreglass facilities evaluated. These data indicate substantial variability of exposures within the industry. The average 4 hour-TWA exposure in 5 plants ranged between 112 and 374 mg/m^3. There was no relationship between the average exposure and the size of plants. The heaviest exposure took place during the lamination of boat shell molds. A comparison of the sampling data with the Quebec recommended 8-hour TWA exposure limit shows that 50 to 100 % of workers sampled in 4 plants would be exposed to concentrations above the limit level of 213 mg/m^3.

The measurement of the short-term concentrations during the tasks showed a great variation in the styrene concentrations over different tasks. In 4 plants, the average concentrations over the duration of the measured tasks were under the Quebec recommended short-term limit of 426 mg/m^3 with one exception. Concentrations over 426 mg/m^3 were registered for X persons in one plant with the heaviest exposure. The duration of the tasks varied between 3 and 67 minutes with 66 % of the tasks under 15 minutes, 26 % between 15 and 30 minutes and only 8 % over 30 minutes.

No peak concentrations were observed in one large and one small plant with average exposures over the VEMP. In the other 3 plants the peak concentrations were 2 – 16 times the mean concentrations. Surprisingly, the highest peaks mounting up to 1781 mg/m^3 were registered for 35 % of the tasks in the plant with the lowest average exposure. The duration of peaks varied between 2 and 11 minutes.

Table 1. Summary data on exposure of workers to styrene in 5 Quebec plants

PLANT		A- large	B-small	C-small	D-medium	E-medium
4-hour TWA conc.	Number of samples	14 6	2	9	4 9	4
	Conc. (mg/m^3)	243 220	218	217	116 112	374
Average conc. during tasks	Number of tasks	10 3	7	7	7 13	
	Duration (minutes)	3-67 14-16	3-10	3-15	4-66	
	Min.-max. (mg/m^3)	55-294 206-215	73-159	63-233	57-575 64 – 256	
Peak conc. during tasks	Number of peaks	- -	-	3	5 12	
	Duration (minutes)	- -	-	2-6	3-5 2-32	
	Min.-max. (mg/m^3)	- -	-	459-546	247-1657 213-1781	
	Peak/ average	- -	-	2.1–2.5	2.1-14.3 2.3-15.9	

Two independent sectors of the plant A and D were evaluated separately

Conc. = concentration

Discussion and conclusion

This investigation in the fibreglass reinforced plastic industry showed that considerable styrene concentrations are involved in the manufacturing processes. The concentrations while doing a specific task (spray-up and hand laminating) did not differ very much between large and small plants. The major factor determining the overall level of exposure to styrene within each plant was (1) the distance between the unprotected worker and the large surfaces from which styrene evaporates (2) the effectiveness of the plant's ventilation systems.

It has been shown that styrene exposure may affect the function of both the central and the peripheral nervous system. In the present study workers were exposed to a number of peak levels up to 1781 mg/m^3 in spite of the low TWA concentration of about 112 mg/m^3. These results indicate that even in plants in which the 8-hour TWA is relatively low, peak concentrations much above recommended short-term limit can be reached. This may raise concerns regarding potential central nervous system effects in the workers.

This study was supported by IRSST (Québec, Canada).

Estimating exposures in asphalt industry for an international epidemiological cohort study of cancer risk

Burstyn I [1,2], Boffetta P [2], Kauppinen T [3], Heikkilä P [3], Svane O [4], Partanen P [3], Stücker I [5], Frentzel-Beyme R [6], Arhens W [6], Merzenich H [6], Heederik D [1], Hooiveld M [1], Langård S [7], Randem B [7], Järvholm B [8], Bergdahl I [8], Shaham J [9], Ribak J [9], Kromhout H [1]

(1) Occupational and Environmental Health Group, Institute for Risk Assessment Sciences (IRAS), Utrecht University, Utrecht, the Netherlands, e-mail: I.Burstyn@vet.uu.nl;
(2) Unit of Environmental Cancer Epidemiology, International Agency for Research on Cancer, Lyon, France;
(3) Finnish Institute of Occupational Health, Helsinki, Finland;
(4) Danish Working Environment Service, Copenhagen, Denmark;
(5) INSERM U.170, Villejuif, France;
(6) Bremen Institute for Prevention Research and Social Medicine (BIPS), Bremen, Germany;
(7) Centre for Occupational and Environmental Medicine, The National Hospital University of Oslo, Oslo, Norway;
(8) Department of Public Health and Clinical Medicine, Umea University Hospital, Umea, Sweden;
(9) Occupational Cancer Unit, Occupational Health and Rehabilitation Institute, Raanana, Israel.

Introduction

The International Agency for Research on Cancer has assembled a cohort of asphalt workers from eight countries. Asphalt workers in the context of the study were defined as individuals involved in handling of asphalt from its manufacture at asphalt mixing plants to its application in paving, roofing or waterproofing. Some of the employees in the companies of interest were also employed in building and ground construction. The study was prompted by an ongoing controversy about carcinogenicity of emissions derived bitumen, the binder used in the asphalt mix. The primary concern was whether lung cancer was associated with bitumen fume exposure. Thus, inhalation of other known and suspected carcinogens that are likely to exist in the study population, such as coal tar, polycyclic aromatic hydrocarbons (PAH), silica dust, diesel fume, and asbestos, also had to be assessed. Exposure assessment was designed to be specific for country, time period, company and job class, since we anticipated that production characteristics nested within these categories affected exposure pattern. The objective of this report was to describe development of an exposure matrix for known and suspected carcinogens for a multi-centric international cohort study of asphalt workers.

Methods

Production characteristics in the companies enrolled in the study were ascertained via a questionnaire and consultations with industry representatives and industrial hygienists. Exposures to bitumen fume, organic vapour, polycyclic aromatic hydrocarbons (PAH), diesel fume, silica and asbestos were assessed semi-quantitatively using company questionnaires and expert opinions on relative exposure intensities. Quantitative exposure estimates for road paving workers were derived by applying regression models (based on monitoring data) to exposure scenarios identified by company questionnaires. Frequency of coal tar use was derived directly from the questionnaires. All estimates were standardized to an 8-hour workshift. The resulting exposure matrix was time period-, company- and job class-specific.

Results

Most of 203 firms from eight countries enrolled in the study were engaged in asphalt paving (51%) and mixing (94%). Coal tar use was most common in Denmark and the Netherlands, but it its frequency declined dramatically since between 1960 and early 1970's; the practice is now obsolete in the studied countries. The highest bitumen fume, organic vapour and PAH exposures occurred among roofers and waterproofers. Exposure matrix identified non-monotonic historical decrease in exposures to all agents except for silica and diesel exhaust (Figure 1). Complex pattern of assessed bitumen fume exposures is illustrated in Figure 2**,** and it emphasizes difference in historical exposure patterns among countries. Bitumen fume and coal tar exposures were moderately correlated (r=0.34), with the highest correlation for pre-1960 time period (r=0.47). There was a very strong correlation among bitumen fume, organic vapour and PAH exposures (r=0.78 to 0.98).

Figure 1

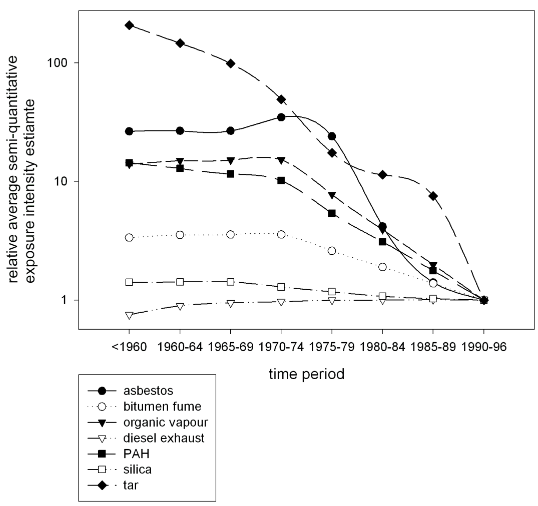
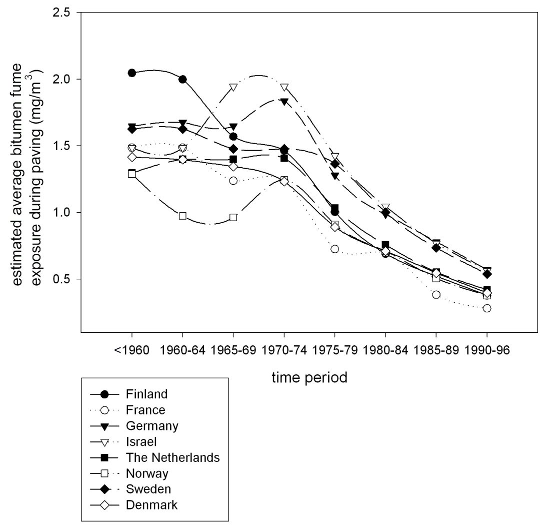


Figure 2



Conclusions

We cannot distinguish among cancer risks associated with bitumen fume, organic vapour and PAH exposures. Adjustment of risk estimates for coal tar exposure should be possible. Our approach produced a data-driven exposure matrix that can be challenged in future studies and easily re-estimated. We have demonstrated that quantitative exposure assessment is possible in multi-centric occupational cohort studies if sufficient occupational hygiene monitoring data can be recovered and subjected to statistical modeling. Complex exposure patterns identified through the exposure matrix could not have been developed with any degree of certainty by relying exclusively on "expert evaluation" methodology.

Does current rather than cumulative dust exposure predict onset of asthma or chronic bronchitis among paper mill workers?

Henneberger PK [(1)], Torén K [(2)], Hoffman CD [(1)], Sallsten G [(2)]

[1] *Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health, CDC, Morgantown, WV, USA, e-mail: pkh0@cdc.gov*
[2] *Department of Occupational Medicine, Sahlgrenska University Hospital, Göteborg, Sweden, kjell.toren@ymk.gu.se*

Introduction

Current dust exposure might be a more relevant metric than cumulative dust exposure when studying asthma and other respiratory conditions. In a previous retrospective cohort study of workers from a soft paper mill in Sweden, asthma was not associated with cumulative dust exposure, and the effect of current exposure was not addressed (1). Also, unpublished analyses of the same data revealed that chronic bronchitis was not associated with cumulative dust exposure. We re-analyzed these data to investigate whether current dust exposure predicted the onset of either asthma or chronic bronchitis. Based on a prior study of air samples from the mill, the dust contained no asbestos and less than 1% silica, and therefore fulfilled the criteria for a particle not otherwise regulated (PNOR) as defined by the USA Occupational Safety and Health Administration (OSHA). A final aim of this study was to investigate whether the OSHA PNOR standard of 15 mg/m^3 total dust was protective for workers in a soft paper mill.

Methods

The subjects included 972 people who were alive in 1987 and had worked at least one year in the paper mill during 1960 to 1987 and 781 others living in the mill town in 1987. Subjects entered follow-up at either age 18 or 1960, whichever was later. Follow-up ended at illness onset for cases and 1987 for non-cases. Subjects completed a postal questionnaire that inquired about the occurrence of asthma since age 15 and respiratory symptoms characteristic of chronic bronchitis. Those who reported these conditions were asked to indicate year of onset. The questionnaire also inquired about work history, cigarette smoking, and childhood atopy. Proportional hazards regression was used with time-dependent outcome and paper-mill-exposure variables. Potential confounders that were considered included both time-dependent variables (e.g., cigarette smoking status) and variables that did not change during follow-up (e.g., childhood atopy).

Historical measurements of airborne dust in the paper mill were combined with self-reported work histories to get annual estimates of current and cumulative exposure for each subject. Based on the available dust measurements, each combination of job title and calendar year was assigned to one of five exposure ranges: 0, >0 to <1, $\geq$1 to <5, $\geq$5 to 10, and >10 mg/m^3. The person-years of current paper mill work were approximately equally split between the exposure ranges of >0 to <1 and $\geq$1 mg/m^3, and these two ranges were considered low and high current exposure, respectively. To estimate cumulative exposure, each year of follow-up for a subject was characterized by one of five exposure levels based on the approximate mid-points of the current-exposure ranges: 0, 0.5, 3.0, 7.0, and 15 mg/m^3. These annual values were then summed to determine an individual's cumulative exposure, expressed in units of mg/m^3-year. The person-years of current mill work were approximately equally split between the cumulative exposure ranges of >0 to 9.5 and $\geq$9.5 mg/m^3-year, and these two ranges were considered low and high cumulative exposure, respectively, among current workers. The relatively small number of person-years in the category of previous mill employment discouraged further division based on cumulative exposure.

Results

There were 44 people with onset of asthma and 119 with onset of chronic bronchitis during follow-up. The incidence of asthma varied little among the current exposure categories of unexposed (1.2 cases per 10^3 person-years), low-exposed (0.6 cases/10^3), high-exposed (1.7 cases/10^3), and previously employed (2.1 cases/10^3), and regression analysis confirmed there was no statistically significant difference between unexposed subjects and each of the other three categories. In contrast, the incidence of chronic bronchitis varied by current exposure level: unexposed 2.2 cases/10^3, low-exposed 2.8 cases/10^3, high-exposed 6.4 cases/10^3, and previously employed 6.3 cases/10^3. The elevated incidence among those with high current exposure was not attributable to the experience of those with very high exposure. In fact, of the 37 cases in the high-current-exposure category ($\geq$1 mg/m^3), 35 were in the exposure range 1 to <5 mg/m^3 with an incidence of 8.5 cases/10^3. Incidence was also elevated relative to the unexposed for current mill workers when they were categorized by low and high cumulative dust exposure (4.6 and 5.3 cases/10^3, respectively). To clarify the relative contribution of current and cumulative dust exposure, the person-time experience of current workers was classified by both simultaneously. Based on regression, hazard ratios were consistently elevated for high current exposure but not high cumulative exposure (Table 1). Further analyses with chronic bronchitis revealed an elevated hazard ratio for current mill work (1.9, 95% CI 1.2, 2.9) independent of smoking status, while an elevated hazard ratio for previous mill work was limited to current smokers (3.8, 95% CI 2.0, 6.9).

Table 1. Proportional hazards regression model for chronic bronchitis[1]

Current/Cumulative Exposure[2]	Hazard Ratio (95 % CI)	P-values
None/None	1.0	
Low/Low	1.3 (0.7, 2.4)	0.41
Low/High	0.9 (0.2, 3.9)	0.93
High/Low	2.7 (1.3, 5.5)	0.01
High/High	2.1 (1.2, 3.5)	0.01
Previously employed	2.5 (1.5, 4.2)	<0.01

[1] Controlling for atopy as a child and current smoking.
[2] The cut points between low and high exposure were 1 mg/m^3 for current exposure and 9.5 mg/m^3-yrs for cumulative exposure.

Discussion

We were able to use historical measurements of dust exposure to estimate job- and time-specific current exposures in a soft paper mill. Current dust exposure at $\geq$1 mg/m^3 predicted onset of chronic bronchitis but not asthma. The findings for chronic bronchitis suggest that the OSHA PNOR standard of 15 mg/m^3 total dust may not be protective for workers exposed to paper dust.

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Measurements of mercury exposure in end-exhaled (alveolar) air

Sällsten G [1], Barregård L[1]

[1.] *Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg, Sweden, e-mail: gerd.sallsten@ymk.gu.se*

Introduction

Inhalation is the most important uptake route for mercury vapour. Mercury (Hg) is readily absorbed through the lungs and distributed to various organs before elimination, mainly by urinary and faecal excretion, but also by exhalation and sweat. For biological monitoring mercury in urine or blood can be used to assess the exposure. A method has also been developed for determination of trace amounts of mercury in end-exhaled air (1). The usefulness of this biological marker for assessment of mercury exposure has been investigated.

Subjects and methods

Mercury in end-exhaled air was investigated in 10 subjects without amalgam fillings, in 32 subjects with amalgam fillings and in four occupationally exposed subjects (without amalgam fillings). In the group of 32 subjects, 17 subjects were frequently using chewing gum, on average 5 hours per day. The remaining 15 subjects had similar amalgam burden as the chewers. Among subjects with amalgam fillings we also determined mercury in plasma and urine.

In two of the occupationally exposed subjects mercury in end-exhaled air was determined immediately after end of work. In the other two occupationally exposed subjects, repeated measurements of Hg in end-exhaled air were performed after end of exposure. In these individuals the half-life of the slow elimination phase was calculated using a one-compartment model.

As ethanol increases the levels of Hg in end-exhaled air (2) no alcohol intake was allowed for eight hours before the investigation.

Mercury vapour was preconcentrated by amalgamation on sampling traps filled with gold. A small air volume (100 ml) was collected at the end of an oral exhalation and repeated sampling was performed up to five times. For subjects with amalgam fillings, the air sample was collected after exhalation through the left nostril in order to avoid contamination of mercury released from their amalgams. A specially designed sampling device, consisting of a modified peak expiratory flow meter, was used (1). Mercury was determined using PSA (PS Analytical, Orpington, UK) Sir Galahad instrument consisting of a two-stage amalgamation technique combined with atomic fluorescence detection. Hg in plasma and urine was determined by an automized cold-vapour atomic fluorescence technique after digestion with acids.

Results

In all 10 subjects without amalgam fillings mercury in end-exhaled air could be detected and, as expected, higher mercury levels were found in subjects with amalgam fillings (Table1). Chewers had significantly higher levels than non-chewers and in subjects with on-going occupational exposure the mercury concentrations were even higher.

Table1. Mercury concentrations in end-exhaled air among different exposure groups

Subjects	Mercury in end-exhaled air, pg/L Median	Range
10 without amalgam fillings	4	3-12
15 with amalgam fillings	19	8-35
17 chewers with amalgam fillings	50	11-287
2 with on-going occupational mercury exposure, no amalgams*	1100	900 and 1300

*The two other occupationally exposed subjects are presented in Table 2.

In the chewers, mercury levels in plasma, urine and end-exhaled air were significantly higher as compared with non-chewers. Among the non-chewers a significant correlation between Hg in plasma and Hg in end-exhaled air was found (r_s=0.74 p=0.002). Among chewers, high correlations were found for mercury in end-exhaled air and mercury in plasma (r_s=0.92 p=0.0001) and urine (r_s=0.94 p=0.001), respectively.

A slow elimination phase of mercury was seen in end-exhaled air in the two subjects after occupational exposure (Table 2). The half-life was 3.5 and 1.5 months, respectively.

Table 2. Mercury concentrations in end-exhaled air after end of occupational exposure.

Subject	Time after exposure (months)	Mercury in end-exhaled air, pg/L
1	4	71
	5	57
	6.8	44
	14.4	7
2	2	75
	3	63
	4.8	26
	24	7

Discussion

Mercury in end-exhaled air could be detected also in very low exposed individuals. The procedure is fast and simple but samples have to be taken in an uncontaminated area. It is necessary to avoid any alcohol intake for at least eight hours before determination of mercury in end-exhaled air since ethanol causes an inhibition of the oxidation of Hg^0 to Hg^{2+} in tissue. In an earlier study (2) an increase of Hg in end-exhaled air was seen also after a very low dose of ethanol (0.1 g/kg body weight).

The method for determination of mercury in end-exhaled air could be a valuable tool to assess short-term Hg exposure, especially if no blood sample can be collected. Mercury in urine is not a good biomarker after short-term exposure. Peak exposure can be detected in end-exhaled air if sampling is performed in connection with the exposure. In blood and urine there is a damping effect and peak exposures are therefore difficult to detect.

A good correlation was found between Hg in plasma and Hg in end-exhaled air in subjects with a steady-state mercury exposure. Mercury in end-exhaled air reflects the concentration of inorganic mercury in blood. Therefore, if inorganic Hg is of interest, Hg in end-exhaled air could be preferred compared to determination of total mercury in blood, which yields the sum of inorganic and organic mercury.

In subjects with long-term exposure, an increased level of Hg in end-exhaled air could be seen even some months after end of exposure. The half-life for the slow phase is in accordance with the half-life for inorganic mercury in humans for the whole body and the kidneys.

Conclusion

Mercury in end-exhaled air is a new non-invasive biological marker for inorganic mercury exposure, of special value at peak exposures.

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Exposure-response relationship of hexahydrophthalic anhydride using total plasma protein adducts as index of long-term exposure

Rosqvist S, Nielsen J, Welinder H, Rylander L, Jönsson BAG.

Department of Occupational and Environmental Medicine, Institute of Laboratory Medicine, University Hospital, SE-221 85 Lund, Sweden, Phone: +46 46 17 31 48, Fax: +46 46 14 37 02, E-mail: seema.rosqvist@ymed.lu.se

Introduction

Organic Acid Anhydrides are a group of industrial chemicals used intensively in the production of a range of everyday products such as plastics, electronic components and paints. They are also known to be one of the most powerful low molecular weight occupational IgE sensitisers (1). The aim of this study was to quantify long-term exposure to a particularly sensitising anhydride, hexahydrophthalic anhydride (HHPA) using the total plasma protein adducts (TPPA) of the anhydride (H-P) as an index of exposure and to relate this to specific immunoglobins (H-Ig) and work-related symptoms.

Subjects and methods

A total of 139 workers from a factory producing electrical components containing epoxy resin which uses HHPA as hardner, were studied. These workers were also exposed to an another anhydride, methylhexahydrophthalic anhydride (MHHPA). There was no correlation between HHPA and MHHPA exposures. Plasma was obtained from these subjects and exposure was estimated by quantification of H-P using a recently published gas chromatography-mass spectrometery (GC-MS) method (2). Serum from the subjects were analysed for H-IgE and H-IgG (1). Information on clinical symptoms were obtained from self administered questionaires and supplemented with interviews by a physician.

Data analysis

Using H-P as exposure index, the subjects were divided into four groups (I-IV), each containing the same number of workers. Percentage of workers positive for i) H-IgE, ii) H-IgG, iii) symptoms from the lower airways, iv) eyes v) nose and vi) suffering from nose bleed were calculated for each of the four groups.

Results

The levels of H-A and the corresponding air levels for HHPA are shown in table 1. Overall, about 20% of all workers were found to be positive for specific Igs (table 2). The percentage of exposed workers having various clinical symptoms ranged from about 8% to 27%.
A clear dose-response relationship was seen in most cases where increasing levels of exposure gave increasing percentage of workers with antibodies and symptoms. The HHPA exposure threshold level for the production of H-IgE was seen to be somewhat lower than that of H-IgG.

Discussion

The results from this study show that TPPA of HHPA is an excellent biomarker of long-term exposure. As well as being stable and easily measurable, it is capable of monitoring a range of exposure levels. Furthermore, it showed good dose-response correlations with immunological effects, such as levels of Igs and clinical symptoms of the allergic disease. It is noteworthy to emphasise that sensitisation had occured at exposure levels even at air levels of just a few $\mu g/m^3$.These results may allow determination of the threshold levels of exposure which cause sensitisation and thus will be useful in prevention of allergic diseases and for establishment of occupational exposure limits.

Table 1. Levels of H-A and the corresponding air levels.

Groups	H-P (fmol/ml)	HHPA Air levels ($\mu g/m^3$)
I	0-40	<1
II	40-100	1-3
III	100-300	3-9
IV	>300	>9

Table 2. Percentage of HHPA exposed workers with positive H-IgE, H-IgG and various clinical symptoms.

Exposure group	H-IgE	H-IgG	Lower airways symptoms	Symptoms from eyes	Symptoms from nose	Nose bleed
I	5.7	5.7	11.6	8.6	17.1	2.9
II	18.9	2.7	8.1	18.9	27.0	8.1
III	25.0	18.8	-	21.9	31.3	6.3
IV	28.6	42.9	22.9	34.3	34.3	14.3
All subjects	19.4	17.3	10.8	20.9	27.3	7.9

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Kinetic pilot studies with naphthalene

Heikkilä, P, Luotamo M, Riihimäki V

Finnish Institute of Occupatinal Health, Helsinki, Finland,
e-mail: pirjo.heikkila@occuphealth.fi

Introduction

Naphthalene is one of the most ubiquitous polycyclic aromatic hydrocarbons at work sites and in the environment. The aim of the pilot study was investigate the excretion of naphthalene as 1-OHN (1-hydroxynaphthalene) in humans following oral, dermal and respiratory exposure.

Methods

The volunteers were two healthy, non-smoking, adult research workers: a woman (age 43 years, weight 59 kg) and a man (age 46 years, weight 73 kg). The volunteers gave informed consent after being informed about the purpose of the study, the methods, potential risks, and their right to withdraw at any time. The pilot study followed the recommendations in the Declaration of Helsinki.

The subjects ingested a single dose of 0.5 mg/kg of naphthalene dissolved in 2 ml of ethanol and mixed with 0.2 l of a cola drink. The excretion of 1-OHN was followed by collecting all the voided urine in separate samples every 2nd hour for the first 8 h and spontaneous voids thereafter for 24 h. Control urine specimens were collected before the experiment.

The same two volunteers applied 0.5 mg/kg naphthalene dissolved in 2 ml diethylether on an area of about 23-25 cm^2 on their ventral forearm skin. The compound was kept under occlusion for 4 h and then washed away with soap and water. The excretion of naphthalene was followed by collecting all the urine voided every 4th hour for the first 8 h and then spontaneously for 24 h. Control samples were obtained before the experiment.

The same two volunteers were exposed by inhalation to a low level of naphthalene in a dynamic exposure chamber. Exposure was generated by mixing saturated naphthalene vapour with laboratory room air drawn into the chamber. The stability of the naphthalene concentration was automatically controlled by an infrared spectrophotometer (Miran 1A) and a processor which varied the feed rate of saturated naphthalene vapour as needed. The airborne concentration was confirmed by collecting samples onto three XAD-2 resin tubes. The samples were analysed by HRGC equipped with a FID detector. The concentration of naphthalene was 0.8 mg/m^3 by HRGC and 0.8-1.0 mg/m^3 by Miran 1A. The exposure time was 3 h 56 minutes.

For the estimation of uptakes via different routes, the following assumptions were made:

- Naphthalene was completely absorbed after oral ingestion.
- Inhalation uptakes were derived by assuming that lung ventilation of the volunteers was 15 l/min (sedentary activity), and that 50% of naphthalene was retained in the lungs.

No data were available on the retention of naphthalene following inhalation. The assumption of 50% was based on the knowledge that only a part (about 70 %) of inhaled air reaches the gas exchange part of the lungs, and that the pulmonary retention of vaporous lipid soluble aromatic compounds such as xylenes, toluene and benzene has been 56-59%, 53% and 50%, respectively, in humans.

Results

Table 1 shows the excreted amounts of the 1-OHN/24 h obtained in the two volunteers following oral, dermal and respiratory exposure to naphthalene. The urine voids collected by the male volunteer were incomplete after the ingestion of naphthalene.

Table 1. The naphthalene doses and the measured excretion of 1-OHN in the experimental study.

Route of exposure	Sex	Dose	Administered or estimated taken dose		Voided urine/24 h	Excreted urinary 1-OHN	Ratio, excreted/ taken or administered
		mg/kg	mg	µmol	L	(µmol)	
ingestion	m	0.5	36[a]	281[a]	0.6[b]		[b]
	f	0.5	29.5[a]	230[a]	1.4	112	0.49
dermal	m	0.5	36[c]	281[c]	1.3	4.4	0.02
	f	0.5	30[c]	234[c]	1.5	2.26	0.01
		mg/m^3					
inhalation	m	0.8	1.4[a]	11[a]	1.6	0.7	0.06
	f	0.8	1.4[a]	11[a]	1.9	0.94	0.09

[a] Estimated absorbed dose
[b] All urine voided in 24 h was not collected
[c] Administered dose

When the given assumptions were used for the calculation of respiratory uptake, in average 7% of the naphthalene taken via lungs was excreted in urine as 1-OHN. After dermal application, 1-2% of naphthalene applied on the skin was found in urine as 1-OHN. In order to estimate the amount of naphthalene that was absorbed through the skin, it was presumed that formation of 1-OHN is similar after dermal and inhalation absorption. Adopting the result from the inhalation study, i.e. that about 7% of naphthalene taken up was metabolised to 1-OHN, shows that 11-26% (mean 18%) of the naphthalene applied to the skin was absorbed. The reason for assuming that the metabolic fate of naphthalene is rather similar following absorption via the lungs and the skin, whilst it may be different after ingestion, is the likely firstpass metabolism in the liver after oral absorption.

Discussion

The fraction of ^{14}C-naphthalene absorbed through the skin after dermal application in rats was 50% (1), but no quantitative data on the absorption of naphthalene in humans are available. Neither are data available on the percentage of naphthalene excreted as 1-OHN in human urine after dermal exposure. The pattern of the metabolites of naphthalene differs among animals and humans (2), and therefore animal studies cannot be used for an extrapolation to humans. In this study, the ratio (7%) of excreted urinary 1-OHN to estimated uptake via lungs was used in calculating the percentage of naphthalene absorbed after dermal application.

The results confirm the importance of skin as a route of entry for naphthalene. A dermal dose of 118 mg of naphthalene has resulted in a urinary 1-OHN concentration of 600-2600 µmol/mol creatinine in psoriatic patients treated with coal tar ointment once a day for 4 weeks (3). Comparable results were obtained in this study: the dermal dose of 30-36 mg naphthalene resulted in a 1-OHN concentration of 300-550 µmol/mol creatinine.

The kinetics of naphthalene metabolism, after entry by different routes into the human body has not been studied before. The results of the pilot kinetic study with two volunteers confirmed that naphthalene enters the body by all routes of exposure - also the skin is a significant route of exposure - and that the fraction of naphthalene excreted in urine as 1-OHN depends on the route of exposure. According to the literature, PAH metabolism varies significantly between individuals. Thus the results from the two volunteers only provide suggestive, not necessarily representive information.

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Leukemia – the effect of occupational environment noxious action?

Todea A, Ferencz A

Department of Occupational Medicine, Institute of Public Health, Bucharest, Romania, e-mail: adystel@pcnet.ro

Introduction

The toxic effects of different exposures at workplaces on the haematopoietic and immune systems are of basic importance due to the time of exposure, lasting on average 8 hours daily during one-week (1).

So, there are many studies about immunotoxic and hematotoxic effects of occupational exposures, such as:

- porphyrinuria and porphyrias have been observed after exposure to chlorinated dibenzodioxines and hexaclorbenzene;
- aplastic anemia may occur after exposure to benzene, pesticides;
- neutropenia was marked after exposure to carbon disulfide, benzene and electromagnetic fields (3).

Leukemia seems to be influenced by different factors: geographical, ethnic, age, sex etc (2).

In spite of a lot of epidemiological studies, precise knowledge about the causes involved in disease's occurrence is still far from being clarified.

Methods

A case-control study has been performed for occupational risk factors of leukemia, based on 23 cases (average age: 37.15 ± 7.89 years) and 71 matched (average age: 37.96 ± 8.62 years).

The subjects were ill persons from a Hematology Clinic (hospitalized in the period January 1998 – December 1999).

Detailed data regarding to: sex, age, occupational route and exposure were analyzed through a detailed questionnaire and assessed by an occupational physician.

The data regarding the accurate diagnostic were filled in from the observation chart of each surveyed case. The odds ratios (OR) were computed using EPIINFO 6.04 program.

Results

The reference disease was leukemia, all types cases hospitalized in the Haematology Clinic.

Occupational route revealed work places were those questioned worked and in this way, we assessed the exposures to benzene, electromagnetic fields and pesticides.

Exposure data were gathered from the hygiene district specialists.

a. Leukemia-benzene

		Leukemia +	-	Total
Exposed to BENZENE	YES	6	8	**14**
	NO	13	72	**85**
		19	**80**	**99**

Statistical significance: OR=2,80; IC: 95% (1,28-6,14); p≤0,01

We found 6 cases of leukemia:

- 5 cases with acute lymphoblastic leukemia;
- 1 case with chronic myelogenous leukemia

b. Leukemia-electromagnetic fields

		Leukemia		
		+	-	Total
Exposed to electromagnetic fields	YES	3	2	**5**
	NO	16	78	**94**
		19	**80**	**99**

Statistic significance: OR=3,53; IC: 95% (1,52-8,19); p≤0,01

We found 3 cases of leukemia:

- 2 cases cu acute myelogenous leukemia
- 1 case cu chronic lymphoblastic leukemia

c. Leukemia-pesticides

		Leukemia		
		+	-	Total
Exposed to Pesticides	YES	2	2	**4**
	NO	17	78	**95**
		19	**80**	**99**

Statistic significance: not significant

We found 2 cases of chronic lymphoblastic leukemia.

We were unable to accurately assess the exposure to pesticides, because many subjects were using substances with unknown composition on their own land (small farmers).

We also assessed the influence of confounding factors, such as: residential environment (urban-rural), smoking, ionizing radiation (medical treatments), detergents in household use, traumatic episodes.

Discussion and conclusions

Our study adds credence to hypothesis that occupational exposure to benzene and electromagnetic fields are leukaemogenic agents.

Exposure to benzene causes mostly acute lymphoblastic leukemia and in the exposure to electromagnetic fields prevail myelogenous types.

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Renal dysfunction and the lead absorption at the exposed workers in Algerian battery factory

Boukerma.Z[(1)]., Touabti.A[(2)]., Maïza.A[(2)]., Bouakaz.M[(1)].

1. Service de Médecine du travail, Centre Hospitalier Universitaire Sétif 19000 Algérie
email : zboukerma@hotmail.com / zboukerma@yahoo.fr
2. Laboratoire central, Centre hospitalier universitaire Sétif 19000 Algérie.

Introduction

Although descriptions of chronic nephropathies secondary to lead exposure are ancient (Ollivier in 1863 and Lancereaux in 1882) they are lately admitted by everybody. Indeed, in different countries, various epidemiological, clinical and anatomical survey were accomplished, some of them are putting in doubt the reality of the renal toxic effect, whereas others are confirming it.

It is true that these nephropathies, that are a belated complications of the lead exposure, are difficult to appreciate. Indeed until these last years, the diagnosis of these renal diseases is essentially based upon the presence or the absence of a more and less important urinary protein that will condition the pursuit of the renal explorations.

But, currently, the present biochemical means allow the exploration of the glomerular and the tubular function. Indeed, it exists a hundred of urinary enzymes which permit the renal disease diagnosis (1-17) and provide a biochemical biopsy that give more information about the site and the importance of the renal lesion.

Method

This survey concerned 100 male workers. Their mean age was 43 years (interval 30-60 years) and their mean exposure was 15 years (interval 8-24). These workers have always been exposed to concentrations of lead in the atmosphere between 1.66 and 3.83 g/m^3 of air according to work post.

The aim of this survey is to study the renal lesion at workers, who have been chronically exposed to the inorganic lead. This survey consists to measure out the proteinuria, the microproteinuria and the urinary enzymes whose activity permit to evaluate the degree and the place of these renal damage. The enzymes dosage, after centrifugation, are made on the morning's urines.

These workers have the following characteristics:

- never have specific treatment of the lead poisoning
- have a normal arterial pressure
- have no urinary infections.
- don't present a mellitus diabetes

Otherwise the dosage of the blood "creatinine", and the dosage of the blood and urinary urea are normal.

Because of feasibility, the dosage is made on the 12 hours urines that are collected at 7 hours a.m.

Results

Concerning the proteinuria, the results show that only 3% of the exposed workers present a proteinuria with an average rate of 510 mg/24 hours. The microproteinuria is also present at 42% of workers with an average rate of 42.39 mg/24h (Table 1).

The rates of microproteinuria are variable and there is no correlation neither with the age of the workers nor with the period of the lead exposure Table 2).

If we compare the urinary activity of the enzymes, we note that the NAG and the GGT have a similar high activity. The intestinal alkaline phosphatase has an average activity; and the urinary activity of the LDH is very weak. Indeed, the urinary dosage of enzymes shows the presence of the NAG at 100% of workers with a fluctuation rates between 1.07 U/l and 57 U/l (Table 3). The GGT is also present at 98% of cases with a rate going between 1U/l and 37 U/l. The activity of the intestinal alkaline phosphatase is lower, and we find it at 23% of cases with a rates varying between 1U/l to 12 U/l. At Last the LDH, is present at only one person.

Table 1 - mean and peak (SEM) urinary enzymes (mg/l) and correlation according to age

Age	Microproteinuria	LDH	alcaline phosphatase	NAG	GGT
31-35	72.55 (87.38)	0	1.05 (2.83)	1.45 (0.29)	2.72 (1.27)
36-40	17 (25.79)	0	0.41 (1.00)	2.16 (0.14)	4.64 (7.60)
41-45	42.31 (73.68)	0.05(0.02)	0.36 (0.83)	2.68 (0.19)	3.63 (3.78)
46-50	42.88 (67.86)	0	0.11 (0.32)	3.58 (0.41)	3.63 (7.41)
51-55	38.61 (45.82)	0	0.23 (0.43)	5.31(0.57)	2.92 (1.11)
56-60	30 (31.11)	0	2.11 (2.71)	19.25 (6.13)	3.33 (2.94)
total	42,39 (64.85)	0.01 (0.1)	0.52 (1.54)	3.95 (5.31)	3.97 (5.31)
r	-0.08	-	-0.01	0.51	0.06

Table 2- mean and peak (SEM) urinary enzymes (mg/l) and correlation according to exposure duration

Exposure duration	Microprotéinuria	LDH	alcaline phosphatase	NAG	GGT
6-10	49.22 (78.71)	0.03(0.19)	0.70 (2.30)	3.18 (1.96)	2.81 (1.07)
11-15	42.27 (66.97)	0	0.27 (0.76)	6.57 (12.60)	2.78 (0.95)
16-20	42.17 (69.05)	0	0.41 (1.08)	2.97 (1.04)	3.67 (3.49)
21.25	34.40 (34.45)	0	0.68 (1.52)	3.55 (1.17)	6.90 (9.86)
	42.39 (64.85)	0.01 (0.1)	0.52 (1.54)	3.95 (5.31)	3.97 (5.31)
r	-0.108	-	-0.01	0.51	0.06

Table 3: percentage of positivity

	%	
Proteinuria	60 %	(macroproteinuria 6% - microprotéinuria 54%)
LDH	1 %	
Alcaline phosphatase	23 %	
NAG	100 %	
GGT	98 %	

Discussion

We always suspected the renal toxicity of the lead, nevertheless the doubt persists concerning the primary responsibility of the lead or of the arterial hypertension in the renal disease. To palliate to that, the survey has been lead on 100 persons exposed to the inorganic lead, and who never received any treatment for the lead poisoning and who have a normal arterial pressure.

The nephrotoxicity of the inorganic lead can express itself through either a glomerular and/or a tubular affection.

The presence of microproteinuria is considered as a precocious glomerular lesion. In our survey the urinary protein dosage showed that 60% of workers present a glomerular lesion among which, 54% at a precocious degree.

To this stadium the dosage of proteins by the test strip procedure used of a systematic manner in occupational health doesn't permit to question a possible glomerular affection, of where the interest of the urinary research of microproteins.

Indeed the microproteinuria, (2-9-10) is defined as being the presence of abnormally high urinary proteins without clinic proteinuria.

The microproteinuria is present when its rate is included between 20 and 200 mg/min (12-15), rate to which the test with the test strip procedure is negative (9) and that corresponds approximately to rates included between 30 and 300 mg/24h (2- 6-11-12).

If the enzymes usually provided information on organs, which are affected by the illness, as the myocardial infarction, it is not the case for the kidney. The reason of this failing is due extensively to the fact that the dosage of only one urinary enzyme can not give a reliable information on the site, the type and the extent of the renal damage. The simultaneous use of several enzymes as the N-acethyl-beta-D-glucosaminidase (NAG), the gama-glutamyl-transferase (GGT) the intestinal alkaline phosphatase (PAL) and the lactate deshydrogenase (LDH) permit an early and precise diagnosis.

In our survey, all the exposed workers to the inorganic lead have a tubular lesion attested by the presence in the urines of N-acethyl-beta-D-Glucosaminidase (NAG) at 100% and the presence of GGT at 98% of workers.

Indeed, witnesses of an irreversible and early proximal tubular damage (17-11-1) the NAG, and the GGT (6) have a high activity at the level of the kidneys in comparison to other tissue such as the lung and the liver (4). These two enzymes are respectively found at 100% and 98% of workers exposed to the inorganic lead. There are no correlations between the values of these two enzymes and the age or the exposure period of the workers. It is explained by the fact that the activity of the NAG reflects the severity of damages of the renal tissue (14); but the possibility to find some normal values can also mean an irreversible partial disturbance due to the tubular cell exhaustion (18).

The dosage of the intestinal alkaline phosphatase permits us to conclude to a tubular effects extended to the S3-segment of the proximal tubule in 23% of cases. Indeed different studies confirmed this enzyme as an indicator of the effect on the S3 segment of the proximal tubule (13).

The LDH, found in 1% of cases, comes to complete other enzymatic dosages, and its presence signs the cellular death (7).

Conclusion

This survey shows that, outside of all arterial hypertension, the inorganic lead is directly responsible of the renal dysfunction. There is not a correlation neither between the tubular lesion and the age, nor between the tubular damage and the period of exposure.

The renal dysfunction are situated at the level of proximal tubule and can be extended to the S3 segment. Moreover the glomérular attack attested by microproteinuria could complicated the tubular lesion.
Making a real biochemical biopsy, the dosage of the microproteinuria and the urinary enzymes are a supplementary and important tool for the precocious nephrotoxicity diagnosis and for the surveillance of exposed persons to toxic risks.

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The assessment of exposure to environmental tobacco smoke for the risk assessment purposes in Finland

Kauppinen T(1), Virtanen SV(1)

1. Department of Epidemiology and Biostatistics, Finnish Institute of Occupational Health, Helsinki, Finland, e-mail: tkau@occuphealth.fi

Introduction

Smoking at workplaces has been prohibited in Finland since 1995 except in isolated smoking rooms and in restaurants. The future health risks due to current exposure to environmental tobacco smoke (ETS) in Finland were recently evaluated. The related assessment of exposure to ETS aimed at providing a solid basis for quantifying risks at work and elsewhere.

Methods

Exposure to ETS was considered to occur if a person (nonsmoker or smoker) inhaled tobacco smoke produced by other people (customers, coworkers, etc.).

The most suitable source of information to assess the extent of occupational exposure was the interview survey of Statistics Finland which inquired from about 3000 workers' exposure to ETS according to the proportion of working time exposed. Exposure at home was estimated on the basis of postal survey of the Finnish Public Health Institute. Exposure outside work place and home could not be estimated, although it was possible to estimate crudely the risk among restaurant customers based on assumptions.

The level of exposure to ETS was estimated on the basis of three recent Finnish studies which reported levels of nicotine (an indicator agent of ETS) in restaurants (2), and in other kinds of work places (1).

Results

On the basis of national interview data we estimated that there were about 340 000 employees (15 % of the employed) exposed occasionally or regularly to ETS in Finland in January 2000. About 30 000 workers (1.5 % of the employed) were exposed almost continuously (Table 1). The number of Finns exposed to ETS at home due to smoking of another person was nearly 600 000 (11 % of the population).

The average exposure level (measured by an indicator agent nicotine) is currently about 10 $\mu g/m^3$ in Finnish restaurants and 2 $\mu g/m^3$ in other premises where exposure may occur. The heaviest exposures in smoky bars, dance restaurants and night clubs exceed 100 $\mu g/m^3$. The level of exposure at homes of smokers has not been measured in Finland, but on the basis of US measurements the level may be on average about 2 $\mu g/m^3$, which corresponds to about 4 $\mu g/m^3$ at work when time-activity patterns are taken into account.

Table 1. Preliminary estimates of current exposure to ETS and of future cases of lung cancer attributable to exposure to ETS in Finland according to the model (3).

Daily duration of exposure	Number of exposed	Average nicotine concen-tration in air (μg/m³)	Cases of lung cancer/45 y	Cases of lung cancer/y	Risk of lung cancer in 45 y /1000 exposed
Restaurant/hotel sector	38 000	6	32	0.7	0.9
Nearly all the time	16 000	9	22	0.5	1.3
About ¾ of the time	5 000	7.5	5	0.1	1.1
Half of the time	2 000	5	1	0.02	0.7
About ¼ of the time	5 000	2.5	2	0.04	0.4
Less	11 000	1	2	0.04	0.15
Other sectors	299 000	0.4	16	0.4	0.06
Nearly all the time	14 000	1.8	4	0.09	0.3
About ¾ of the time	4 000	1.5	1	0.02	0.2
Half of the time	15 000	1	2	0.04	0.15
About ¼ of the time	33 000	0.5	2	0.04	0.07
Less	233 000	0.2	7	0.16	0.03
Occupational exposure	337 000	1	48	1	0.15
Exposure at home	570 000	4	340	8	0.6
Other exposure	?	?	320	7	?

Remarks: Daily duration was assumed to be 90% (nearly all the time), 75% (about ¾ of the time). 50% (half of the time), 25% (about ¼ of the time) and 10% (less). The level of exposure measured as the nicotine concentration was assumed to 10 μg/m³ in the restaurant/hotel sector, 2 μg/m³ in other sectors, and 2 μg/m³ at homes (time/activity weighted level at homes 4 μg/m³).

Epidemiological studies have usually shown relative risks (RR) between 1.2 and 1.4 for lung cancer in populations exposed to ETS. One epidemiological risk model (3) estimates that 45 years of occupational exposure to a nicotine concentration of 6.7 μg/m³ causes an absolute risk of 1/1000 of contracting lung cancer. If this model is applied to the Finnish exposure situation, current occupational exposure would in the future result in about 1 case/year among those exposed. Exposure at home would result in about 8 cases/year. If there were on average 10 restaurant customers inhaling similar smoky air as restaurant workers, and the exposure-response relationship is assumed to be linear, there would be 7 cases/year among the customers. The total amount adds up to 16 (10-30) cases/year attributable to ETS which is about 1 % of all incident lung cancers in Finland (Table 1). The average risk of lung cancer after 45 years of occupational exposure to ETS is according to this model 1-2 per 10 000 exposed, but the highest risks are as high as 1-2 per 100 among long-term workers in smoky restaurants where exposure level is about 100 μg/m³ of nicotine.

Discussion

The strength of our approach is that it addresses both the prevalence and the corresponding level of exposure thus allowing direct application of quantitative risk models. One of the basic difficulties in the risk assessment of ETS is the comparison of the past exposures of epidemiological studies, which are used to derive risk estimates, with the current exposures, whose future effect is to be assessed. Due to the lack of past and current exposure data this comparison is debatable and a potential source of large errors. Our approach overcomes this difficulty partly by providing accurate knowledge on current exposures.

The weakness of our approach is mainly in assumptions we had to make to estimate exposures at home and during leisure time. This uncertainty is carried over to estimates of cases attributable to ETS whose validity depends also on the validity of the risk model adopted.

Lung cancer is used here as one example of risks due to ETS. Other health outcomes, such as ischemic heart diseases, developmental effects, and respiratory effects in children, may be more prevalent and significant than lung cancer which is only one factor to be taken into account in the evaluation of risks due to exposure to ETS.

Conclusions

In spite of legal restrictions, exposure to ETS was still widespread at work, home and elsewhere in Finland in January 2000. Data on the prevalence and level of exposure can be efficiently used in the assessment of population risks provided that quantitative models on dose-response relationships exist.

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Use of an existing exposure database to evaluate lung cancer risk and silica exposure in Vermont granite workers

Attfield MD and Costello J

Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health CDC, Morgantown, WV, USA, e-mail: mda1@cdc.gov

Introduction

Vermont granite workers are known to have experienced high past exposures to silica dust. Since most have had little other occupational exposure, they are, therefore, a very suitable group for study of lung cancer and silica exposure. Previous studies have provided evidence of excess lung cancer mortality among the higher and longer exposed granite workers, particularly longer-tenured workers in the sheds. These studies have been handicapped, however, through restriction of the analysis to job and tenure surrogates, with the resulting potential for misclassification and inability to evaluate quantitative exposure-response. The omission was not through lack of environmental exposure data. From 1924 to 1977 six environmental surveys were undertaken in Vermont granite sheds and quarries, resulting in an extensive database of industrial hygiene information, which has also already been summarized (2). To remedy this omission, therefore, the mortality follow-up data for the Vermont cohort has been analyzed in conjunction with dust concentration data from these sources, incorporating job histories available in the cohort to provide cumulative respirable silica exposures.

Methods

Details of the cohort and methods of mortality follow-up are presented elsewhere (1,3). The job-time exposure matrix published as Table I of Davis et al. (1983) formed the basis of the cumulative exposure derivation. This matrix was derived from six environmental surveys undertaken between 1924 - 77. As noted by Davis and colleagues, this time period corresponds closely with the years the cohort was employed in the granite industry. Adjustment was made for the period of transition when control measures were being introduced in the 1940s.

Work history information available for each cohort member was matched with the job titles available from the job-time exposure matrix; exposures for jobs not included in the exposure matrix were estimated by substituting data from other jobs. Cumulative exposures were then calculated by summing the products of years in job and dust concentration. Finally, conversion from mppcf-yr to mg-yr/m^3 was made employing a conversion factor of 10 mppcf = 0.07 mg/m^3 respirable free silica.

In the current analysis, the exposure data were divided into groups having approximately equal numbers of deaths in each category, but with the cut-points rounded to increments of 0.25 mg-yr m^{-3} for ease of description; SMRs were derived for each group. Model fitting was undertaken using Poisson regression incorporating both internal and external adjustment for age and time period, and log and untransformed exposures. In addition, the same models were fitted after allowing for a 15 year lag in cumulative exposures.

Results

After jobs with similar or equivalent titles had been reconciled, twelve accounted for 75% of the 7,428 work history record entries. Each of the summarized job titles was matched with the job titles in the job-exposure matrix (2). Ten of the 12 most frequently reported job groups could be linked directly with specific jobs in the exposure matrix. Table 1gives the summary statistics of dust exposures and other indices for the cohort. The mean cumulative exposure was 2.1 mg-yr/m^3 with an s.d. of 3.8 mg-yr/m^3. The average intensity of exposure (i.e., the free silica dust concentration) was 0.08 mg/m^3, with 10% being greater than 0.21 mg/m^3.

Mortality from malignancy of the trachea, bronchus and lung is shown in Table 2 and rises almost consistently with exposure level from an SMR of 0.77 in the lowest exposure group to 1.70 in the penultimate exposure group (3.0 - 6.0 mg-yr/m^3)[3]. The elevations in the SMR for the penultimate two exposure groups are statistically significant (p<0.05 and p<0.01). Poisson models eliminating the highest exposure group all had highly significant coefficients in comparison (p<0.005 for all). Within this group there was little difference between models based on the log transformed versus untransformed exposure, and between those using internal versus external adjustment for age and decade. However, the log transformed models had marginally greater statistical significance.

Discusssion

The results show a clear relationship between extent of silica exposure and lung cancer mortality. Although it was not possible to adjust for smoking in the analysis, there was little evidence of confounding from this factor, since causes of death typically associated with smoking (e.g., NMRD and emphysema) tended to be elevated in the lower rather than higher silica exposed groups. The workers had little or no exposure to any other carcinogens, such as asbestos, radon, or arsenic.

Conclusion

This study has provided confirmation that exposure to silica dust can lead to lung cancer.

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Table 1 Summary statistics on respirable free silica exposure variables			
	Cumulative exposure (mg-yr/m^3)	Tenure (yr)	Dust concentration (mg/m^3)
Mean	2.1	20.2	0.08
Standard deviation	3.8	15.3	0.10
Median	0.72	18	0.045
Lower decile	0.02	1	0.01
Upper decile	6.4	43	0.21

Table 2 Mortality statistics for malignancy of trachea, bronchus, and lung by respirable free silica exposure groups. Time since first exposure = 15 years or more		
Cumulative exposure group (mg -yr/m^3)	SMR	SRR
0-	0.77	1.00
0.25-	0.98	0.91
0.5-	1.26	1.28
1.0-	1.25	1.32
1.5-	1.33	1.32
2.0-	1.47*	1.38*
3.0-	1.70**	1.76**
6.0-	1.16	0.86
All	1.17*	1.30**

* one-sided p<0.05, ** one-sided p<0.01

Supporting the clinical occupational history with an intelligent database of occupational toxicology

Brown J A

Consultant for the Toxicology and Environmental Health Information Program at the National Library of Medicine, Bethesda, Maryland, USA, e-mail: brownjay99@msn.com

Introduction

The occupational history is the key screening test for most work-related diseases caused by exposure to hazardous chemicals. Detecting patients with work-related diseases in the clinic is difficult because of the low prevalence of occupational diseases and the minimal training of health professionals in occupational toxicology. Most physicians lack the training and knowledge base necessary to distinguish between harmless and significant exposures, and the occupational history if frequently omitted.(1) An information tool is needed to support the decisions of health care professionals and increase the positive predictive value of the occupational history.

Methods

A decision-support system was envisioned as a map of the knowledge domain of occupational toxicology, drawing from the disciplines of toxicology, industrial hygiene, epidemiology, and occupational medicine. During the development process, a list of important features to support the occupational history as an effective screening test was compiled:

1) Computer-based – Only a computer can sort hundreds of records in a fraction of a second.
2) Graphical-user interface – An intuitive interface helps users to find information quickly.
3) Relational database – Linked tables allow information in one table to be related to information in other tables.
4) Information comprehensively collected – A content expert should gather information about toxic chemicals, hazardous job-tasks, and occupational diseases from all pertinent sources and disciplines.
5) Information systematically indexed – A content expert should systematically classify all information using a controlled vocabulary and hierarchical categories.
6) High-risk jobs targeted – For each occupational disease, identify all high-risk jobs.
7) Exposure assessment information detailed – For each hazardous chemical, show all available information about properties, thresholds, exposure limits, and adverse effects that would be useful in distinguishing between harmless and significant exposures.

Results

Haz-Map is a prototype intelligent database that indexes the voluminous information in the knowledge domain of occupational toxicology. A controlled vocabulary and hierarchical classification systems are used to index the nine tables of information in the Microsoft Access database. Comprehensive indexing of the entire domain provides quick access to more detailed information about hazardous job-tasks, toxic chemicals, and occupational diseases. The user can "zoom in" or "drill down" to the facts needed for the particular case being evaluated.

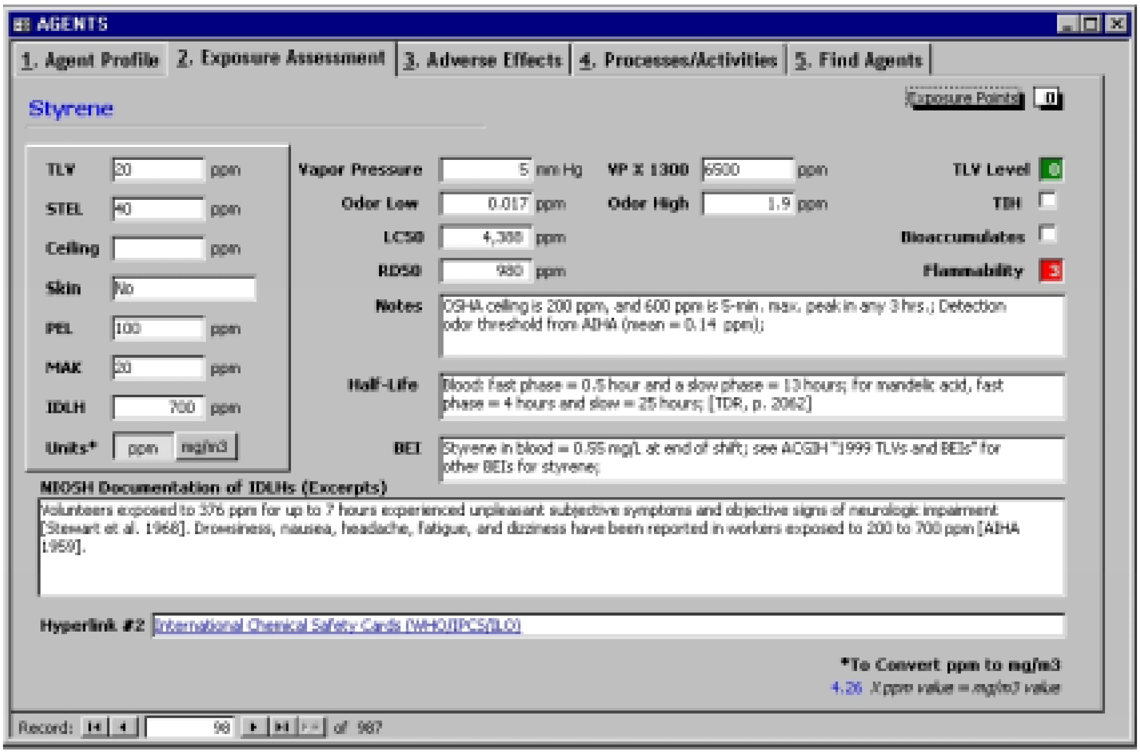

Fig. 1. – The Exposure Assessment page from the Haz-Map software application

Discussion

In the surveillance cycle to identify and prevent occupational diseases, the occupational history is the weakest link. Effective surveillance for occupational lead exposure can be achieved by monitoring laboratories for blood lead results.(2) But the control and prevention of most occupational diseases depends on an effective occupational history.(3, 4)

There are two general strategies for increasing the positive predictive value of a screening test. One is to target high-risk groups. The other is to increase the specificity of the test. An information tool that targeted high-risk occupations and gave health professionals access to job-specific information for exposure assessment would achieve this goal.

Knowledge bases to support the information-intensive task of exposure assessment have been designed and used in case control studies and in clinical practice. (5, 6) Rather than using a knowledge base to generate job-specific questionnaires, Haz-Map takes a different approach. That approach is to provide decision support with an intelligent database of comprehensively collected and systematically indexed information. With the aid of an intelligent database, the health professional can ask the right questions to elicit a specific exposure history.

When incorporated into the workflow of the clinic, computer-based practice guidelines and other clinical reminders can improve patient care.(7) Haz-Map could be used as a module of a computer-based patient record system. For example, it could remind physicians when a patient with the diagnosis of asthma also had a job title associated with an increased risk for occupational asthma.(8) Students of medicine and industrial hygiene could use the database to help them learn the information-intensive field of occupational toxicology. After becoming familiar with the database, trained professionals could readily access specific information throughout their careers and improve the recognition and prevention of occupational diseases. Haz-Map is being evaluated by staff at the Toxicology and Environmental Health Information Program, National Library of Medicine with plans to make the database available for free searching on the Internet.

Conclusions

An intelligent database of occupational toxicology could be used to improve exposure assessment in clinical practice.

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Measurements of diesel particles in an iron ore mine

Lidén G, Figler B, Waher J

National Institute for Working Life, Solna, Sweden, e-mail: goran.liden@niwl.se

Introduction

During recent years diesel fumes have incurred an increased interest because several exposure tests have shown that not only the chemical composition of a particle, but possibly also a large amount of small, chemically inert, particles (<100 nm) may cause negative health effects. In workplaces, the aerosol consists of both diesel fumes and of particles from other sources. Diesel particles in such samples usually constitute only a small share of the total mass, whereas the diesel fumes generally dominate by numbers. Therefore the number and size distribution of the particles may be more important parameters when measuring exposure than traditional mass concentrations.

The aim of this study is to investigate the exposure to particles from diesel engines in workplaces. Airborne diesel samples were collected in an iron ore mine.

Methods

Samples were collected in an iron ore mine for both personal and stationary measurement. At two occasions, personal samples were collected in the breathing zones from 22 and 15 workers respectively. The workers were classified into six groups: Construction, Loading (diesel trucks), Loading (electric trucks), Transportation, Air, water and ventilation, and Wall and roof maintenance. The loading and transportation workers spent much of their time in ventilated cabins. Additionally the particle size number distribution was measured with a stationary instrument, a TSI Inc. Scanning Mobility Particle Sizer (SMPS) 3934 with Condensation Particle Counter (CPC) 3022A, at five locations within the mine. At one of these electric trucks were used. The SMPS was run alternatively with two flow rates (0.3 and 2 l/min) in order to be able to efficiently sample particles in the range 6-600 nm. Measured concentrations were corrected for diffusional losses inside the SMPS. The personal samples were studied by Scanning Electron Microscopy (SEM) to investigate the morphology, size distribution, and particle number concentrations. Particles in the range 30 – 1000 nm were sized and counted. Analysis of elemental carbon was performed on the personal samples.

Almost all diesel vehicles used some kind of particle traps at the exhaust. All diesel vehicles used the Swedish environmental diesel fuel, MK1, with a very low sulphur content and a low aromatic content.

Results

The results for the personal samples of elemental carbon are shown in Table 1. One sample of elemental carbon was failed. The personal samples of elemental carbon are in the range 5-81 µg/m^3 with average (standard deviation) equal to 29 (17) µg/m^3.

Table 1. Personal exposure to elemental carbon [µg/m^3]

Occupation	No of Samples	Average	Range	SD
Mine construction workers	9	27	15 – 59	17
Loading (diesel trucks)	5	46	26 – 81	21
Loading (electric trucks)	5	22	5 – 56	20
Transportation workers	7	29	12 – 67	18
Air, water and ventilation workers	3	18	14 – 21	14
Maintenance of walls and roofs	3	19	8 – 27	10
Unclassified	4	36	24 – 61	17
Total	36	29	5 – 81	17

The results for the SEM counting of diesel particles from the personal samples are shown in Table 2. The personal samples of diesel particles are in the range $0.2*10^4 – 4*10^4$ particles per cm^3, with an average of $2*10^4$ particles per cm^3.

Table 2. Personal exposure to diesel particles [$1*10^4$ particles per cm^3] measured with a SEM for particles exceeding 25 nm

Occupation	No of Samples	Average	Range
Mine construction workers	4	2.4	1.7 - 3.2
Loading (diesel trucks)	2	2.0	0.9 - 3.2
Loading (electric trucks)	4	0.8	0.2 - 1.5
Transportation workers	5	2.3	1.5 - 3.8
Air, water and ventilation workers	2	2.2	1.6 - 2.9
Maintenance of walls and roofs	2	2.4	1.0 - 3.9
Unclassified	3	2.1	1.9 - 2.5
Total	22	2.0	0.2 - 3.9

The particle number distributions measured with the SMPS showed the existence of two modes: a nano particle mode peaking at ~30 nm and an accumulation mode peaking in the range 80-130 nm. See Figure 1. At some locations only the accumulation mode was observed, whereas at other locations only the 30 nm mode was observed. The larger particles consist mainly of elemental carbon and adsorbed polyaromatics. At the four locations the average number concentration over 2-3 hours ranged $2*10^5 – 7*10^5$ particles per cm^3.

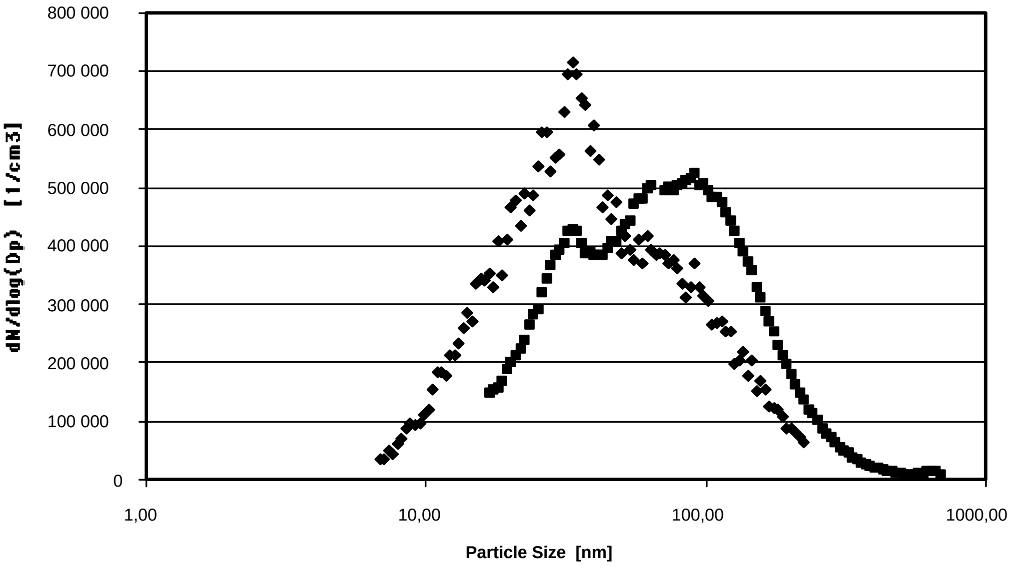

Figure 1. Size distributions measured with two flow rates at a crossroads in the mine.

Discussion and conclusion

There is no large difference in personal exposure to either elemental carbon or diesel particles between those who worked inside or outside of ventilated cabins.

The personal concentrations of elemental carbon for the Swedish miners were below the German limit value for elemental carbon, 100 µg/m^3. On the other hand the exposures exceeded ACGIH's new (February 2001) recommendation for a TLV for elemental carbon of 20 µg/m^3. Only for six workers was the exposure lower than 20 µg/m^3. In order that the exposure should not excede ACGIH's recommendation it would be necessary to reduce the emissions considerably relative to the current technology.

The particle size distributions measured stationary with the SMPS-CPC showed two modes. A mode with a count median diameter of ~100 nm which consists of elemental carbon and adsorbed polyaromatics, and a mode with nano particles with a count median diameter of ~30 nm. The use of MK1 Swedish environmental diesel has not eliminated the occurrence of nano particles. The particle number concentrations in the iron mine are one-tenth to half of the particle concentration during rush hours in a road tunnel in Stockholm (Sweden).

The particle concentrations measured with the SEM are generally approx. one order of magnitude smaller than those sampled with the SMPS-CPC system. The main reason for this is that the smallest particle size detected is much lower for SMPS-CPC than for SEM, 7 vs. 25 nm.

Assessment of exposure to chrysotile and amphiboles for a case-control study of the risk of lung cancer among Slovenian asbestos-cement workers

Dodic-Fikfak M [(1)] Quinn MM [(2)] Kriebel D [(2)] Wegman D [(2)] Eisen E [(2)]

(1) Institute of Occupational Medicine, Ljubljana, Slovenia, metoda@greenmail.net
(2) University of Massachussets, Lowell, MA, USA

Introduction

Considerable controversy still surrounds the question of whether the two different types of asbestos -- amphiboles and chrysotile -- have different carcinogenic potencies. The “amphibole hypothesis” holds that chrysotile is less likely to cause lung cancer and mesothelioma than are the amphiboles. The ability to clarify this question is limited by a lack of quantitative data with which to estimate separate dose-response curves for the two fiber types.

For this work an exposure assessment was conducted for a case-control study of the risk of lung cancer among 6,714 production workers employed in a Slovenian asbestos cement factory between 1947 and 1996. The factory made two products, one of chrysotile and the other of amphiboles, each in a separate facility with a separate workforce. Thus it was possible to estimate separately worker exposures to amphibole and chrysotile forms of asbestos.

Objectives

The objectives of this study were to develop quantitative estimates of airborne concentrations of chrysotile, amphibole, and total asbestos for: 1) major tasks and operations in the technologic time periods related to asbestos exposure and 2) each job in each production area for each year of the epidemiologic study.

Methods

Exposure measurements were available for most exposed jobs beginning in 1961.

Three different methods of measurement were used: a konimeter, measuring particles/cm^3, a gravimetric method measuring milligrams/m^3, and a membrane filter method measuring fibers/cm^3. Operation-specific conversion factors among these methods were developed using a set of 78 paired side-by-side membrane filter and gravimetric air samples, and a smaller set of konimeter and membrane filter samples collected over a similar time period.

For the jobs and time periods lacking measurement data, the airborne concentrations of total asbestos, chrysotile and amphibole were estimated using production process records and interviews with long-service employees and factory managers, engineers, physicians and environmental managers.

Production Job Exposure Matrices comprising quantitative exposure intensity estimates for chrysotile, amphibole, and total asbestos were completed for all production jobs and all years of the epidemiologic study.

A subset of the study population held jobs without fixed work locations (maintenance, cleaning), and for these workers, quantitative exposure estimates were made on the individual worker level.

Results

More than 1,000 air samples were available, beginning in 1961. From these, estimates of the airborne concentration of total asbestos, chrysotile, and amphibole were made for the major tasks and operations for the technologic periods associated with changes in asbestos exposure (Table 1).

Table 1. Mean (arithmetic and geometric) measured concentrations of particles, total dust and fibers in air for selected tasks and production periods.

	1961-1971	**1972-1973**	**1975-1984**	**1985**	**1986-1989**
Task	**Particles (p/cm^3)**	**Particles (p/cm^3)**	**Total dust (mg/m^3)**	**Fibres (f/cm^3)**	**Fibres (f/cm^3)**
Milling	2795.5* 2330.6**	4627.0 4391.9	11.3 3.0	13.7 3.5	1.5 0.6
Mixing	4134.5 3003.4	5087.7 4943.3	31.8 26.3	3.9 3.9	1.3 0.5
Machine line	955.2 706.7	/	6.3 4.4	0.6 0.3	0.2 0.1
Sawing	1305.7 1012.8	/	17.0 8.7	10.8 1.3	1.4 0.6
Grinding	2280.7 1548.8	1970.0 1970.0	/	2.7 1.6	4.5 2.3

* arithmetic mean
** geometric mean

Discussion

Several unique features of the factory made it a good site for an asbestos study. These features, many related to the factory's socialist management between 1947 and 1990, include: 1) the factory building was structured in two, physically separated production areas, one making asbestos sheets almost exclusively from chrysotile, and the other making asbestos pipes from a mixture of amphiboles and chrysotile; 2) there were detailed asbestos consumption records available for each production area; 3) each production area was organized like a separate factory with different management and employment systems. This ensured that the workers were hired in one area and did not transfer between production areas; 4) once hired in a production area, workers tended to remain in the job for which they were hired; 5) detailed time management records were available for most jobs in each production area; 6) complete work history records were available for most workers in the study population; and 7) over 1,000 air measurements associated with specific tasks and jobs were available.

On average, the airborne concentration estimates to total asbestos were low with respect to some of the major historic populations such as Dement's (1) study of asbestos textile workers in which the estimated mean fiber concentrations for a machine operator in the period 1965 - 1975 was 17.2 f/cm^3 (range 13.1-21.3 f/cm^3). However, the total asbestos concentration estimates for this study were similar to those found by Albin et al. (2), Ohlson and Hogstedt (3) and Gardner et al. (4) for Swedish and British asbestos-cement operations respectively. These factories used similar work practices and control technologies, although in different time periods. When similar technological periods were compared, the estimated airborne concentrations of fibers in the Slovenian plant were usually within a factor of 2 of the concentrations in the Swedish and British plants, and always within an order of magnitude.

Conclusions

It was possible to estimate the airborne concentrations of amphibole and chrysotile separately and in such a way that these estimates can be used to estimate separate exposure-response curves in an epidemiologic study.

We have confidence in the exposure estimates because the exposure data were fairly numerous and very reliable and because the final estimates of the airborne concentrations of total asbestos were similar to those previously published for similar operations that occurred in similar exposure situations.

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Occupational lead exposure associated health problems and disease in industrial workers

A. Bener [1], A. M. Almehdi [2], R. Alwash [3], F. R. M. Al-Neamy [3]

1. Dept. of Community Medicine, Faculty of Medicine & Health Sciences,
2. Dept. of Chemistry, Faculty of Science,
3. Dept. of Preventive Medicine, Ministry of Health, UAE University PO Box 17666 Al-Ain, United Arab Emirates
e-mail:abener@uaeu.ac.ae
e-mail:abaribener@hotmail.com

Background: The United Arab Emirates (UAE), similar to other developing countries, has witnessed a rapid development in many aspects of life during the last two decades [1]. The rapid growth has led to many social and environmental problems. Exposure to lead is considered a major health problem for the people in the industrial and oil-producing countries.

Aim: The aim of the present study is to determine the effect of blood lead on the health of industrial workers in United Arab Emirates [UAE].

Design: This is a cross-sectional study.

Subjects: The study consisted of 100 industrial workers (exposed) and 100 non-industrial workers (non-exposed), matched for age, sex and nationality selected from Al-Ain, Abu-Dhabi Emirate. Exposed group consisted of 100 male industrial-workers working in heavy industrial activities. Non-exposed group consisted 100 male workers working in the not exposed to lead activities.

Methods: The blood lead level was measured by Philips PU 9100X (Byunikan) using an Atomic Absorption Spectrophotometer (AAS) equipped with graphite furnace and Zeeman background correction system. We have performed the analytical method that described by Wu et al. (2) and Parsons (3).

Results: The mean age of 100 industrial workers was 34.6±8 years, and duration of their employment was 8.3±5.9 years, respectively. The mean age of non-industrial workers was 35.5±9.4 years and duration of employment was 9.4±7.5 years, respectively. Industrial workers had significantly higher mean of blood lead level (77.5 ± 42.8 µg/dl) than non-industrial workers (19.8 ± 12.3 µg/dl) with $p<0.0001$. Table 1 summarize, the socio-demographic characteristics for lead-exposed and non-exposed workers. Reported symptoms among industrial and non-industrial workers are presented in Table 2. As can be seen from this Table industrial workers had higher prevalence of symptoms than non-industrial workers for nausea/vomiting, muscular symptoms; dizziness, fatigue, irritability, memory disturbances; insomnia, allergic of conjuctival, allergic rhinitis and allergic dermatitis. Table 3 presents the respiratory symptoms among industrial and non-industrial workers. This Table shows that the industrial workers had a higher prevalence of respiratory symptoms than non-industrial workers for phlegm, shortness of breath and diagnosed asthma.

Conclusion: In conclusion, this study determined possible exposure and associated risk factors

with lead exposure among industrial workers and there is evidence that some of the illnesses obtained in this study could be related to excessive exposure to lead.

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Table 1: The Socio demographic characteristics and Blood lead levels [BLL, µg/dl] among exposed and non-exposed workers.

Variables	**Exposed workers** (N=100) **Median**	**GM**	**Non –exposed workers** (N=100)	**Median**	**GM**
Blood Lead Level (µg/dl)	80.9	62.0		11.0	13.3
Age groups in Year					
< 25 Years	47.2 *	42.2		10.9	14.5
25 - 34.9 Years	73.2 *	61.9		11.0	11.2
35 – 44.9 Years	86.6 *	63.3		10.6	13.6
> 45 Years	55.8 *	90.2		18.5	19.8
Occupation **			**Occupation**		
Heavy industry worker	88.6	72.3	Shopkeeper	10.8	12.3
Garage worker	91.7	77.1	Tailor	13.3	13.0
Taxi driver	40.8	34.6	Skilled / unskilled manual workers	12.0	13.3
Petrol gas filler	81.2	72.1			
Chemical production worker	80.0	62.1			
Painter	70.6	67.7			

* Mann - Whitney test p<0.0001 ** One Way ANOVA p<0.0001

Table 2: Reported symptoms among industrial and non-industrial workers.

Symptoms	Industrial workers N =100 Yes (%)	Non –Industrial Workers N=100 Yes (%)	Odds ratio [OR]	Confidence interval 95% [CI]
Blood Lead Level (μg/dl) Mean ± SD	77.5 ± 42.8	19.8 ± 12.3		
Gastrointestinal				
Nausea/vomiting	15 (15.0)	4 (4.0)	4.23	1.31-13.25
Abdominal Pain	15(15.0)	13(13.0)	1.18	0.53-2.63
Neuromascular				
Headache	26 (26.0)	23 (23.0)	1.17	0.61-2.24
Myalgia	5 (5.0)	4(4.0)	1.26	0.32-4.84
Muscular symptoms	28 (28.0)	11 (11.0)	3.14	1.46-6.75
Psychiatric				
Dizziness	16 (16.0)	9 (9.0)	1.92	0.80-4.59
Fatigue	18(18.0)	6 (6.0)	3.43	1.30-9.07
Irritability	21 (21.0)	9 (9.0)	2.68	1.16-6.20
Memory disturbances	10(10.0)	1(1.0)	11	1.38-87.64
Insomnia	14 (14.0)	7(7.0)	2.16	0.83-5.61
Allergy				
Allergic of conjuctival	18(18.0)	12 (12.0)	1.61	0.73-3.55
Allergic rhinitis	36 (36)	12 (12)	4.13	1.89-9.14
Allergic dermatitis	16 (16.0)	7 (7.0)	2.53	0.92-7.18

Table 3: Reported prevalence of respiratory symptoms among industrial and non-industrial workers.

Symptoms	Industrial workers N =100 Yes (%)	Non – Industrial Workers N=100 Yes (%)	Odds ratio [OR]	Confidence interval 95% [CI]
Throat discomfort	10 (10.0)	22 (22.0)	0.44	0.18-1.05
Cough	26 (26)	22 (22)	1.41	o.70-2.82
Phlegm	19 (19)	8 (8.0)	2.70	1.05-7.14
Shortness of breath	16 (16.0)	9 (9.0)	1.71	0.67-4.48
Wheeze	26 (26.0)	23 (23.0)	1.18	0.59-2.36
Doctor diagnosed asthma	28 (28.0)	11 (11.0)	3.15	1.39-7.26

Distribution and determinants of trihalomethane levels in the UK indoor swimming pools; a pilot study

Nieuwenhuijsen MJ, Chu H, and Elliott P

TH Huxley School of Environment, Earth Science and Engineering, Imperial College of Science, Technology and Medicine, Royal School of mines, Prince Consort Road, London SW7 2BP, UK. Email: m.nieuwenhuijsen@ic.ac.uk

Introduction

For many decades chlorination has been used as a major disinfectant process for public drinking water and swimming pool water in many countries. However, there has been rising concern over the possible link of disinfectant by-products (DBPs) with adverse reproductive outcomes in drinking water. Greater amount of DBPs can be found in swimming pools and therefore it is believed to have a higher concentration of trihalomethane (THM) and therefore greater health risk. As part of a large epidemiological of birth outcomes in relation to disinfection by-products we carried out a pilot study to determine the importance of exposure to disinfection by-product in swimming pools. The purpose of this study was to estimate levels and determinants of THMs in UK indoor swimming pools.

Methodology

Samples of swimming pool water were collected from eight different indoor swimming pools once every week for three weeks in London. The samples were sent to the Thames Water Quality Centre for analysis total organic content (TOC) and THMs. Water and air temperature were measured along with the pH level during the collection of pool samples. The turbulence level and the number of people in the pool at the time were also accounted for. Determinants of THMs levels and the within and between pool variance components were assessed using SPSS.

Results

The geometric mean concentration of TOC for all swimming pools was 5.8µg/l and the geometric mean concentration of chloroform for all swimming pools was 113.3µg/l. The geometric mean concentration of total THM for all swimming pools was 132.4µg/l, which is fairly high compared to previous studies. This was also much higher than tap water samples.

A clear positive linear correlation was observed for the number of people in the swimming pool and total THMs ($r = 0.7$, $p<0.01$) and TOC and total THMs ($r = 0.5$, $p<0.05$).

The between pool variance was greater than the within pool variance component for chloroform, bromodichloromethane, dibromochloromethane and total THM whilst TOC had a larger between pool variance component.

Conclusions

In conclusion, relatively high concentration of THMs was found in London's indoor swimming pools. Pools may provide an important pathway of exposure for those who swim regularly. The levels were in correlation with the number of people in the pool and the TOC concentration. Variation in THM levels was larger within pools than between pools. This study provides further information for the exposure assessment of our epidemiological study.

Assessment of new exposure agents in mechanical wood harvesting

Kallunki H, Kangas J, Laitinen S, Mäkinen M, Ojanen K, Susitaival P

Kuopio Regional Institute of Occupational Health, Kuopio, Finland, e-mail: heikki.kallunki@occuphealth.fi

Introduction

Almost all wood harvesting is made mechanically in Finland. The rate of mechanisation of logging operations is approximately 90 %. New chemical and biological agents are recently taken in to use in forestry machines. Some of the forestry companies demand the use of biodegradable hydraulic and chain oils, marking colours and fungicides in their logging sites. These new agents have caused some doubts and fears among the forestry operators. The aim of this study was to find out the extent of the exposure to chemical and biological agents in mechanical wood harvesting.

Methods

Field measurements were made in five different forestry machines in province of Savo during the summer 2000. Biodegradable hydraulic and chain oils, marking colours and fungicides were used in all five machines. Measurements were made in five machines totally 12 times.

Fluorescent tracer technique was used to asses the dermal exposure to chainoils and fungicides. The technique is developed to indicate pesticide deposition on the skin quantitatively. Harvester operators wore a white cotton whole body overall during four hours of normal harvesting operation and fluorescent colouring agent was mixed with chainoil and fungicide spray liquid respectively. After the work the operators were photographed by digital camera.

Exposure to fungicides especially to root rot antagonist *Phlebiopsis gigantea* was assessed by taking airsamples from the breathing zone. Environmental viable microbes and endotoxin concentrations were also analysed from the samples. The samples were taken during the normal harvesting operation. Breathing zone microbe and endotoxin concentrations were compared to the forest air samples, which were taken at the same time from the forest air. In addition to airsamples material samples were taken from the cabin air filters, oils used in hydraulic system and chain lubrication, fungicide spray liquid and from the water used to dilute the fungicide.

Results

Microbe concentrations in the breathing zone varied between less than the detection limit and 5920 cfu /m^3 and in the forest air between less than the detection limit and 3180 cfu /m^3. Endotoxin levels in the breathing zone varied between <0,01 and 3,4 ng/ m^3 and in the forest air between 0,1 and 2,5 ng/ m^3. *Phlebiopsis gigantea* concentrations were below the detection limit or very low in all samples. Microbe concentrations in chainoil and hydraulic oil were below the detection limit or low. In the fungicide liquid concentration of fungi and yeast varied between 251 and 10800 cfu/ml and bacteria concentrations between $4{,}7x10^6$ and $2{,}9x10^8$ cfu/ml. Endotoxin concentrations in chainoil, hydraulic oil, fungicides and clean water, which was used to make the fungicide mixture are shown in table 1.

Table 1. Endotoxin concentrations in chainoil, hydraulic oil, fungicides and water

Sample	N	Range, ng/ml
chainoil	4	<0,004 - 0,009
hydraulic oil	4	<0,004 - 0,1
fungicide	9	96 - 1500
water	5	1,3 - 42

Concentrations of microbes on the outer surface of cabin air filters were higher than on inner surface.

Occasionally, a few small spots of the fluorescence tracer mixed to the fungicide were found from the whole body overalls after the working periods, and it was not considered relevant to quantify the exposure in these situations.

Discussion

Microbe and endotoxin concentrations were low in the operators breathing zone and at the same level than in the forest air. Concentrations of *Phlebiopsis gigantea* was lower than detection limit or very low in all samples.

In the fungicide samples, which were taken from the fungicide container after the working period, microbe and endotoxin levels were high. This may cause dermal symptoms if operators have to handle the spray liquid for example while washing the fungicide container.

The air filters of cabins prevents the microbes to get into the harvesters cabin indoor air if those are cleaned and changed according to manufacturer instruction.

According to fluorescent tracer analys operators didn't have dermal exposure to the chainoil or fungicide during the normal harvest operation.

Conclusions

The harvester operators are not exposed to fungicides, marking colours, hydraulic or chain oils during the normal harvesting operation. Harvesting operators should avoid dermal contact to the fungicide mixture, which contains high amount of the root rot antagonist *Phlebiopsis gigantea* and other microbes and their biological components.

Exposure to microorganisms in three types of swine confinement buildings

Rautiala S, Reiman M, Louhelainen K, Kangas J

[1.] *Kuopio Regional Institute of Occupational Health, Kuopio, Finland, e-mail: Sirpa.Rautiala@occuphealth.fi*

Introduction

Exposure to bioaerosols in swine confinement buildings has been connected to respiratory problems in many studies (1,3). One reason for these health problems may be microorganisms including bacteria and fungal spores and their metabolites. In traditional swineries, concentrations of bacteria have been high (10^5-10^6 cfu/m^3), while concentrations of fungal spores are smaller, ranging from 10^1 to 10^5 cfu/m^3 (1,4,2). Recently, new at-site composting facilities have become more common in Finland. The aim of this study was to find out if there is any difference in the farmers' exposure to microorganisms in traditional liquid manure system swineries and in composting facilities.

Methods

Concentrations of viable microorganisms and total concentrations of spores were measured in seven liquid-manure system swineries and in twelve at-site-composting facilities. Five of the at-site composting facilities used peat and seven sawdust as the composting bed. In liquid-manure system swineries samples were taken during feeding of swines and at-site composting facilities before any work was done (background) and during turning of the compost bed. Samples for airborne viable microorganisms in workroom were collected with six-stage cascade impactor (model 10-800, Andersen Samplers, Inc., Atlanta, Ga) calibrated at a flow rate of 28.3.l/min. Sampling time varied between 1-5 minutes. The culture media and incubation temperatures and times were: mesophilic fungi rose bengal malt extract (Hagem) agar at 25º C for 7 days, xerophlic fungi Dichloran glycerol agar (DG18) 25º C for 7 days, thermotolerant fungi DG18 agar 40º C for 5 days, thermophilic actinobacteria half-strength nutrient agar 55º C for 3 days and Gram-negative bacteria EMB agar 37º C for 2 days. The concentrations of microorganisms were calculated using a positive hole correction method and expressed as colony-forming units/m^3 (cfu/m^3). Fungal colonies were identified to genus with an optical microscopy. Total concentrations of spores were measured using the filter sampling and direct count on microscopy. The total spore concentrations are expressed as spores/m^3.

Results

Concentrations of microorganisms are presented in Table 1.

Table 1. Concentrations of microorganisms in swine confinement buildings. Concentrations of viable microorganisms are expressed as cfu/m^3 and total spore concentrations as spores/ m^3.

Sampling phase/fungal group	Geometric mean	Range
Liquid manure system, feeding (n = 9)		
Mesophilic fungi	$2.0*10^3$	610-8400
Xerophilic fungi	$6.5*10^3$	1410-57800
Thermotolerant fungi	$5.2*10^2$	50-3770
Thermophilic actinobacteria	$2.7*10^1$	< 12-460
Gram-negative bacteria	$3.4*10^3$	9300-52280
Total concentrations of spores	$4.0*10^5$	194300-1036440
Composting facilities, saw-dust, background (n = 10)		
Mesophilic fungi	$2.4*10^3$	740-27600
Xerophilic fungi	$2.4*10^3$	890-5070
Thermotolerant fungi	$1.9*10^2$	< 12- 9900
Thermophilic actinobacteria	$3.7*10^1$	< 12 - 4220
Gram-negative bacteria	$1.7*10^4$	2240-104620
Total concentrations of spores	$1.7*10^5$	23040-840000
Composting facilities, saw-dust, turning (n = 10)		
Mesophilic fungi	$7.2*10^3$	1970-42300
Xerophilic fungi	$4.5*10^3$	1370-244230
Thermotolerant fungi	$1.9*10^3$	130-216970
Thermophilic actinobacteria	$4.3*10^1$	< 12-7900
Gram-negative bacteria	$2.5*10^4$	1040-346930
Total concentrations of spores	$3.6*10^5$	45730-1154720
Composting facilities, peat, background (n = 18)		
Mesophilic fungi	$4.7*10^4$	3730-339070
Xerophilic fungi	$5.9*10^4$	1330-341500
Thermotolerant fungi	$1.9*10^4$	1500-337830
Thermophilic actinobacteria	$4.9*10^3$	300-127570
Gram-negative bacteria	$6.8*10^4$	7530-454270
Total concentrations of spores	$2.0*10^6$	640000-14000000
Composting facilities, peat, turning (n = 5)		
Mesophilic fungi	$7.8*10^4$	5570-350200
Xerophilic fungi	$1.4*10^5$	24030-350200
Thermotolerant fungi	$7.2*10^4$	14300-184230
Thermophilic actinobacteria	$2.7*10^4$	5780-124400
Gram-negative bacteria	$1.2*10^5$	45770-350200
Total concentrations of spores	$3.4*10^6$	2600000-4000000

In liquid-manure system swineries *Aspergillus, Penicillium, Cladosporium, Scopulariopsis, Wallemia* and yeasts were the most common fungi. In at-site composting swineries, fungal genera were more numerous than in liquid-manure system swineries. *Aspergillus*, especially *Aspergillus flavus, Penicillium* and yeasts dominated in composting facilities.

Discussion

Concentrations of viable microorganisms varied between 10^1-10^4 cfu/m^3 in liquid-manure system swineries and at-site composting facilities using sawdust as composting bed. In composting facilities using peat, concentrations of viable microorganism were higher, ranging from 10^3 to 10^5 cfu/m^3. High concentrations of thermotolerant fungi and thermophilic actinobacteria, which have been considered to be causative agents of farmer's lung, were found in at-site composting facilities using peat. Furthermore, total concentrations of spores were on average one order of magnitude higher in composting facilities using peat than in the other two types of studied swineries. Obviously the reason for elevated results was higher total dust concentrations in facilities using peat as composting bed.

Conclusions

In composting facilities using peat as composting bed, concentrations of microorganisms were at least one order of magnitude higher than in the liquid-manure system swineries and at-site composting facilities using sawdust as composting bed. No major difference in concentrations was observed between the traditional liquid-manure system swineries and at composting facilities using sawdust as compost bed.

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An objective assessment of the present method of asbestos fiber evaluation

Yousefi Vali

National Centre for Occupational Health, National Heath Department, P O Box 4788, Johannesburg, 2000, South Africa, E-mail YouseV@health.gov.za and or NCOHVY@Iafrica.com

Introduction

Asbestos fiber is used for many purposes and is found in different forms. Unsafe use and handling of the asbestos fiber and or asbestos containing material results in the release of fiber and cause inhalation exposure. Asbestos is a magic mineral as well as a killer fiber. Regulation (1) requires personal and or area monitoring. Law requires tests to be performed to check the compliance with the regulations as well as for personal exposure assessment and for efficiency testing of engineering control methods. Main objective of assessment is quantification of hazard and then to attempt to either eliminate or minimize risks to health arising from the use of asbestos. Generally, the membrane filter method, which is based on the Asbestos International Association (2) recommended method is accepted for airborne asbestos fiber monitoring. Phase contrast light microscopy is adopted for sample evaluation (2 & 3). Much reliance is always attached to this evaluation. Although, limited quality control is often applied to this evaluation both nationally and intentionally. Yet bias and variability is not always investigated and managed properly. The fault correction is either not practiced or poorly managed. Consequently, exposures are not assessed correctly. The worker and the public at large may be misled, be exposed to high levels of airborne fibers, their health affected and may therefore contract disease. The health care institution may unnecessarily pay the cost of medical examination, care and medication, whilst the culprit companies sometimes go unpunished.

Material and method

Exposure assessment to asbestos fiber is mainly based on the Membrane Filter Phase Contrast (MFPC) Microscopic method, with occasional confirmation tests by electron microscope (2). A battery operated sampling pump is used with specially designed and pre-loaded cowl filter holders for this sampling. Sample packaging, transportation, and preparation are critical factors and require professional care and attention. Microscope calibration, sample preparation, fiber identification and optical fiber counting require special skill, dedication and care. In this study, the phase contrast asbestos fiber counting method by some experienced and some registered counters was assessed with an international round robin. A double-blinded sample was submitted to the counters for normal routine counting. Data were assessed statistically to determine the degree of bias and variability.

Result

Repeated counts of samples by a person counting two categories of average fiber concentration (Table 1, categories 1 & 2) was studied searching for bias. This is intra-counter bias, which is the difference between true fiber counts produced by one counter when counting the same sample at two different times.

Table 1. Intra-counter relative standard deviation

(Category 1 = low range fiber count i.e. 5 to 20.5 F/mm^2)

Sample #	1^{st} count = X_1 F/mm^2 =	Recount =X_2 F/mm^2	$\overline{X}$=(X_1+X_2) /2 F/mm^2	True average fiber F/mm^2	Standard deviation F/mm^2 **S =0.707 Abs*(X_1 - X_2)**	Relative standard deviation **Sr = S / $\overline{X}$**
1	19	34	26.5	20	10.6	0.4
2	9	4	6.5	12	3.53	0.54
3	17	10	13.5	5	4.95	0.37
4	10	30	20	14	14.14	0.707

*Absolute

Sr (pooled)= 0.272

Sr (pooled, square root scale) = 0.136

(Category 2 = high range fiber count i.e. >=50.5 F/mm^2)

1	400	350	375	110	3535	0.09
2	80	120	100	90	28.28	0.28
3	70	100	85	9	21.21	0.24
4	100	90	95	80	7.07	0.07
5	85	7	77.5	60	3.53	0.04

Sr (pooled) = 0.03

Sr (pooled, squae root scale) = 0.015

Discussion

The MFPC method is widely used for asbestos exposure assessment. There is no reliable reference material for asbestos to use as base line to assist and to reduce the difference of results obtained by different laboratories / counters. The nature of the fiber counting method and the lack of reference material are the inherent difficulties of MFPC method this is responsible for the bias between laboratories which is not easily identifiable and cannot therefore be corrected. Asbestos fiber counting is subjective, and each result is influenced by the “mind set” of the counter at the time. The fibers are usually randomly distributed over the filter with no preferred orientation. Many decisions regarding workers and the public at large exposure to asbestos are often made on the basis of such counting data. Problems inherent to sample collection, transport, storage, preparation and fiber counting should be examined systematically, in order to detect bias and variability. The study of a single counter’s ability to produce representative results are the “intra- counter”, is an estimate of the relative standard deviation (Sr) of the concentration recorded. Statistical analyses of fiber count data will assist to limit bias and variability. These faults must be identified and corrected for as early as possible. Failure to use a qualified and experienced asbestos fiber counter and reliance on untrained staff can generate utterly useless and dangerous results.

Therefore, the bias and variability should always be identified and managed. The present fiber evaluation method needs to be reviewed, so as to be standardized and applied internationally in order to facilitate the comparison of exposure data recorded.

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1. Asbestos Regulation Occupational Safety and Health Act, 1993
2. Asbestos International Association AIA Recommended Technical Method 1 (RTM1) and RTM2
3. NIOSH Method 7400

Field study on monitoring workers' time activity patterns using a new electronic time activity recorder

Tung-Sheng Shih[1], Ho-Yuan Chang[3], Peng-Yau Wang[2*]

[1]*Institute of Occupational Safety and Health, Council of Labor Affairs, 4th Fl, 132 Min-Sheng E. Rd., Taipei, Taiwan, Republic of China.*
[2] *Graduate Institute of Environmental Engineering, National Central University, Chun-Li, Taiwan, Republic of China.*
[3] *Graduate Institute of Environmental and Occupational Health, College of Medicine, National Cheng Kung University, Tainan, Taiwan, Republic of China.*

Abstract

This paper presents new equipment to investigate workers' time activity patterns (TAP) in work environment. A real-time chemical sensor coupled with a data logger comprises the new electronic time activity recorder (ETAR). TAP data obtained from traditional workers' recalled questionnaires, working schedule of the plant, and ETAR were compared with the golden reference, direct observation. No statistical difference was found between the TAP data obtained from ETAR and the direct observation. Linear regression showed close correlation for both time blocks (R^2 = 0.83, slope = 0.92, n = 108) and 8-h work shifts (R^2 = 0.93, slope = 0.97, n = 27). On the other hand, very poor correlation was found for data obtained by other traditional methods ($R^2 < 0.2$). It was concluded that the new ETAR could provide a cheap, simple, real-time, fully automatic, and reliable information to accurately monitor workers' TAP in work environment.

Key words: task activity pattern, real-time, exposure assessment, time activity recorder, work environment

Table 1. Linear regression of time-block TAPs of 27 exposed workers.

	Linear regression	R^2	n
$T_{H, ETAR}$ vs $T_{H, observed}$	Y = 0.8921 x X + 5.1935	0.8343	108
$T_{M, ETAR}$ vs $T_{M, observed}$	Y = 0.8336 x X + 0.4896	0.6017	108
$T_{L, ETAR}$ vs $T_{L, observed}$	Y = 0.9116 x X + 7.1155	0.8143	135
$T_{H+M, ETAR}$ vs $T_{H+M, observed}$	Y = 0.9243 x X + 3.5295	0.8316	108
$T_{H+M, questionnaires}$ vs $T_{H+M, observed}$	Y = - 0.0046 x X + 46.373	0.0001	108
$T_{L, questionnaires}$ vs $T_{L, observed}$	Y = - 0.1189 x X + 82.817	0.109	135
$T_{H+M, plant schedule}$ vs $T_{H+M, observed}$	Y = 0.4726 x X + 19.153	0.1799	108
$T_{L, plant schedule}$ vs $T_{L, observed}$	Y = 0.2563 x X + 58.239	0.0606	135

n: total number of time blocks.

Table 2. Linear regression of 8-h work shift TAPs of 27 exposed workers.

	Linear regression	R^2	N
$T_{H, ETAR}$ vs $T_{H, observed}$	Y = 0.9673 x X + 9.6409	0.9463	27
$T_{M, ETAR}$ vs $T_{M, observed}$	Y = 0.8266 x X + 2.9269	0.6811	27
$T_{L, ETAR}$ vs $T_{H, observed}$	Y = 1.0207 x X – 5.2579	0.9803	27
$T_{H+M, ETAR}$ vs $T_{H+M, observed}$	Y = 0.9701 x X – 7.9186	0.9341	27
$T_{H+M, questionnaire}$ vs $T_{H+M, observed}$	Y = 0.1421 x X + 176.04	0.0671	27
$T_{L, questionnaire}$ vs $T_{L, observed}$	Y = 0.5945 x X + 115.93	0.4132	27
$T_{H+M, plant\ schedule}$ vs $T_{H+M, observed}$	Y = 0.7321 x X + 21.811	0.7229	27
$T_{L, plant\ schedule}$ vs $T_{L, observed}$	Y = 1.3946 x X – 57.804	0.9209	27

N: total numbers of 8-h working shifts

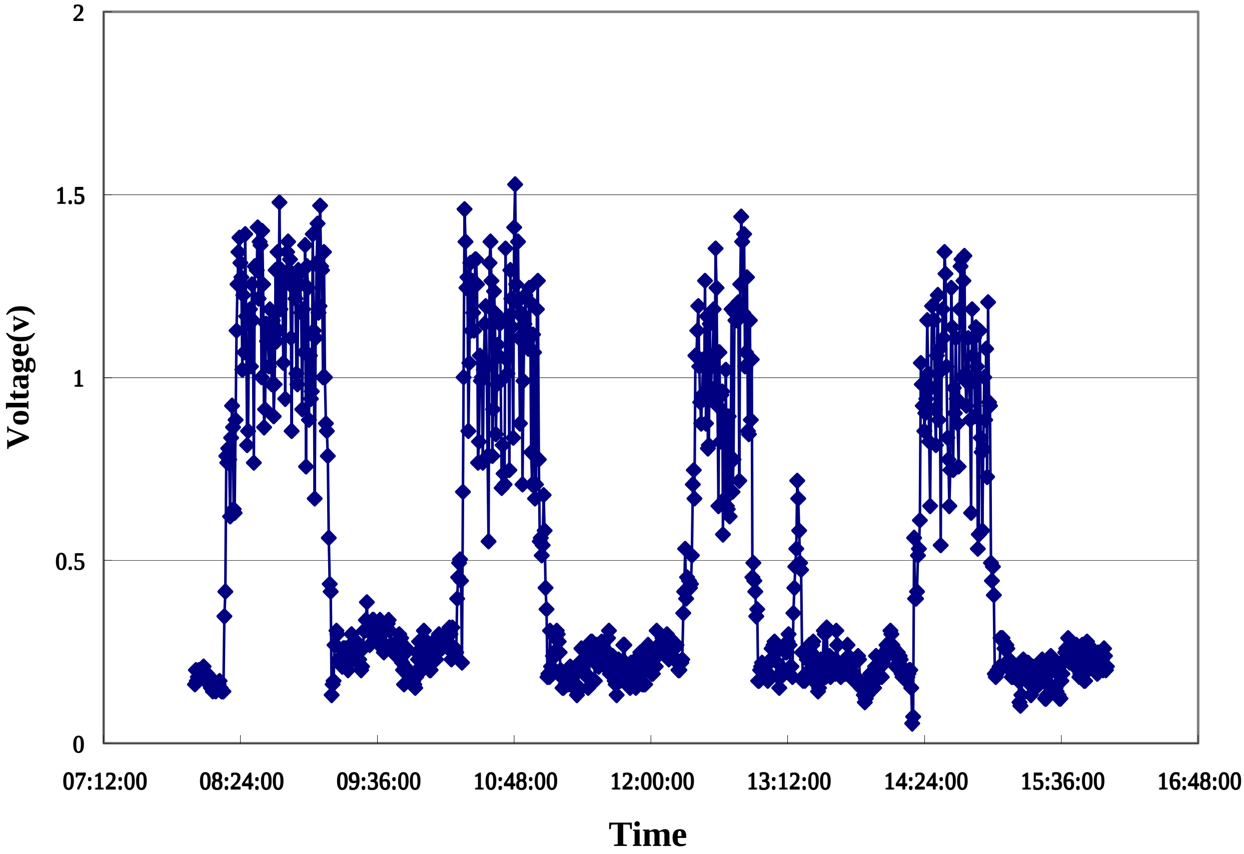

Figure 1. Voltage-time profile of ETAR in an 8-h work shift

Occupational conditions as risk indicators for unemployment among women and men in a four-year follow-up: the influence of non-occupational conditions and ill health

Bildt C (1) and Michélsen H (2)

1. National Institute for Working Life, S-112 79 Stockholm, Sweden. E-mail carina.bildt@niwl.se. 2. Dep. Pedagogic, Stockholm University, Sweden.

Introduction

Unemployment is a reality for many individuals in today's working life, and several individuals do experience one or more episodes of unemployment without dropping out permanently from the labour market (1) even thus the risk of being unemployed is higher among individuals with earlier experience of unemployment (4). Health consequences from unemployment have been discussed to a large extent (2, 3, 5), but also has ill health been analysed as a potential predictor for unemployment (2, 6). Occupational factors have seldom been analysed as potential risk indicators for unemployment (5), even thus it could be expected that certain work characteristics can be risk indicators for unemployment. The aim of the study was to examine the relation between occupational factors, non-occupational factors, ill health and unemployment, among women and men.

Methods

The study group is a sample from the general Swedish population (between 42 and 58 years of age in 1993). The base-line examination took place in 1969, and the follow-ups in 1993 and 1997. The study group in the present study consists of the 420 participants (222 women and 198 men) who participated in both follow-ups. Data about working conditions, living conditions and health was collected, and only data from the two follow-ups are analysed in the present study. Both a variable and a person-oriented approach have been used in the present study. In the variable approach the information about occupational and non-occupational conditions in1993 was analysed as potential risk indicators for unemployment in 1997, in bivariate analyses of associations (calculating relative risks, RR). In the person-oriented approach the data from 1993 was analysed to identify clusters of individuals with similar occupational characteristics.

Results

In 1997, 25 women (11%) and 26 men (13%) were unemployed. Occupational factors were found to be risk indicators for unemployment among both genders, mainly factors related to job insecurity, but among women, also few developmental possibilities at work did predict unemployment later on (table 1). Ill health in 1993 did also to some degree predict unemployment in 1997, as did earlier unemployment periods.

Table 1. Associations* between the different occupational and non occupational factors in 1993 or earlier and unemployment in 1997 found in age adjusted analysis; per gender

	Women N=220		Men N=198	
Occupational factors	RR	c.i.	RR	c.i.
Heavy physical workload	1.3	0.5, 3.9	1.6	0.6, 4.4
Sedentary work	1.1	0.4, 2.9	0.2	0.0, 0.8
High perceived workload	0.5	0.2, 1.5	1.9	0.7, 4.7
Full time work	0.4	0.2, 1.1	0.7	0.2, 3.6
Overtime work	0.4	0.2, 1.4	0.8	0.3, 2.3
Shift work	1.9	0.8, 5.0	1.1	0.3, 4.1
Temporary employment	13.8	7.1, 27.2	17.4	7.8, 38.7
Low occupational pride	2.8	1.2, 6.7	0.6	0.1, 3.3
Job strain	0.5	0.1, 2.6	1.6	0.3, 8.6
Difficult decisions	0.5	0.2, 1.7	0.4	0.1, 1.2
Low flexibility in work	0.6	0.2, 1.9	0.8	0.3, 2.4
Few possibilities for on-the-job development	2.9	1.3, 6.8	0.7	0.1, 3.5
No education at employer's expense	5.9	2.0, 17.3	0.7	0.2, 2.1
Threat of unemployment	9.4	4.3, 20.5	17.8	8.8, 35.8
Non-occupational factors				
Low frequency of social contacts	1.1	0.4, 2.8	1.4	0.6, 3.6
Poor quality of social contacts	0.2	0.0, 1.7	0.8	0.2, 2.8
Demanding life events	1.7	0.6, 4.3	0.3	0.1, 1.6
High perceived physical load	2.4	1.0, 5.6	1.4	0.5, 4.1
Inadequate coping strategies	0.2	0.0, 2.4	0.7	0.1, 3.5
Earlier unemployment	8.8	5.2, 14.6	10.7	6.4, 17.7
Ill health				
Low back pain	0.9	0.4, 2.4	2.2	0.9, 5.7
Neck and shoulder pain	0.9	0.3, 2.6	2.1	0.7, 6.1
Sub-clinical depression	0.9	0.2, 4.9	1.1	0.2, 6.0
Reduced psychological wellbeing	3.2	1.4, 7.6	4.8	2.0, 11.4
High alcohol consumption	1.0	0.2, 5.4	0.6	0.2, 3.2

RR=relative risk, c.i.=confidence intervals. *= age also included in the model

Seven clusters were identified, where the individuals had distinctly different characteristics, regarding both working conditions, conditions outside work, health and unemployment (figure 1).

Conclusions

Job insecurity was a risk indicator for later unemployment among both genders, as was also few developmental possibilities at work among women. These factors did predict unemployment, also when non-occupational factors and ill health are taken into consideration. Cluster analyses did identify groups of individuals with highly demanding occupational and non-occupational conditions in 1993 and high level of unemployment in 1997.

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Figure 1. Clusters of individuals with common characteristics. In the squares are only variables where the cluster differs from the whole group presented (≥ = lower then the mean value for the whole group. ≥≥ = much lower then the mean value for the whole group. ≤ = higher then the mean value for the whole group. ≤≤ much higher then the mean value for the whole group.).

1.Unsecure working conditions and demanding living conditions. N=10, 40% unemployed, 10% women

Characteristics at work
≤≤ Temporary employment
≤ Difficult decisions
≤ Low flexibility in work
≤ Threat of unemployment
Characteristics outside work
≥ Low frequency of social contacts
≤ High perceived physical load
≤≤ Inadequate coping strategies
≤≤ Low back pain
≤≤ Reduced psychological wellb.

2. Physically demanding work and demanding living conditions outside work. N=28, 14% unemployed, 32% women

Characteristics at work
≤≤ Heavy physical workload
≥≥ Sedentary work
≤ High perceived workload
≥≥ Shift work
Characteristics outside work
≥ Poor quality of social contacts
≥ Demanding life events
≤ High perceived physical load
≤ Inadequate coping strategies
≤≤ Earlier unemployment
≤ High alcohol consumption

3. Multi-demanding work and poor musculoskeletal health. N=17, 12% unemployed, 100% women

Characteristics at work
≤ Heavy physical workload
≤ High perceived workload
≥ Overtime work
≤ Shift work
≤ Job strain
Characteristics outside work
≤≤ Demanding life events
≥ Earlier unemployment
≤ Low back pain
≤ Neck and shoulder pain
≥ Reduced psychological wellbeing

4. Demanding and hampered work, and demanding living conditions. N=11, 9% unemployed, 64% women

Characteristics at work
≤ Heavy physical workload
≥ Overtime work
≤≤ Shift work
≤ Low occupational pride
≤≤ Job strain
≤ Few possibilities for on-the-job development
≥ Threat of unemployment
Characteristics outside work
≤≤ Demanding life events
≥≥ Inadequate coping strategies
≥≥ Earlier unemployment
≥ Sub-clinical depression
≥ High alcohol consumption

5. Mentally demanding work and demanding living conditions. N=31, 6% unemployed, 36% women

Characteristics at work
≤ Overtime work
≤≤ Shift work
≥ Difficult decisions
Characteristics outside work
≥ Demanding life events
≤ Inadequate coping strategies
≥≥ High alcohol consumption

6. Physically light work with developmental possibilities, and health problems. N=9, 0% unemployed, 89% women

Characteristics at work
≥≥ Heavy physical workload
≥ High perceived workload
≥≥ Shift work
≥≥ Job strain
≥ Few possibilities for on-the-job development
≥ No education at employer's expense
Characteristics outside work
≤ Low frequency of social contacts
≤≤ High perceived physical load
≥≥ Earlier unemployment
≥≥ Low back pain
≤ Neck and shoulder pain
≤≤ Sub-clinical depression

7. Mixed physically light daytime work. N=195, 3% unemployed, 49%

Characteristics at work
≥ Heavy physical workload
≥≥ Shift work

Mood ratings at work and their relation to psychosocial factors

Mats Eklöf

Department of occupational and environmental medicine, Sahlgren university hospital, Göteborg, Sweden. mats.eklof@ymk.gu.se

Introduction

Several studies have found associations between psychosocial factors at work and health problems [1, 2]. Models for the relationships between situational characteristics (e.g. psychosocial factors at work), psychological responses (cognitive as well as emotional), physiological responses and health outcomes have been formulated.[1, 3, 4]. One major idea in these models is that situations perceived as demanding or difficult to control may trigger negative cognitive, emotional and physiological processes, eventually leading to health problems and other negative outcomes. Mood is one way to conceptualise and measure emotional states at work [5, 6]. Associations between psychosocial factors and mood in a sample of employees in a car factory were studied by Kjellberg et al [7]. High Psychological demands were found to be associated with negatively valued high activity moods ("Stress"). Social support was found to be associated with positively valued high activity moods ("Energy"). The interaction between Psychological demands and Control was also a significant predictor of Energy. High Stress was associated with increased risk for neck and shoulder symptoms.

Aim

The aim of this study was to investigate associations between self reported psychosocial exposure and mood at work among computer users.

Method

Data collection was carried out as part of baseline (to be referred to as T1, n=462, response rate 96%), and follow-up 6 months after baseline (to be referred to as T2, response rate 82%), of an intervention study. Questionnaires were completed at ergonomist-supervised meetings at workplaces representing the following trades: Bank/finance (28% of respondents at baseline), public administration (21%), industry, white collar (20%), wholesale (13%), transport, white collar (9%) software engineering (9%). All respondents did computer work. Average number of work hours per week was 38, with 72% of work time spent working at computer (self reported). 64% were women. Age ranged from 21-65, the mean being 43 years.

Psychosocial factors (psychological demands, decision latitude and social support) were measured using a questionnaire developed by Karasek, Johnsson and Theorell [8]. Mood at work was measured using a mood adjective checklist designed for work environment studies [5]. The instrument measured two mood dimensions: Stress and Energy. The stress dimension ranged from positively valued low-activity moods, e.g. "relaxed" (low stress) to negatively valued high-activity moods, e.g. "under pressure" (high stress). The energy dimension ranged from negatively valued low-activity moods, e.g. "dull" (low energy) to positively valued high-activity moods, e.g. "active" (high energy). In this study, mood ratings were made with reference to moods experienced at work during the last month. For mood and psychosocial factors, difference variables were also computed (to be referred to as "change")

Internal consistency (Cronbch´s alpha) was >0,70 for all scales except Control at T2, for which the internal consistency was 0,66. Correlations were computed as Pearson r:s. Standard (enter) multiple regressions were performed.

Results

Bivariate correlations indicated that Stress was most strongly associated with demands, but also with social support. Energy was most strongly associated with Control but also with Social support. Since the psychosocial factors were not orthogonal, multiple regressions were performed. In these, Stress ratings were primarily associated with psychological demands and, to a lesser degree, social support, which was negatively associated with Stress (table 1)

Table 1 Multiple regressions of psychosocial factors on Stress

	T1* R=.56		T2 R=.60		Change R=.46	
	β	p	β	p	β	p
Demands	.45	.000	,52	.000	.42	.000
Control	-.03	.515	-,12	.004	-.05	.368
Social support	-.25	.000	-,16	.000	-.14	.006

**T1: Baseline; T2: Follow up (T1+6 mo); Change: T2-T1.*

Psychosocial factors explained a lesser proportion of the variance in Energy (table 2). Control and social support were significant predictors of Energy in all 3 models, control consistently showing the strongest associations with Energy (table 2).

Table 2 Multiple regressions of psychosocial factors on Energy

	T1* R=.33		T2 R=.28		Change R=.28	
	β	p	β	p	β	p
Demands	.11	.023	.11	.033	.05	.338
Control	.22	.000	.20	.000	.24	.000
Social support	.17	.001	.15	.004	.11	.048

**T1: Baseline; T2: Follow up (T1+6 mo); Change: T2-T1.*

Discussion

The results showed a substantial degree of association between psychosocial factors and mood at work, particularly with regards to Stress. Variation in psychological demands at work was primarily associated with variation in the degree of negatively valued mental activation. Variation in Control was primarily associated with variation in the degree of positively valued activation. Higher social support was associated with less negative activation and more positive activation. These results are in line with general models of psychosocial work environment and job design. Results are also similar to findings reported by Kjellberg et al [7]. An interesting finding was that the pattern of relationships between the variables showed some stability over time and was present also for change variables. The issue about causality between psychosocial factors and mood was not dealt with in this study.

Acknowledgement: This study was financially supported by the Swedish council for working life research.

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Using the demand control job strain model in conjunction with the effort-reward imbalance model

Ostry AS, Barrotevena M, Hershler R, Demers PA, Teschke K, Hertzman C

All the authors from Department of Health Care and Epidemiology, UBC
e-mail: ostry@interchange.ubc.ca Canada.

Introduction

Both the demand/control and effort/reward imbalance models have successfully predicted "hard" disease outcomes (5,7). In the first comparative study with both models, Bosma demonstrated predictive effects for new coronary heart disease of low task-level control as well as effort/reward imbalance (1).

The purpose of this investigation is to compare the predictive validity of the demand/control and reward/imbalance models for self-reported health status and the presence of any chronic disease condition in a sample of former and current sawmill workers. Because task-level control is the only element which is completely absent from the effort/reward imbalance model, and because this variable has been consistently predictive of a range of health outcomes for the past 2 decades, the predictive validity of effort/reward imbalance in conjunction with task-level control is also tested.

Methods

This investigation is based on a sample of 3,000 sawmill workers drawn randomly from an already gathered cohort (2). Interviews were conducted in 1998/99 and task-level work characteristics measured using a shortened version (6) of the demand/control instrument (3) and effort/reward imbalance measured using the complete instrument (7). The two instruments were operationalized in the usual way and logistic regression conducted with self-reported health status and presence of any chronic condition.

The combined effect of task-level control and the effort-reward imbalance model on both outcomes was tested by forming 6 categories created by all possible combinations of effort/reward imbalance (3 categories) and the two categories high and low task-level control.

Results

Low task-level control (OR=1.6; CI=1.12-2.28) and high psychological demand (OR=1.65; CI= 1.21-2.26) predicted poor self-reported health. Effort/reward imbalance and job strain both predicted poor health status. The risk of reporting poor health status for subjects with high job strain was approximately twice as high as those with low strain (OR=2.07; CI= 1.18-3.66). And, the risk of reporting poor health status for subjects with both high efforts and low rewards was approximately 3 times higher than those with low efforts and high rewards and statistically significant (OR=3.05; CI= 1.95-4.81). Effort/reward imbalance was the only variable which predicted the presence of a chronic condition.

For self-reported health status, combining effort/reward imbalance with task-level control produced odds ratios which increased in a regular gradient moving from the reference category (high reward/low effort/high task-level control) to the "worst" category (low reward/high effort/low task-level control (Table 1). The odds ratio for this latter category was 4.71

(CI=2.44-9.27). In the case of chronic conditions, a less regular gradient was observed. The odds ratio for low reward/high effort/low task-level control was 1.86 (CI= 1.15-3.06) (Table 2).

For self-reported health status, the Model Chi Square for the combined model was 100.15 compared to 95.29 for effort/reward imbalance and 85.5 for task-level control. In the case of any chronic condition the Model Chi Square for the combined model was 41.63 compared to 40.15 for effort/reward imbalance and 7.85 for task-level control.

Table 1: Associations between Effort/reward Imbalance Model combined with Task-level Control and Self-reported Health Status

Hi reward and low effort/ HIGH task level control	1***
Hi reward and low effort/ LOW task level control	1.65 (0.75-3.72)
Hi reward or low effort/ HIGH task level control	2.43* (1.19-5.08)
Hi reward or low effort/ LOW task level control	3.21** 1.59-6.52)
Low reward and high effort/ HIGH task level control	3.08** (1.58-6.21)
Low reward and high effort/ LOW task level control	4.71*** (2.44-9.27)

Numbers in parentheses are 95% confidence intervals
Model Chi Square= 100.15
*p=0.05-0.01
**p=0.01-0.001
***p<0.001

Table 2: Associations between Effort/reward Imbalance Model combined with Task-level Control and Self-report of Any Chronic Condition

Hi reward and low effort/ HIGH task level control	1
Hi reward and low effort/ LOW task level control	0.96 (0.60-1.80)
Hi reward or low effort/ HIGH task level control	1.32 (0.81-2.16)
Hi reward or low effort/ LOW task level control	1.20 (0.73-2.01)
Low reward and high effort/ HIGH task level control	1.43 (0.90-2.29)
Low reward and high effort/ LOW task level control	1.86* (1.15-3.06)

Numbers in parentheses are 95% confidence intervals
Model Chi Square=41.63
*p=0.05-0.01
**p=0.01-0.001
***p<0.001

Discussion

Effort/reward imbalance and job strain independently predicted self-reported health status and the effort/reward imbalance model predicted the presence of a chronic condition. As well, the effort/reward imbalance model in conjunction with task-level control predicted both self-reported health status and the presence of a chronic condition.

Odds ratios were higher for the combined model compared to effort/reward imbalance and task-level control on their own. The combined model explained 5.1% and 17.1% more variance in self-reported health status than the effort/reward imbalance model and task-level control alone. Similarly, the combined model explained 3.7% and 15.7% more variance in self-reported chronic condition than the effort/reward imbalance model and task-level control alone. These results confirm and extend those obtained from the Whitehall study (1). Future work should use effort/reward imbalance and task-level control as a “gold standard” for assessing psychosocial working conditions.

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Ergonomic and psychosocial exposures among computer users in the Swedish workforce

Anna E Ekman (1) Alf Andersson (2) Mats Hagberg (3) Ewa Tornqvist-Wigeaus (4)

(1)anna.ekman@ymk.gu.se, Occupational and Environmental Medicine Sahlgrenska, University Hospital, S:t Sigfridsgatan 85, SE 412 66 Göteborg, Sweden,
(2) Statistics Sweden, Working environment, Box 24 500, 104 51 Stockholm, Sweden,
(3) Occupational and Environmental Medicine Sahlgrenska, University Hospital, S:t Sigfridsgatan 85, SE 412 66 Göteborg, Sweden,
(4) Ergonomics, ALI, 112 79 Stockholm, Sweden

Introduction

The rapid development of information technology has made a major part of the work force dependent on computers (1). This development shapes new work environments, both physical and psychological, and new tasks. The aims of the study were to describe the work environment among computer users and to compare workers health between computer users with contrasts in the work environment, for men respectively women.

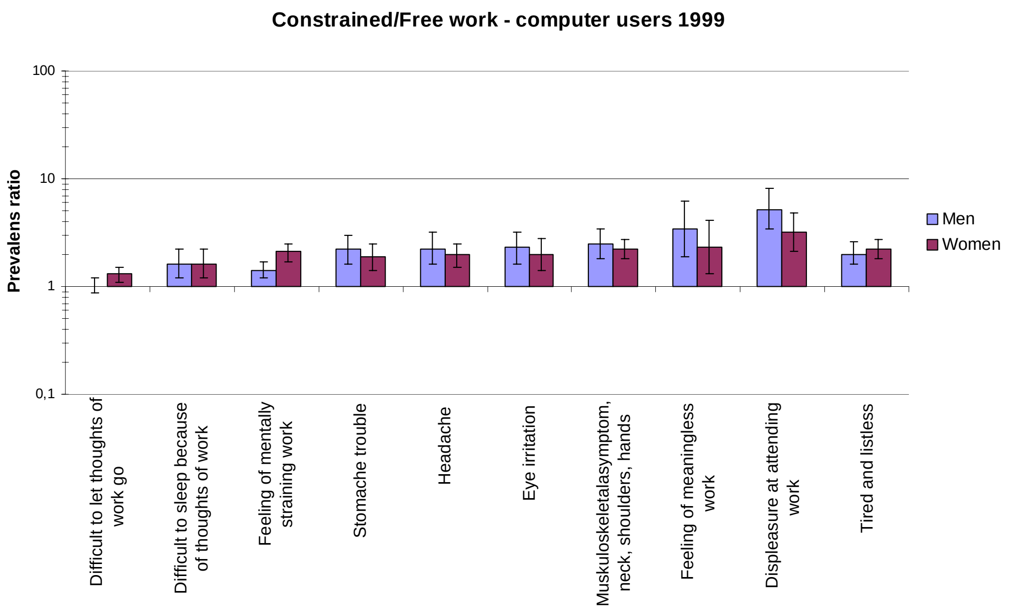
Materials and methods

The material in the study is based on the Work environment survey conducted by Statistic Sweden 1999. The material is representative of the Swedish working population. In the survey questions were asked about working conditions and health, questions by phone and a questionnaire buy mail. The questions asked by phone are answered by 12 546 persons (88 %) and the questions asked by the questionnaire are answered 9798 persons (70%).

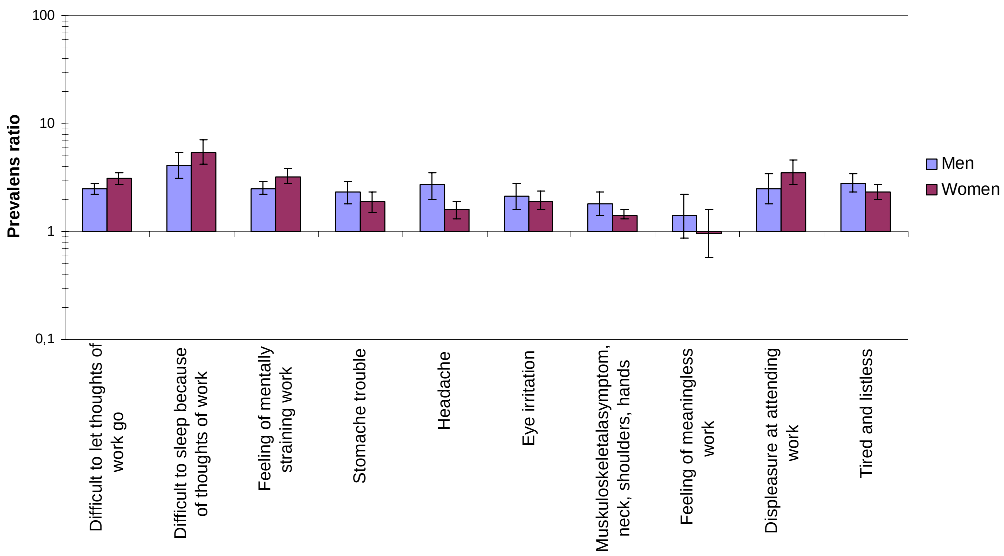
Computer users were defined as persons working with personal computers, or equivalent device, at least ½ of their working time. If not defined as computer user a person is called to belong to the remaining. Constrained work was defined as work were repeated tasks are present at least ¼ of the time, at most ½ of the time one can decide over the work pace and at most ½ of the time one can take short breaks to talk. Free work was defined as the opposite of constrained. (Constrained/Free 561/729 persons) Stressful work was defined as work were one has to skip lunch, work overtime or bring work home at least 1 day per week and at least ½ of the time one can not talk or think of anything else then work due to stress. Relaxed work is defined as the opposite of stressful. (Stressful/Relaxed 734/1218 persons) Work with poor management were defined as work were you almost never or never had possibility to get encouragement and support from superiors, when work felt troublesome, and were your superior seldom or never, the last 3 months, had shown appreciation for something you have done. (Poor/Good leadership 599/1599 persons.)

Results

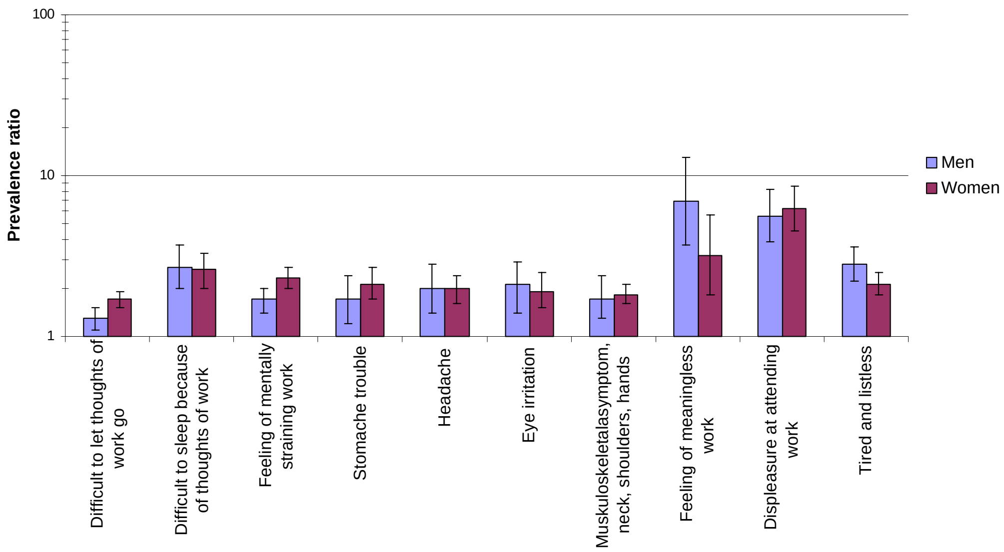
Computer users, compared to the remaining, seemed to be exposed to less twisted working postures, more encouragement and support from superiors and possibilities to develop and learn new things. On the other hand, computer users seemed to have a more stressful work environment with too much to do and more overtime then the remaining. Male computer users had less repetitive tasks then the remaining male workforce. Female computer users seemed to have more repetitive tasks then the remaining female workforce.



Stressful/Relaxed work - computerusers 1999



Poor/Good management - computerusers 1999



Discussion

Many of the negative working conditions were less common among computer users then the remaining. On the other hand were most of the associations between working conditions, as constrained, stressful work with bad management, and symptoms slightly stronger among computer users then the remaining.

The use of computerised equipment is increasing rapidly and so is the share of the working time devoted to computers. Research about computer work and its potential effects on workers health therefore are considered important.

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Effects on performance of medication in the working population

Haslam C[(1)], Hastings S[(2)], Brown S[(2)], Haslam RA[(2)]

[1.] *Department of Health Studies, Brunel University, Osterley Campus, Isleworth, Middlesex, TW7 5DU, UK. email: Cheryl.Haslam@brunel.ac.uk*
[2.] *Health and Safety Ergonomics Unit, Department of Human Sciences, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK.*
email: S.Hastings@lboro.ac.uk, S.Brown@lboro.ac.uk, R.A.Haslam@lboro.ac.uk

Introduction

The extent to which medication is used to treat depression and anxiety in the working population is unknown, although levels are thought to be considerable.(1,2) Studies have highlighted the poor knowledge that exists concerning the effects of prescribed medication on work performance.(1-3)

Psychotropic medicines impair performance on a wide range of laboratory measures, with effects found for attention, vigilance, memory and motor coordination.(1,2) However, it is not clear how these findings translate to performance in the workplace.(1,4) There are problems with generalising from laboratory studies as they are often limited to testing with young, healthy subjects and minor decrements in performance on sensitive laboratory tasks may have little relevance to real world activities.(4,5) It is not clear, therefore, to what extent medication may affect quality of work, productivity and safety.

Lack of treatment for psychiatric illnesses may actually be a greater problem in terms of work performance than the side-effects of medication(2). Employees suffering with depression or anxiety are likely to experience a range of symptoms that would impair performance at work, including: tiredness, lack of motivation, poor concentration and forgetfulness, poor timekeeping and attendance. Failure to seek or comply with treatment may arise from the stigma associated with mental ill-health or, alternatively, some people may be reluctant to take medication because of fears about side-effects. This research collected new and in-depth data on the use of psychotropic medication among the working population to improve understanding of the impact of mental health problems and the treatment for these conditions on performance and safety in the workplace.

Method

This research used focus groups. A focus group is a group interview whereby the data obtained arise from the discourse generated by a discussion.(6) Topics are supplied by the researcher who acts as 'moderator' for the discussion. The moderator should facilitate discussion rather than interview. This is a very useful exposure assessment technique for measuring psychosocial factors. The technique is well suited to this study which aimed to elicit information about the personal experience of mental health problems and the impact of drugs on work performance. Focus groups also afford participants a degree of anonymity.

Fourteen focus groups were conducted across a broad spectrum of employment sectors. Two groups were conducted with participants from anxiety and depression management courses run by clinical psychology services. The course participants come from a wide range of professions. Two groups comprised staff from Human Resources and Occupational Health and Safety across a range of organisations. These groups provided information regarding organisational perspectives on the mental health of employees. The remaining ten focus groups were conducted with participants from a range of industrial sectors. The study strategically targeted sectors known to be high-risk for mental health problems (health care, education, extraction and utility industries and manufacturing). In addition, the focus groups encompassed other sectors, such as the construction industry and transport, to explore any differences in experience resulting from different working practices and organisational structure.

Results

The focus groups were recorded and fully transcribed. The data were analysed by sorting verbatim material into thematic categories. Preliminary results from participants in anxiety and depression management groups indicate that the symptoms of anxiety and depression were considered to be similar to the side effects of the medication including confusion, dizziness and difficulties with decision-making. Medication caused feelings of nausea for many workers. Non-compliance with drug regimes was common due to the unpleasant side-effects and also concerns about dependency.

Respondents felt that it took them longer to do their work and that their medical condition caused them to have lower performance levels. Many felt unable to cope with their workload even though it may not have changed. When managers and supervisors were approached about work problems they were often dismissive of the difficulties encountered because no one else in the workplace had indicated that they were having problems. However they were not always informed when employees were diagnosed with anxiety and depression.

When asked what kind of support they would want, respondents highlighted practical help with the volume of work at difficult times. It was also suggested that support services such as occupational health or a counselling service should be available, or simply the opportunity for a confidential talk. Respondents felt that if anxiety and depression were better understood, managers and colleagues would be more able to give appropriate support.

Discussion and Conclusions

Workers were not well informed about their drug treatment and non-compliance was common. Work performance was thought to suffer due to both the conditions and medication. Support at work was most beneficial when colleagues were able to help with the workload or offer a confidential talk. This study has provided detailed information regarding the impact of mental health problems and their treatment on performance at work. The results will inform future guidelines for employers and employees.

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A comparison of different methods for assessment of psychosocial risk factors for shoulder and neck pain

Holte KA, Westgaard RH

Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology, Trondheim, Norway,
e-mail: Kari.Anne.Holte@iot.ntnu.no

Introduction

The demand-control model by Karasek and Theorell (1) has been the main model to evaluate psychosocial work strain. The model used on musculoskeletal complaints has shown contradictory results. In a study done on female health care workers and shop assistants with high prevalence of presumed stress-related shoulder and neck pain, no association was found neither between the traditional model and shoulder and neck pain nor between our own questionnaire and shoulder and neck pain (2). Our own questionnaire has in earlier studies distinguished between pain-sufferers and pain-free workers (3).

The problems in establishing a correlation between psychosocial job demands and pain in service occupations made us extend the study design to include a more qualitative approach in a follow-up study. It was thereby possible to compare different methods of reporting perceived work demands to see if they differentiated pain-sufferers and pain-free workers in their perception of job strain.

Methods

Female health care workers (n=20), shop assistants (n=21), bank employees (n=26) and secretaries (n=26) with (n=38) and without (n=55) shoulder and neck pain were studied. Three methods of subjective evaluation of exposure factors were used.

Specific questions on perceived psychosocial and physical stress at work, psychological profile, general health and psychosocial stress factors were formulated with the responses indicating the degree of satisfaction. Variables were scored on 10-cm visual analogue scales (VAS) and on categorical scales.

Secondly, to identify whether fatigue, stress or tension (one item) was mostly influenced by psychosocial or physical demands, general questions on psychosocial and biomechanical exposures during work and leisure were included. The answers were scored on VAS with end points “not significant” and “highly significant”. Finally, an interview was conducted using a guide with 17 open-ended questions. Physical and psychosocial issues, both in occupational and in private life were included. Each interview lasted about one hour. The interview was tape recorded and transcribed to text files.

Results

Analysis of the questionnaire data identified the variables in Table 1 to be associated with shoulder and neck pain. Perceived general tension showed the strongest association ($p<0.001$).

Table 1. Questionnaire variables identified by univariate statistics, which was significantly different in the pain and the no-pain group.

Variable	Pain/no-pain	p-values
Perceived general tension (VAS)	5.3 / 2.9	<0.001
Load variation (VAS)	4.3 / 5.6	0.03
Self-realisation (VAS)	4.7 / 5.9	0.04
EPQ-N	9.2 / 7.6	0.09
Job satisfaction (VAS)	7.9 / 8.4	0.09

A logistic regression analysis with shoulder and neck pain as the dependent variable and the variables in Table 1 as independent variables retained only perceived general tension in the regression equation (R^2=0.21, p=0.001).

When the subjects were asked to assign specific factors to feeling fatigued, stressed or tensed, both psychosocial and biomechanical work factors were reported significantly more important among pain-sufferers than among pain-free workers (Figure1). This was also the case for these factors in the leisure time. VAS scores identified psychosocial strain as more demanding than biomechanical strain. When the subjects were allowed to identify critical work demands in their own words in the interview, the most demanding psychosocial factors were professional and social relationships, which include relationship to colleagues, supervisors, clients and customers (Table 2). Each professional group showed the same tendency. In addition, many other causes of psychosocial strain were listed.

Table 2. The most demanding psychosocial factors in the work environment for those with and without shoulder and neck pain. The table shows the distribution of answers. Multiple scoring was allowed.

Psychosocial demands	Pain (n=23)	No-pain (n=35)
Professional and social relationships	14	18
Organisational changes	4	0
Administrative responsibility	3	3
Time pressure	3	4
Job influence	1	2
Demands of skills upgrading	4	2
Lack of challenges	1	0
Work distribution	0	1
Satisfied	0	5

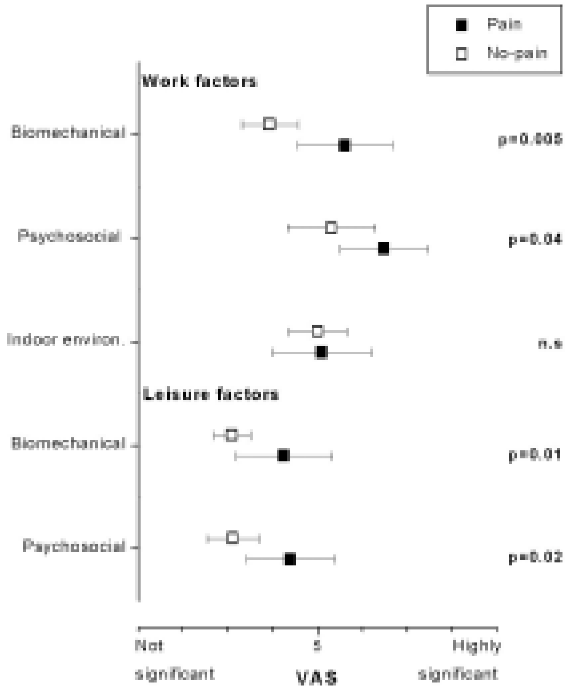

Figure 1. Mean with 95 % CI scored on VAS from ”not significant” to ”highly significant” for the questions assigning different factors to fatigue, tension or stress (one item).

Discussion and conclusion

Questions relating general exposure factors to fatigue, stress or tension distinguished better between pain-sufferers and pain-free than questions on satisfaction with specific workplace factors. The results from the qualitative interview did not differ between pain-sufferers and pain-free workers. For both groups, professional and social relationships were reported as the most strenuous exposure factor.

The lack of association between pain and specific exposure could be due to individual variation in the perception of the work environment as indicated by the many strenuous factors reported in the interview. Another explanation could be that the questions do not represent the perceived strain well.

The qualitative interview allows the respondents to use their own words in the description of stressors. This could be a valuable approach in the design of a quantitative questionnaire. Firstly when studying occupations earlier not studied, an interview can provide valuable information about potential risk factors in these occupations. This makes it possible to better define the research question. Secondly, the interview also makes it possible to develop questions that takes into account the language and concepts used by the workers, thereby ensuring that the questions are understood by the work groups studied.

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Combining practical tools and quantitative measurements in the assessment of physical load at work

Alex Burdorf

Department of Public Health, Erasmus University Rotterdam, the Netherlands

The exposure assessment strategy of physical load at work encompasses several components which characterize awkward postures, strenuous movements, and force application. While designing appropriate strategies, two interrelated issues have to be addressed: the selection of relevant variables that permit specific inferences, and their parameterization. Researchers are usually faced with a large array of variables that need to be quantified. In general, this requires a comprehensive measurement effort that combines different approaches and measurement techniques into a limited number of exposure measures that adequately describe exposure profiles in the populations under study. These exposure profiles should take into account differences in daily work practices among workers and, hence, are subject to measurement errors arising from sampling periods, within worker variability, and between worker variability. Ideally, the best approach would be to obtain information for each worker on his exposure distribution of physical load over a period of several weeks, where measurements are taken during a series of tasks and workplaces representative to his job. However, this ideal is very difficult to achieve in practice due to feasibility and cost constrains.

Assessment techniques for exposure to physical load are broadly classified into three categories of data collection: (1) self-reports, (2) direct observations, and (3) direct measurements. Progressing from self-report to direct measurements, the amount and quality of the exposure information increases, but usually at the expense of higher costs due to expensive devices and more manpower. It is important that the assessment method chosen is appropriate to the aim of the investigation. Practitioners may apply questionnaires and checklists to identify problematic elements of tasks and jobs or to assess physical load in occupational groups in crude qualitative classifications, like low, moderate, and high. However, these instruments do not provide a quantitative assessment of physical load and do not present sufficient information to demonstrate compliance with existing guidelines or to prioritize risk factors of physical load for reduction. Often observational methods or direct measurements techniques are needed to acquire sufficient detail on intensity and frequency of determinants of physical load. Although direct measurement techniques are favoured for their precise and accurate measurements as well as their informational content, they have certainly disadvantages. First, these techniques are limited to a few determinants of physical load whereas questionnaires may address a large array of potential risk factors. Second, direct registration of exposure data is predominantly performed while sampling during particular periods on a limited number of days. In general, their ability may be questioned to estimate long-term mean exposure to physical load which adequately reflects variations in work practices and production processes.

A potential solution to the problem of arriving at accurate assessments of long-term exposure to physical load at work is to combine practical tools and direct measurement methods. Relatively inexpensive instrument such as questionnaires, checklists, and logbooks can be used among large groups of workers to assess specific aspects of exposure with sufficient accuracy, such as duration of tasks and frequency of materials handled. This exposure information may even be readily available from production figures and work process analyses. Subsequently, detailed quantitative measurements are performed in a limited sample of workers and activities in order to present the full array of required exposure parameters on awkward postures and external forces. Combining both sets of information allows modelling of the physical load of individual workers.

This approach was adopted in a study on lifting materials during scaffolding. Manual materials handling is the most dominant activity during the three principal tasks of scaffolders, i.e constructing scaffolds, taking down scaffolds, and transporting scaffold materials such as poles, boards, baseplates, and guard rails. Scaffolding teams were observed during which lifting frequencies, weights, and distances were registered for each lifting situation involving specific materials by means of a checklist. It took the researchers several days to complete the measurements required to fill out all the checklists' items on manual materials handling for several scaffolding teams. Subsequently, production figures were collected on the number of materials used on particular days to build up or take down the scaffold. This information was readily available since the scaffolding company keeps records on daily production (for billing purposes) and on the numbers of scaffolding materials that have to be delivered to a certain construction site. Combining these production figures with the checklist information enabled the calculation of the Composite Lifting Index according to the NIOSH equation for lifting. This procedure resulted in an accurate prediction of the total physical load due to lifting among scaffolders. The alternative approach of observing over 60 scaffolders for working time spent on the different tasks as well as the percentage in each task spent on lifting of scaffolding materials took more than four weeks and, in the end, provided comparable information.

A similar approach was chosen in a study among tank terminal workers. Assessment of physical load was performed by direct observation of awkward postures and forceful exertions during normal activities. Workers filled out a diary regarding the executed tasks during one shift. Subsequently, the cumulative load over a workday of individual workers was calculated as the product of the load per task and the duration and frequency of the tasks on an average workday. The results of this study illustrated that exposure assessment at individual level was substantially improved by linking task-based estimates of physical load (direct observations) with individual task registration (self-reports in a log). The modelling of exposure greatly reduced the random measurement error (especially the within worker variability) and presented detailed information on physical load of each worker. This strategy may be especially successful in workplaces with highly dynamic work.

Both examples illustrate the benefits of combining information from practical tools with detailed quantitative measurements that calibrate the elementary measures derived from questionnaires and checklists. Costs of practical tools are low and, hence, they can be applied to collected elementary exposure information over longer periods. It is our experience that questionnaires and diaries/logbooks may provide crucial information on frequency and duration aspects of exposure (e.g. task distribution, frequency and weights of materials handled) which will be difficult to collect with direct measurement techniques among large groups of workers. This information is sometimes readily available for production records. Linking information from practical tools with quantitative measurements will facilitate measurement strategies that address both exposure intensity and exposure duration. It is expected that in this approach long-term mean exposure to physical load is assessed less precisely but more accurately then using direct measurement methods in the traditional strategy of sampling few workers during particular periods on a limited number of days.

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Roundtable to identify standard approaches to exposure assessment in epidemiologic studies

Stewart, P.A. [(1)], Herrick, R.F. [(2)]

[(1)] US National Cancer Institute, stewartt@epndce.nci.nih.gov
[(2)] Harvard School of Public Health, USA, herrick@hohp.harvard.edu

Introduction

What is the goal of exposure assessment in epidemiologic studies? The primary goal is to optimize the classification of people to accurately reflect their exposure. Valid exposure classification increases the likelihood that exposure-disease relationships will be correctly identified, and the nature of these relationships properly characterized. We conduct exposure assessment in epidemiology to provide information necessary for testing the hypothesis that the exposure received through inhalation, dermal and ingestion routes is associated with the risk of disease.

Exposure assessments are conducted by collecting all information available in the most comprehensive manner, to develop as precise an estimate for each individual subject as possible for the agent(s) of interest, recognizing that these may not necessarily be what was measured. We also collect information on other risk factors including possible confounders, given what is known about the underlying mechanism of toxicity and the natural history of the endpoint of interest.

Years of experience in exposure assessment have led to the identification of some components of a “standard” exposure assessment. These include: selection of one (or more) agent(s); identification of an exposure metric; strategies for creating exposure groups; and approaches to dealing with missing information on exposure. This Roundtable addresses the last two of these components.

Synopsis of the Roundtable

The Roundtable will feature presentations by researchers experienced in dealing with these questions in epidemiologic studies, and ample time for discussion will be included.

Strategies for creating exposure groups

-Under what circumstances should individuals be formed into groups, and on what basis? When can exposures of individuals be estimated? When can job title be considered a valid criteria for grouping individuals?

-How can statistical tests guide a grouping strategy? What happens when there is data for only some individuals or jobs?

-When can a rigorous evaluation of presumed determinants of exposure, rather than measured exposure data, be considered acceptable?

-How can between and within group variability be estimated, and how can this be used in a grouping strategy?

Approaches to dealing with missing information on exposure

-How do you decide how many measurements are necessary to support an exposure classification strategy?

-When should statistical methods vs. empirical methods be used to estimate missing exposures?

-When should you use point estimates of exposure measurements vs. ranges of measurement units vs. semi-quantitative categories (low, medium, high)?

-Is mixing of methods acceptable? If so, does it require any special approaches?

-What criteria should considered in selecting statistical approaches such as regression, vs. deterministic approaches? What criteria should guide the selection of a surrogate for exposure?

-How can you evaluate the appropriateness of a strategy for dealing with missing information?

Peak exposure to volatile organic compounds during spraying activities

Preller L[(1)], Pater N de[(1)], Burstyn I[(2)], Kromhout H[(2)]

[1.] *TNO Chemistry, Dept Chemical Exposure Assessment, Zeist, The Netherlands e-mail: Preller@chemie.tno.nl.*
[2.] *EOH Group, Institute for Risk Assessment Sciences, Utrecht University, Utrecht, The Netherlands*

Introduction

Chronic Toxic Encephalopathy (CTE) attributed to occupational exposure to volatile organic compounds (VOCs) is at present subject of discussions in The Netherlands. It has been suggested that CTE may be stronger related to regularly occurring peak exposures rather than more or less constant concentrations during a shift.

The aim of the present study was to support the discussion on standardisation of peak exposure to neurotoxic VOCs by giving information on both the exposure profiles and the correlation structure between different measures of peak-exposure.

The study was restricted to situations where VOCs were dispersed by spraying.

Methods

Personal inhalation exposure to VOCs was measured each second during one spraying session (lasting for 4.6 to 159 min) with a Photo-Ionization Detector (PID) for real-time monitoring during spraying activities, for twenty-seven persons in fifteen companies. Charcoal tube samples were taken to determine composition of the VOC-mixture, for correction of PID-readings and assessment of the OEL of the mixture (OEL_{mix}). OEL_{mix} depends on the fractions of the specific compounds in the mixture and their OELs (3).

The industries measured included the glass-reinforced plastics industry (n=7), shoe manufacturing (n=5), (industrial) spray painting of transportation means (n=8), production of mattresses (n=2), production of furniture and window frames (n=4) and leather covering of car seats (n=1). In these industries, coatings, glue and resins are dispersed by spraying.

There is no univocal definition of peak exposure. Therefore several measures of peak exposure were considered in the present study. A peak exposure was defined as a period during which exposure exceeds a reference level, in this study OEL_{mix} and the TWA exposure of the observation period of each observed worker. Six peak characteristics were distinguished: *number of peaks per hour*, *duration of peaks* and *time between peaks* being time related measures, and *average concentration* (=average of the one-second readings per peak), *maximum concentration* (highest one-sec. reading per peak) and *ratio between maximum and average concentration* per peak being intensity related measures. For all characteristics, the average value over the spray period was calculated. For all observations, the 6 characteristics were determined for both reference levels and 3 averaging time (5 sec., as proxy for inhalation duration, 1 min., and 15 min, already in use in standard setting), resulting in 36 peak measures. For each second the average concentration was calculated for the preceding averaging time period.

Exposure profiles were described in terms of peak exposure measures. Associations between TWA exposure and peak exposure measures and peak exposure measures mutually were studied using principal component analysis (PCA) (on 24 variables based on 5 sec. and 1 min. averages and on TWA exposure) and by determination of correlation coefficients.

Results

TWA exposure varied from 6.8 to 341 ppm and OEL_{mix} from 26 to 288 ppm.
The results show variation in exposure profiles between as well as within industries. Industry specific peak patterns are schematically given in Figure 1. Exposure is only presented when exceeding the industry specific OEL_{mix}. The shoe industry, whith much higher OEL_{mix} and very few peaks, is not presented.

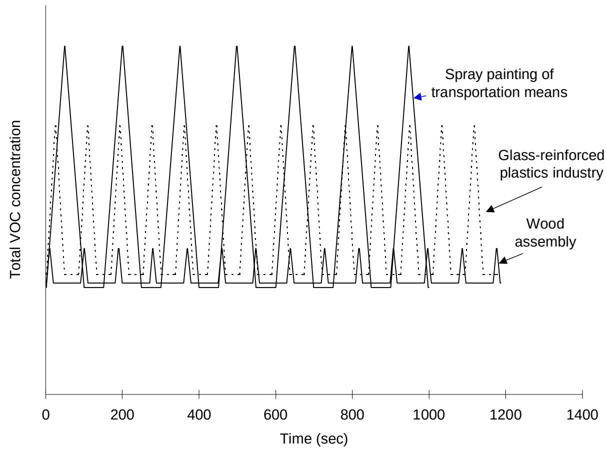

Figure 1. Average exposure pattern per industry (schematised), based on peak measures determined for 5 sec. averaging time and OEL_{mix} as reference.

Peak measures were influenced by reference level and averaging time to a certain extent, except for maximum concentration and average concentration. Use of longer averaging time resulted into less peaks per hour, longer duration of peaks and more time between peaks, and comparable ratio, maximum concentration and average concentration averaged over the spray period. For the studied workers, using OEL_{mix} in stead of TWA as a reference level resulted into fewer peaks per hour, longer duration of peaks and more time between peaks, higher ratio, and no influence on peak maximum and average concentration. Part of the latter results will strongly depend on the proportion of observations in which TWA exceeds OEL_{mix}, in this study this occurred 13 times (48%).

PCA yielded three relevant principal components to describe exposure profiles. For each principal component a representative peak measure was chosen, resulting in the following three exposure characteristics for description of peak exposure profiles, *i.e.* TWA exposure, time between peaks, and number of peaks per hour. Based on PCA and correlation coefficients, TWA exposure, maximum concentration and average concentration of a peak were highly correlated.

Discussion and conclusions

In the literature, information on peak exposure especially with respect to chronic health effects is very scarce. For exposure to VOCs, a more harmful effect of peak exposure compared to constant exposure has been suggested (2). For this hypothesis, evidence is lacking and peak exposure is not defined. PBPK-modelling with realistic exposure scenarios by Bos et al. (1) showed that in certain circumstances, the concentration of the compound in the brain is higher when exposed to during the working day fluctuating concentrations compared to constant exposure, with the same total day dose.

Different alternatives to define peak exposure were analysed. The study was restricted to periods during which products containing VOCs were dispersed by spraying. Results can differ for other applications and for situations in which a less restrictive sampling period is considered.

An increase in averaging time affected time related peak measures, but not intensity related measures. A larger averaging time dampens the highest individual peaks, resulting into comparable values for maximum and average peak concentration and for their ratio because short (low) peaks do not contribute to the average.

The selected exposure measures based on PCA follow normal exposure assessment strategies with intensity, duration and frequency of exposure being the designated parameters to characterise exposure. Since these (peak) exposure measures can be distinguished, their potential separate effect can be studied with respect to exposure-response relationships and, in case of expected or proven biological relevance, used for standard setting purposes.

The high correlation between TWA exposure, maximum and average peak concentration indicated that their individual effect on health can not be assessed and that separate standard setting for these intensity related parameters will be redundant in this exposure situation. The loading of time related exposure measures on other components in the PCA-analysis suggests that these measures could be studied as different characteristics of peak exposure in exposure-response analyses. With proven biological relevance, they could be used for standard setting and compliance purposes.

In general, the approach of using PCA supported by correlation calculations can be used for selection of relevant exposure measures with respect to exposure-response relationships, standard setting and compliance purposes. It can be applied to different exposure situations, with other types of hazardous substances and with different types of biologically relevant exposure measures.

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Assessment of emissions with pulsed tracer gas release coupled with continuous FTIR monitoring

Svedberg U

Dept. of Occupational & Environmental Medicine, Sundsvall Hospital, Sweden
e-mail: urban.svedberg@lvn.se

Introduction

To correctly calculate emissions from an occupational or domestic activity, two major measurements must be in place, the ventilation measurement and the emission concentration measurement. Assuming the emitting sources are contained within a defined space (building) the ventilation data is traditionally obtained by flow measurement in ventilation ducts. However in many cases the ventilation is of diffuse or passive nature and a substantial amount may leave the building passively through doors, windows, cracks and other openings. Common cases are homes or workplaces with self-draught ventilation systems. In those cases a tracer gas decay technique may be the only practical way to obtain a correct picture of the actual ventilation pattern.

The aim of this study was to investigate if process emissions in a complex ventilation environment could be calculated using a pulsed tracer gas release technique coupled with a continuous monitoring FTIR instrument over an extended time period. A lumber chamber dryer of a sawmill was chosen for the study, Figure 1. Emissions from lumber dryers have not previously been described and the aim was to determine the total amount of terpenes emitted during a complete drying cycle in order to calculate a specific emission value for the Scandinavian conifer Scot's pine (*Pinus sylvestris*).

Methods

The dryer cycle was a continuous operation lasting up to ten days. The temperature and the relative humidity in the chamber was automatically monitored and controlled by a heater, an exhaust ventilation fan and a draught valve. The air in the drying chamber was circulated in alternate directions through the heater. Two passive air ducts eliminated under-pressure during the operations. Active ventilation was provided by the exhaust fan, passive through the pressure regulating air ducts and through other non-specified openings of the room. The volume of the dryer room was 938 m^3. The loaded amount of lumber was 102.3 m^3.

An FTIR instrument (Bomem MB100) with a 20.25 m White cell (Foxboro) and a MCT detector (Belov Inc.) was positioned in a room adjacent to the drying kiln. A 50 m PVC, ½ inch sampling line was drawn from the instrument and inserted into the exhaust duct just below the fan. A dispenser line from a tracer gas flask (N_2O) was inserted into the drying chamber. A timed valve on the flask was set to release tracer gas into the chamber during 15 minutes every two hours. This gave a rapid and even distribution of the gas in the drying chamber. For tracer gas decay rate calculations, the general formula for complete mixing ventilation was used; $C = C_0 \cdot e^{-t/T}$ where; C is the concentration at time = t, C_0 is the concentration at time = 0, t is the time between C and C_0 , T is the time constant for the room. The air exchange rate is given by 1/T.

Data was collected continuously as FTIR interferograms, representing 6-min averages. The fourier-transformation of the interferograms, and the following spectral analysis, was performed with Lab Calc software from Galactic Inc. The data was collected in the mid-IR region between 600 and 4000 cm^{-1}, at 1 cm^{-1} wavenumber resolution and saved to disk as single-beam spectra. In this spectral region both hydrocarbons and tracer gas are measured simultaneously. The calibration procedures of the FTIR have previously been published. (1)

Results

The regular pattern from the pulsed releases of tracer gas in the exhaust duct is shown in Figure 2. A marked increase of the concentration towards the end of the seventh day is explained by the stopping of the exhaust fan at the end of the drying cycle. In order to use the tracer gas decay for calculations the natural logarithm of the tracer gas concentrations is plotted as a function of time. By calculating the slope of each of the decays, interpolate for the points in-between the air exchange rates as a function of time is obtained. **Figure 2** shows how the initial exchange rate is very low during the first two hours. It reaches its peak value after the start-up of the fan and gradually decreases over the seven day drying cycle, and finally drops to near-zero levels again when the cycle is over and the process and the fan is automatically turned off. During two occasions the process increases the ventilation drastically. This is clearly indicated by the two peaks in the air exchange rates on the 13^{th} and 16^{th} of July.

The initial analysis of sample spectra revealed the presence of methanol. A-pinene and 3-carene dominated among the terpenes with steady state levels around 100 mg/m^3 Figure 3. The methanol level reached a steady state level around 30 mg/m^3. The initial build up of high concentrations of terpenes is explained by the almost zero-ventilation during the first few hours when the dryer chamber is heated up. When the starting drying temperature is reached, the exhaust fan starts and the terpene levels drops immediately. This is clearly demonstrated in **Figure 3**, which also shows the drastic increase after the end of the drying cycle when the fan has been turned off, and the drop to near zero levels after the opening of the main chamber door a few hours later.

All decays showed linear behavior when fitted according to the least square method (r^2>0.95) which indicates complete mixing of the air in the chamber and that first-order kinetics could be applied. The decay rates between the measured 2-hour periods were interpolated and a decay rate for each six-minute period was obtained matching the temporal resolution of the FTIR spectra. A value of the exhausted air from the room could then calculated yielding a total exhausted volume of 172 251 m^3. During the same period the quantitative analysis of the terpenes shows that 33,35 kilograms had been exhausted. Since 102.3 m^3 of lumber was loaded in the batch dried during this study, the specific emission is concluded to be 326 grams per m^3. The annual terpene emission from the combined dryers would amount to 48 900 kg based on an annual production of 150.000 m^3 at the investigated sawmill.

Discussions

The determination of the ventilation parameters is usually a weak point in industrial hygiene surveys. This is particularly true in buildings equipped with self-draught or poor mechanical ventilation. The studied drying chamber is an example of a complex ventilation system where passive ventilation could not be excluded. A continuous release tracer gas method could also have been used but it would have had required more tracer gas and careful monitoring of the flowrate while the pulsed decay method, the gas flow rate is not critical. The decay method was chosen due to its simpler design. Flow rate measurements in the ducts would not embrace passive ventilation. The temporal resolution used for collecting spectra was 6 minutes while the decay determinations had a temporal resolution of 2 hours. By the nature of the FTIR system temporal resolutions of 1 second can be obtained with a sacrifice of sensitivity.

Conclusions

A substantial amount of terpenes are released from sawmill dryers. The figure obtained in this study adds to already high amounts emitted from other sections of the sawmills, and which are presently under investigation. The total amounts are such that the geographical locations of sawmills in relation to domestic housing should be seriously considered. A pulsed tracer gas decay technique is useful when monitoring the changes in ventilation over time even in places where there is only passive ventilation. When used in combination with an FTIR system a number of emissions can be monitored simultaneously with high temporal resolution thus giving clarity to complex patterns. A single instrument could both measure the ventilation tracer and the concentrations of the chemicals of interest. The set-up needed attention about every 20 hours after which the MCT detector needed to be refilled with liquid nitrogen.

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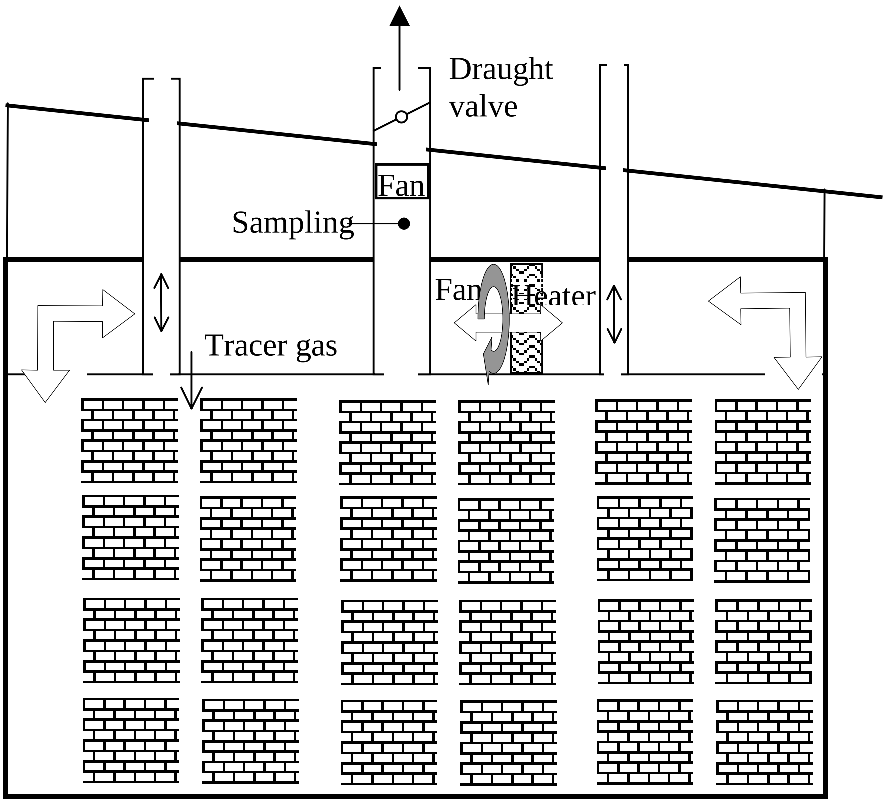

Figure 1. Schematic of the lumber dryer

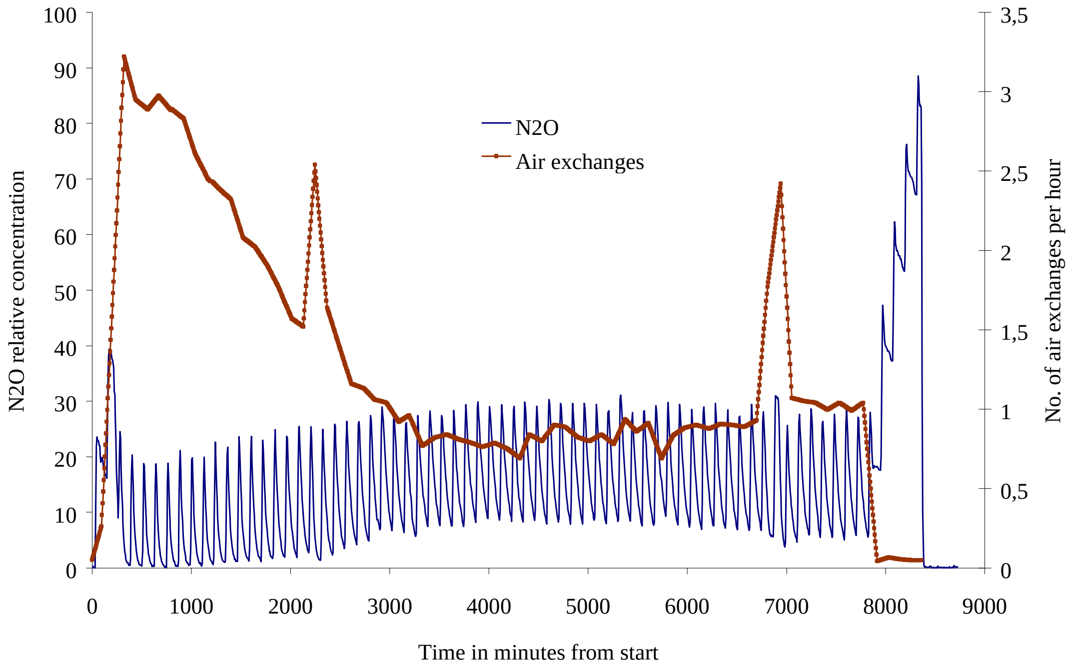

Figure 2. Recording of tracer gas concentration and calculation of the number of air exchanges over the seven-day experiment

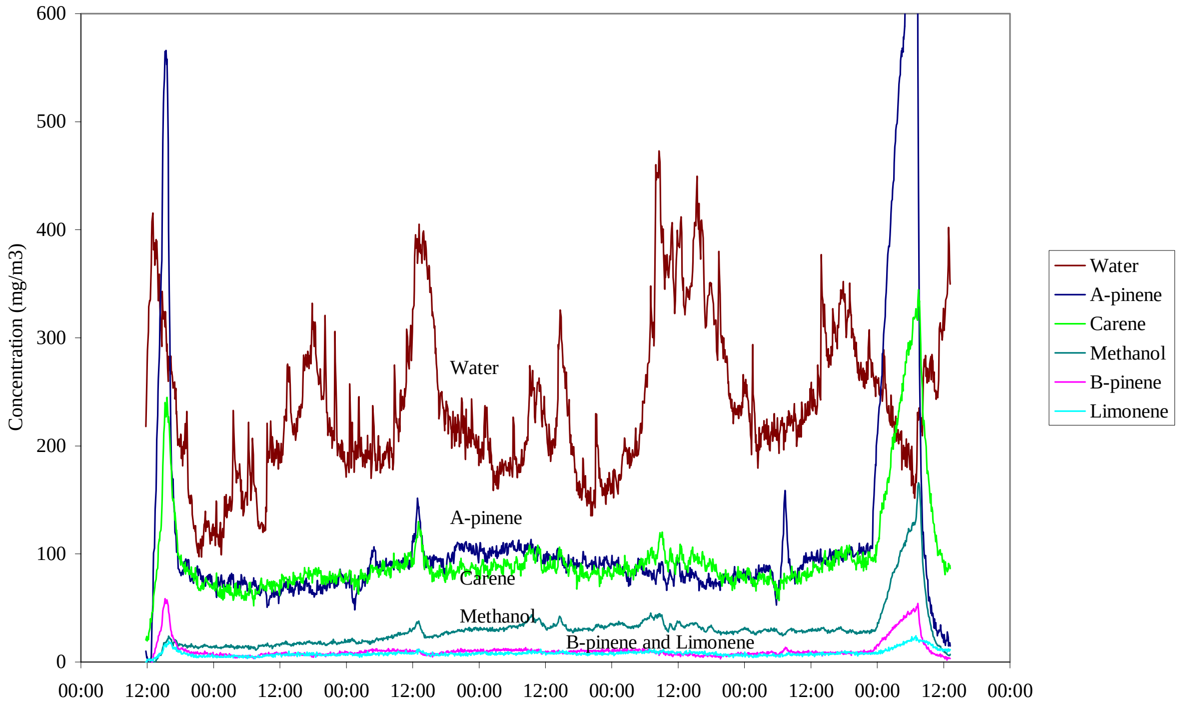

Figure 3. Fluctuations of air borne chemicals during the seven day experiment. Water levels are relative only.

Field study on chemical exposures during preventive maintenance of metal etching machine in wafer plants

Yu YC [(1)] Chang CP [(1)] Lin YC [(2)] Shih TS [(1)]

[(1)] Institute of occupational safety and health, Council of labor affairs, Taiwan, R. O. China. E-mail: yichunyu@mail.iosh.cla.gov.tw
[(2)] Institute of environmental health, National Taiwan University, Taiwan, R. O. China.

Introduction

Hazardous chemical exposure is an important issue in semi-conductor industry. The chemical emissions of wafer factory may cause three problems: affect the health of worker; affect the safety integrity of the facility; affect the productivity of the whole plant. Many workers complained about the strange odor in the wafer plants located in Hsin Chu Scientific Based Industrial Park. The engineers of metal etching felt notably stinging smell during preventive maintenance (PM). First et al [1] discovered that the plasma etching machines would produce hydrocarbon compounds, which could adhere to the surface of reaction chamber, and would generate the toxic or corrosive gas. HCl, HBr, HF and Cl_2 emission while chamber was opened were reported. Pais [2] predicted that metal etching process could produce F_2, HCl, HF, Al_2Cl_6, and CNCl in plasma condition. Bauer et al [3] found that aluminum metal etching process would generate compounds with C, H, N, and Cl in plasma condition, which include aliphatic ($C_xH_yCl_z$), carbocyclic (C_xCl_y, C_xCl_yO) and aliphatic nitrogenous ($C_wH_xN_yCl_z$) compounds. Some of those substances were known to be harmful to liver, kidney and central nervous system, and some of the substances were carcinogen and mutagen.

Closed-cell Fourier Transform Infrared spectrometer (FTIR) was employed to evaluate the continuous and instantaneous peak exposure of toxic gases during preventive maintenance of metal etching machines in wafer manufacturing plants. The newly designed engineering controls would be proposed to verify that the hazardous releases were captured.

Material and Methods

The exposure assessment technique was used within a close cell FTIR (MIDAC G series, USA), which was set to had the scan range from 400 to 4000 cm^{-1} with $1cm^{-1}$ resolution. The location of sampling was at the breathing zone of PM engineer, which was above the chamber. The operation procedures for the PM included opening the chamber, removing the cover and wiping the wall of chamber by isopropyl alcohol or deionized water. Time of sampling would be designed to cover the whole stage of PM. Some types of metal etching machines were investigated and one special type of metal etching machine was focused in the kinetics study.

The engineering control was mandated by a local exhaust ventilation system. The transparent acrylic plates were used to construct the shell of the hood. A piece of soft, transparent and round plastic material (2mm in thickness) was centered-cut into 10 parts to form a wedge-shaped teeth, which was fixed on the top of the hood. And the area of the hood opening was 15-30 cm^2 depends on the worker's activity. The head of suction was achieved by a vacuum cleaner (NILFISK GM80), and the air flow rate in the exhaust ventilation system was measured by rotameter. The capture velocity was determined by a hot-wire anemometer.

Results and Discussion

After monitoring for PM procedures of metal etching, we found that all the detected gases (CCl_4, CO, HCl, HCN, HCOOH, SiF_4) by FTIR during PM were not of process gases. High concentration of HCN was found in this study, however, most gases were found and discussed in some reports [4-7]. Extremely high concentrations of hydrogen chloride (90 ppm) and hydrogen cyanide (65 ppm) were detected when engineers were wiping the reaction chamber with isopropanol or deionized water, and nitrogen-containing materials, respectively, even though these two toxic gases were not used as raw materials. The HCN evolution had a regular pattern as showed in Figure 1. While opening the chamber, the first peak was observed and identified as HCN by FTIR, but the concentration of HCN was low. While using deionized water to clean the chamber, the second peak was detected and much higher than the previous one. The highest concentration of HCN was about 65 ppm, the Ceiling limit of HCN in Taiwan is 10ppm, and was much higher than the Ceiling limit. The trend of HCl concentration was very similar to HCN, also had two peaks, first one was much lower than the second one. The highest concentration of HCl was 90 ppm where it was measured above the chamber and was 195 ppm inside the chamber, respectively. The Ceiling limit of HCl in Taiwan is 5 ppm. As Chung [4] stated that, chlorine reacted with the aluminum and produced $AlCl_3$ during the metal etching, and then $AlCl_3$ reacted with H_2O releasing HCl. Therefore, during the preventive maintenance, when workers used water to scrub the reaction chamber, it produced HCl. Nitrogen-atom containing gases which was accelerated by plasma was collided with carbonaceous compounds, then, CN^- ion was formed and highly suspected for HCN release. In order to verify this hypothesis, the reaction chamber was filled with nitrogen and plasma was applied to accelerate etching reaction followed by normal preventive maintenance procedures. Highly increasing of the HCN concentration was detected. Several control measures were carefully examined for the effectiveness of reduction of exposures during preventive maintenance. A newly designed low-volume high velocity local exhaust ventilation system with capture velocity of 10-15 m/s was then installed and found effectively improving the working environment. This kind of hood could let the operator to put his hand into chamber easily and enhance the hazardous release withdrawn. This new system is now widely used in wafer manufacturing plants in Taiwan. It was concluded that FTIR is a useful tool to measure the un-scheduled exposures.

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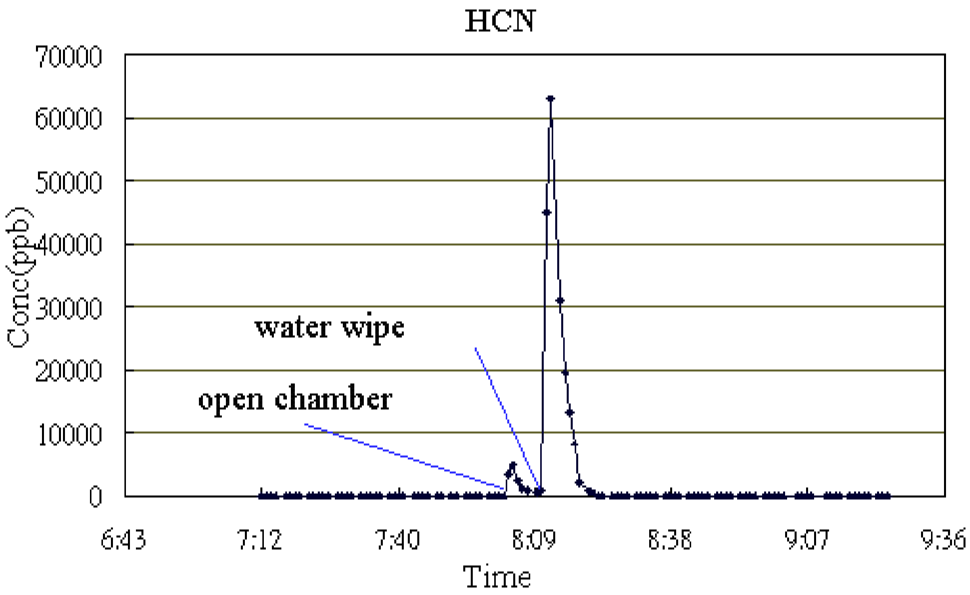

Figure 1. The concentration trend of released HCN.

Wood dust exposure in the Danish furniture industry in relation to occupational hygiene parameters

Mikkelsen AB [1], Schlünssen V [1], Sigsgaard T [2], Schaumburg I [1]

[1] *Department of Occupational and Environmental Medicine, Skive Hospital, 7800 Skive, Denmark, e-mail: ssamaabm@vibamt.dk*
[2] *Department of Environmental and Occupational Medicine, University of Aarhus, 8000 Aarhus C, Denmark.*

Introduction

The International Agency for Research on Cancer (IARC) has classified wood dust as a human carcinogen. Furthermore, results from epidemiological studies indicate, that workers exposed to wood dust stand an increased risk of suffering from respiratory symptoms and impairment of lung function. An epidemiological cross-sectional study in the Danish furniture industry among 2,381 woodworkers has been carried out, in order to investigate the relation between wood dust exposure and respiratory diseases. In this abstract we present an assessment of wood dust exposure in the Danish furniture industry in relation to hygienic parameters.

Methods

A total of 54 furniture factories participated in the study, and the base study population was defined as all 2,381 workers employed in wood working departments, assembly departments, and stock departments of these factories. The factories were visited between October 1997 and April 1998.

Personal dust sampling was carried out with passive dust monitors. The method is based on measuring light extinction before and after sampling on transparent foils. The light extinction increase was reported as dust covered foil area and converted into equivalent inhalable and total dust concentrations by linear regression models, based on calibration measurements. A total of 1,685 valid wood dust measurements were performed [(1)] .

At the same time occupational hygiene variables like work task, use of compressed air, level of automation, exhaust ventilation present etc. were recorded.

Results

The parameters for the distributions for inhalable dust are seen in Table 1. The wood dust exposure for all personal measurements at “woodworking” was larger than that at “mixed and other tasks” which again was larger than that at “handling/assembling”. No difference was seen between the parameters for all the personal measurements and for the the subgroup of 1,236 persons working at the same place during the whole measuring period.

Table 1. Wood dust exposure (mg/m^3) as a function of exposure group for all persons§, geometric mean (GSD) for inhalable dust.

	All tasks N = 1,685	Woodworking N = 743	Handling and assembling N = 716	Mixed and other tasks N = 189
All personal measurements	0.94 (2.10)	1.23 (1.97)	0.69 (2.03)*	1.04 (1.94)*

* p < 0.001 Mann-Whitney test; group vs. "woodworking".

§ For 37 persons, no exposure group was available.

Within the subgroup of 1,236 persons a total of 601 performed woodworking. The highest exposure was found for "manual sanding" (1.99 mg/m^3). Among cutting machines, circular saws had the highest exposure level (1.37 mg/m^3).

Of the woodworking machines 88 % were equipped with exhaust ventilation. On the other hand only 26% of the machines were found to have an adequate ventilation.

The wood dust exposure for "presence of exhaust ventilation" was somewhat decreased, but for "adequate exhaust ventilation" the effect was more pronounced, 0.95 vs.1.36 mg/m^3, $p < 0.001$ for "woodworking" and similar results for several specified woodworking jobs.

The "presence of full or partial enclosure" meant a significantly reduced exposure level for "woodworking" 1.07 vs. 1.38 mg/m^3, $p < 0.001$. It was especially pronounced for automatic sanding, 1.19 vs. 1.79 mg/m^3, $p < 0.05$ and for surface routing machines, 0.70 vs. 1.49 mg/m^3, $p < 0.001$.

Dust was present at the work piece at 56% of the cases leading to larger exposure for "woodworking", 1.27 vs. 1.06 mg/m^3, $p < 0.001$, most pronounced for "manual sanding", 2.40 vs. 0.91 mg/m^3, $p < 0.01$.

Compressed air was used by 71% of the persons occupied at woodworking. This was accompained by a moderate increase in the dust level, 1.24 vs. 1.12 mg/m^3, $p < 0.05$. Exposure to dust was found to depend on degree of automation of the woodworking job with the largest exposure for manual jobs (Table 2).

Table 2. Inhalable dust (mg/m^3) as a function of degree of automation

	Automatic, N = 105	Semi automatic, N = 339	Manual, N = 145
Woodworking	1.06*	1.12*	1.57

* p < 0.001 Mann-Whitney test; group vs. manual.

Discussion

Inhaled wood dust has two main sources: Primary emission from woodworking processes and resuspension (secondary emission) of dust deposited on surfaces. Resuspension can be induced by eg. cleaning processes, by walking or by running trucks over deposited dust and chips. One heavily dust-emitting source may determine the exposure at several neighbouring machines, thus making hygienic information collected about the work at these machines more or less irrelevant. From these considerations one cannot expect to explain but a restricted part of the variation of exposure data by the help of hygienic variables like those mentioned above.

A smaller exposure at handling and assembling work (without sanding) was demonstrated, see Table 1, in agreement with more recent findings (2) . However, the exposure should not be regarded as negligible. As demonstrated in earlier studies, manual sanding separated out as a woodworking process of high exposure (1,2,3).

The presence of exhaust ventilation did not seem to be an important parameter in our study, although very difficult to investigate, as nearly 90% of all woodworking machines in fact had exhaust ventilation. For the parameter “adequate exhaust ventilation” a decrease in wood dust exposure was found for most of the jobs, which underlines the importance of considering the quality of the exhaust ventilation.

An association between presence of enclosure and dust level was found. This has to our knowledge not been reported before, although it is not surprising.

Degree of automation has not been included as a parameter in earlier investigations. In the univariate analyses we found manual processes to give the largest exposure.

Multivariate analyses including cleaning procedures are ongoing and results will be presented at the conference.

Conclusions

Wood dust exposure was found to depend on working process, encapsulation, exhaust ventilation and degree of automation.

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Trends of dust exposure in the European carbon black manufacturing industry

van Tongeren MJA (1), Gardiner K (1), Kromhout, H(1,2)

[1]*Institute of Occupational Health, University of Birmingham, Birmingham B15 2TT, United Kingdom. email: m.j.a.van_tongeren@bham.ac.uk.*
[2] *Environmental and Occupational Health Group, University of Utrecht, The Netherlands.*

Introduction

A was carried out study to investigate the effect of exposure to carbon black on respiratory health amongst workers in the carbon black manufacturing industry. This study was designed as three cross-sectional studies which were carried out between 1987 and 1995. A large number of personal inhalable dust measurements were taken during these three cross-sectional surveys.(1)

This paper describes the trend of exposure to inhalable dust over time by using mixed effects analysis of variance. In a previous publication, it was shown that exposure levels in this industry have been reduced significantly since the start of the study.(1) Further analyses were carried out to assess if the trend in exposure was determined by factory, company and/or country.

Methods

Exposure to inhalable dust was measured during three sampling periods between 1987 and 1995, with 16 to 19 factories participating and a total workforce between approximately 2400 to 2900 employees. The factories were located in seven European countries, with all factories belonging to one of three companies. One factory provided data only in Phase II and was therefore excluded from the analyses. All workers were categorised into 8 job categories. In each phase and factory, a number of workers from each job category were selected randomly for personal monitoring. Repeated measurements on the same worker were collected in Phase II and III to allow the estimation of the variance components in the exposure data.

The Mixed procedure in SAS for Windows was used to test for each job category if statistically significant differences in exposure occurred between factories and phases. An interaction term between phase and factory was included in the mixed-effect model to test if the trend in the log-transformed exposure data from Phase I to Phase III was dependent on factory. Annual declines were calculated for each factory and job category and analysis of variance was carried out to test if the mean annual declines varied between factories, countries or companies.

Results

In total, 7794 personal inhalable dust exposure measurements were collected from 2734 workers. Personal inhalable dust exposure reduced significantly between the first and the third survey. The largest reductions were found for the warehousemen (GM from 1.3 mg/m^3 to 0.8 mg/m^3), site cleaners (GM from 1.2 to 0.4 mg/m^3), process operators (GM from 0.6 to 0.3 mg/m^3) and fitters/welders (GM from 1.1 to 0.5 mg/m^3).

The mean annual declines across the factories ranged between 5% for the administrative staff to 14% for the site cleaners. There were, however, large differences in reductions in exposure levels between the factories. The interaction term between factory and phase was statistically significant for all job categories, with the exception of process operator/conveyor operator and site cleaner, indicating that the trend in log-transformed exposure varied between the factories. For example, the mean annual decline between Phase I and III for the warehousemen ranged from –0.8% for a factory in Italy to 25.7% for a factory in The Netherlands (Table 2). Interestingly, the factory in The Netherlands had the highest geometric mean exposure for the warehousemen in the first survey (GM 3.5 mg/m^3), whilst the factory in Italy one of the lowest (GM 0.7 mg/m^3). Also in other factories with high exposure levels in Phase I for the warehousemen, such as factories 5 and 18, were high annual declines of exposure observed (22 and 15%, respectively). Generally, there appeared to be a reasonably strong correlation (>0.5) between the geometric mean exposure in the first survey and annual decline.

Table 1: Geometric mean inhalable dust exposure for the Warehousemen by factory and Phase and the mean annual decline.

		Phase I	**Phase II**	**Phase III**	
country	**Factory**	**GM (mg/m^3)**	**GM (mg/m^3)**	**GM (mg/m^3)**	**Decline (%/year)**
UK	1	1.86	1.44	1.63	1.85
	2	1.54	0.82	0.45	16.12
France	3	2.04	1.36	0.72	13.86
	4	1.00	0.71	0.64	6.29
	5	3.17	0.35	0.54	22.40
Germany	6	1.53	1.03	1.26	2.65
	7	0.06	0.18	-	*-46.16*†
	8	0.52	0.58	-	*-3.68*†
	9	3.36	1.64	1.11	14.65
	10	1.85	0.84	0.63	14.33
The Netherlands	11	3.54	0.80	0.44	25.68
	12	2.17	0.83	0.63	16.25
Italy	13	0.35	0.17	-	*20.95*†
	14	-	-	-	-
	15	0.72	1.27	0.76	-0.76
Spain	16	2.51	0.92	0.86	14.20
	17	1.35	0.27	1.13	2.46
Sweden	18	3.00	1.16	0.85	16.52
Total		1.32	0.70	0.77	7.30‡

† Annual declines from Phase I to Phase II only.

‡ Average annual decline based on those factories with data from Phase I to III.

Statistical significant differences in the mean annual decline (across all job categories) were found between factories with generally strong declines in factories 5 (18%), 13 (15%), 2 (14%) and 3 (14%). No statistical differences were found in annual decline between companies; but some differences were found between countries, with the highest average annual decline in the UK (12%) and the lowest in Spain (4%).

Conclusions

Statistically significant reductions in exposure were observed for all job categories in the European carbon black manufacturing industry. However, the reduction in the log-transformed exposure data varied significantly between the factories for all but two job categories. The mean annual decline of exposure was generally associated with the level of exposure in the first survey. This probably indicates that some factories have introduced new technology and control measures to reduce exposure prior to the first survey, whilst others have lagged behind and introduced these measures during study.

Statistical significant differences in mean annual declines were observed between factories, but not between companies. There were, however, some differences between the countries, with the highest mean annual decline found in the UK and the lowest in Spain.

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Validity, reliability and applications of an inclinometer based on accelerometers

Hansson G-Å [(1)], Asterland P [(1)], Holmer N-G [(2)], Skerfving S [(1)]

[1.] *Department of Occupational and Environmental Medicine, University Hospital, Lund, Sweden, e-mail: gert-ake.hansson@ymed.lu.se*
[2.] *Department of Biomedical Engineering, Lund University, Lund, Sweden*

Introduction

In epidemiological studies of work-related musculoskeletal disorders, there is a great need for objective and quantitative measuring of postures and movements, e.g. for the head, the back and the upper arms. By using the line of gravity as a reference, two – out of the three – degrees of freedom in orientation can be measured by inclinometers.

Traditional inclinometers have, partly due to there construction with moving parts, limitations. Today, small, micro-machined uniaxial accelerometers with a DC response – i.e. they are sensitive to the gravity of the earth – are commercially available at a reasonable price.

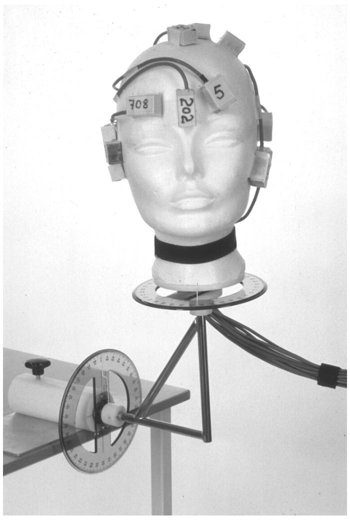
The aim was to evaluates the validity (error), reliability (reproducibility) and feasibility of using triaxial accelerometers, assembled from uniaxial accelerometers, for inclinometry.

Methods

We built triaxial accelerometers from uniaxial solid-state accelerometers, comprising a seismic mass, which is deflected by acceleration (including the gravity of the earth).

Instead of aligning the X-, Y- and Z-axis of the triaxial accelerometers (transducers) to the axis of the body segments – which is time consuming and introduces errors – we mounted the transducers in arbitrary orientations, and, by recording of two reference positions of the body segments ('upright' and 'forward') transformed the co-ordinates from the transducer system to the body-segment system. We also performed a second transformation, from the Cartesian co-ordinates of the body segment to spherical co-ordinates, giving the magnitude (r), inclination (θ) and direction (φ) of the acceleration vector.

The signals from the accelerometers were sampled at 20 Hz using a 12-bit A/D-converter. Data loggers, enabling recordings of up to 12 h, were used (2). The transducers were calibrated at +1 *g* and -1 *g* by placing each of their six sides horizontally on a table. After the recording, the data were transferred to a PC. The data processing and analyses was carried out in an application software that we developed.



A lightweight model of a head was used for determining the error and reproducibility (figure 1). Combinations of inclination (θ) and direction (φ) angles were exactly set using graduated arcs, and the output signals from the transducers were recorded. After this recording, the same combinations were set for a second time. The angular error was calculated as the difference between the recorded angles and the pre-set values. The reproducibility was calculated as the angular difference between the first and the second recording.

Figure1. The model with mounted transducers.

Results

The *angular error* of the inclinometers was independent of the orientation of the model, and the mean error was low, on average 1°. The *reproducibility* was high; the difference between the first and the second recording of the same position was, on average 0.2°. The stability of the individual accelerometers was crucial for the performance of the transducers. If accelerometers with a high stability are selected, the already high performance of the transducers can be even further improved.

The triaxial accelerometers, in combination with the software for calibration, co-ordinate transformations and analysis, have been used in field measurements of various occupations (e.g., 1,4,3).

For the *head and the back*, two-dimensional displays of the inclination are highly relevant for characterising the postures. For example, dentists showed high head inclinations in combined forward and sideways directions (1). Moreover, for these segments, the forward and sideways projections, and for calculation of movements, their time derivatives, may be used for compatibility with observation methods.

Regarding the *upper arm*, flexion/extension can, in general, not be separated from abduction. This is obvious: when the upper arm is moved, from 90° of abduction to 90° of flexion, without rotating the arm, the orientation relative to the line of gravity of a transducer attached to the upper arm is not changed. Hence, it seems relevant to use the inclination angle and a generalised angular velocity to describe the posture and movements of the upper arms.

Discussion

Intuitively, inclinometers measure the angles relative to the line of gravity. However, this interpretation is restricted, since, in fact, the angle is measured relative to the orientation of the acceleration vector, which, in the presence of dynamic acceleration might deviate from the line of gravity. Hence, during dynamic conditions, the inclinometric interpretation may not be valid. However, for recordings during these conditions, the magnitude of the acceleration (r) will deviate from 1 *g*, and the maximal possible angular error may be estimated, if the dynamic acceleration is assumed to be orientated perpendicular to the line of gravity.

Of course, the acceleration vector, either in Cartesian or spherical co-ordinates, which reflects the forces acting on a body segment, is generally valid, including applications with high dynamic conditions, e.g. figure skating.

For static and quasi-static conditions, our method may be applied for measurements according to the suggested ISO standard 'Ergonomics – Evaluation of working postures' (ISO/CD, 1995), since the method adheres to the definitions of trunk, neck, head and upper arm postures of this standard.

Conclusions

The accelerometer-based transducers surpass traditional inclinometers: (1) Their error is small, and independent of the orientation of the body segment; (2) Their basic output is acceleration, and hence the dynamic accelerations are also recorded; (3) They are small, easy to mount, and eliminate the alignment error; (4) They include no moving parts, and thus have a high frequency response.

The developed transducers, in combination with the software, are suitable for objective assessment of postures and movements during whole-day ambulatory recordings of occupational work.

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A triaxial accelerometer for measuring upper arm movements

Bernmark E [1], Wiktorin C [1]

[1.] *Department of occupational health, Stockholm, Sweden, e-mail: Eva.Bernmark@smd.sll.se*

Introduction

A portable triaxial accelerometer used as an inclinometer has been developed for measuring postures and movements over time (Logger Technology HB, Malmö, Sweden)(1). The inclinometer can measure the inclination of a body segment in relation to the vertical line (the line of gravity) and the direction of the inclination. It can not measure rotations. The principle for the inclinometer measurements is to continuously register how the static acceleration (the gravity) is distributed on the three accelerometers, but when the sensors move dynamic accelerations also affect the sensors, which may influence the results. The precision of the measurements has been tested in laboratory tests and considered to be very precise (1). However, the inclinometer has not been evaluated for measuring arm movements with different speeds. Moreover, in upper arm movements, rotation around the long axis of humerus is always present which also may affect the results. The aim of this study was to investigate if the inclinometer could measure the elevation of the upper arm in relation to the vertical line and if the inclinometer could differ between arm flexion and arm abduction i.e. measure the direction of the elevation.

Methods

Six test persons, 3 females and 3 males, participated in the tests. The mean age was 43 (range 28-58) years and mean height 176 (range 148-193) cm. The inclinometer system (IS) consists of one portable data logger and up to four sensors (figure 1). Each sensor consists of three accelerometers mounted perpendicular to each other in the x-, y- and z- directions. Each sensor measure the total acceleration (ρ) acting on the bodysegment, the inclination (θ) in relation to the vertical line and the direction (φ) of the inclination. Thus, the position of the sensor, and thereby the bodysegment, is described by spherical co-ordinates (ρ,θ,φ). The sensor can not measure rotations around the long axis of the moving bodysegment.

The reference system used in this study was a three-dimensional optoelectronic movement analysing system, the Mac Reflex (MR) system. (Qualysis AB, Partille, Sweden) (2).

One inclinometer sensor was taped caudal to the insertion of the deltoid muscle on the right upper arm. Two Mac Reflex, 20 mm markers, were taped on the same arm, one on the caput of humerus and one on the lateral epicondyle of humerus.

Five test movements were performed. The first three tests were performed to investigate how well the inclinometer measured the degree (θ) and the direction (φ) of armelevation at different arm positions i.e. the sensors were influenced only by static acceleration. The last two tests were performed to investigate how well the inclinometer can measure arm positions (θ,φ) when the arm is moving with different rates i.e. the sensors were influenced by both static and dynamic accelerations. One of the dynamic tests was armswings with three different rates and the other was three minutes painting of a wall. In the last test the degree of arm elevation angles (θ) were pooled into 20°-intervals, 0°-19°, 20°-39° up to 160°-180° for each subject.

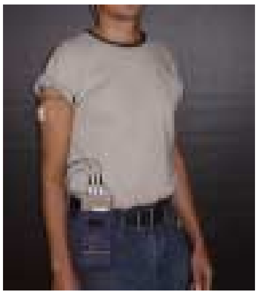
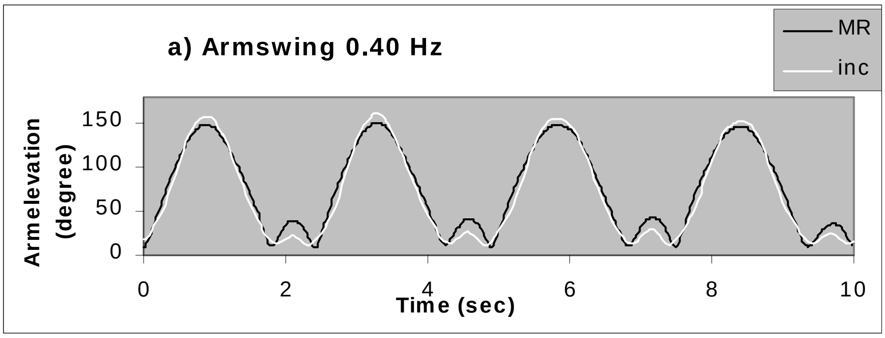


Figure 1. One IS sensor attached on the arm and a data logger in the belt.

Results

When measuring the degree of arm elevation (θ) without influence of dynamic acceleration IS and MR registration corresponded very well. The mean difference between the IS and MR angles for all positions was –1° (95%CI: (– 2.4) – 0.4). The IS could not differ between arm flexion and arm abduction. IS could not measure the direction (φ) of armelevation.

Also when measuring the degree of arm elevation (θ) with the influence of dynamic acceleration IS and MR corresponded well. When the armswings were performed with high and very high rates (figure 2a-b) the curves coincides, but at very high rates (figure 2b) there were an increased divergence in the turning points dependent on large dynamic accelerations.



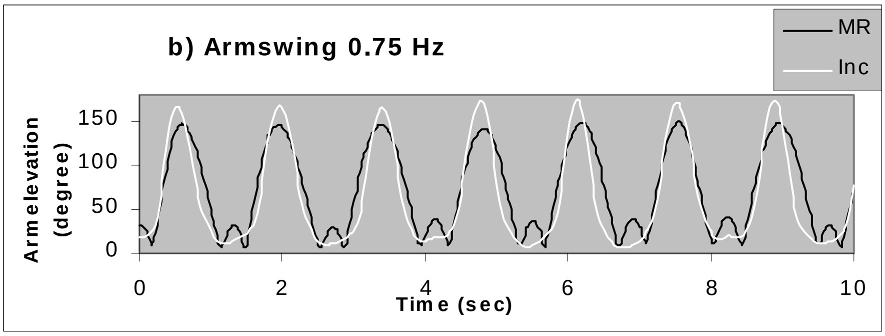


Figure 2. 2 typical curves from one test subject showing 10 sec long armswings with high rate (figure a), and very high rate (figure b). The white curves represent the result from the Inclinometer and the black curves represent the Mac Reflex measurements.

During the 3 minutes painting test the proportion time spent in each of the nine elevations intervals were almost identical for the two measuring systems (table 1).

Table.1 Painting 3 minutes. Mean percentage time for the upper arm elevation angle (θ) spent in each 20° interval.

θ (degree)	0-19	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-180
IS	17%	28%	16%	14%	18%	6%	2%	0%	0%
MR	19%	27%	14%	13%	18%	6%	2%	1%	0%

Discussion

IS measured the degree of armelevation with very high precision for all movements with normal to high velocities. For movements with very high velocity and, especially if the velocity is directed perpendicular to the line of gravity, the measuring error can become large. However, persons do normally not move their arms with such high speeds.

IS can not differ between armabduction and armflexion because of the rotations around the long axis of the upper arm.

The painting test (table 1) demonstrated that IS seems to be sufficiently accurate to be used as an instrument at an individual level for measuring the percent time spent in a posture during a day or part of a day as could be the intention in an ergonomic intervention study.

In this study, we have only been testing upper arm movements but the inclinometers can be placed anywhere on a (rigid) body segment. In earlier studies the inclinometer has been attached to the head, back and upper arms (3,4). The inclinometer is at the first hand developed to be used for measuring postures and movements during occupational work. The inclinometer could also be used for measuring patients before and after a specific rehabilitation program.

Conclusions

Also at relatively high velocities (influence of dynamic accelerations) IS can describe the degree of armelevation with high precision. IS can not differ between armabduction and armflexion.

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Comparison of two goniometers for measurement accuracy during pronation and supination

Peter W. Johnson [1], Per Jonsson [1] and Mats Hagberg [1]

[1] *Section of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Gothenburg, Sweden; e-mail: pete.johnson@ymk.gu.se*

Introduction

The frequency, magnitude and direction of wrist movement are thought to be important factors which may play a role in the development of upper extremity musculoskeletal disorders. Collecting dynamic measurements of wrist movements is important and electrogoniometry has often been the method of choice.

Electrogoniometers have been shown to be prone to two main types of measurement errors: crosstalk and offset errors. Crosstalk is a phenomenon where movement in one wrist plane (e.g. F/E flexion/extension) causes a false signal in the other wrist plane (e.g. R/U radial/ulnar deviation). Offset errors occur when the goniometer's signal moves away from the original zero/reference position.

The purpose of this study was to characterize and compare differences in measurement accuracy over a wide range of pronation and supination movements between a commonly used biaxial, single transducer wrist goniometer and a biaxial, two-transducer wrist goniometer.

Methods

Five women and three men (mean age = 31, range 19 to 54) who were free of upper extremity musculoskeletal disorders and prior injury participated in this study. Two wrist goniometer systems were evaluated. The first system, designated as System A, consisted of a single-transducer, biaxial goniometer (Model X 65; Biometrics; Gwent, UK). The second, System B, consisted of a two-transducer, biaxial goniometer (WristSystem; Greenleaf Medical; Palo Alto, California). Goniometer System A was attached to the subjects' right wrist using the methods prescribed by Buchholtz and Wellman (1997). System B was secured to the subjects wrist using a lycra fingerless glove.

The goniometers were calibrated with the subject's wrist in 90˚ pronation. Four different pronation and supination positions were tested: palm down, 90° pronation (90 P); 45° pronation (45 P); palm vertical, 0° neutral (0 N) and 45° supination (45 S). In each pronation/supination position, subjects moved from 40° of flexion to 40° of extension in 20° increments while in 0° of R/U deviation and from 10° of radial deviation to 20° of ulnar deviation in 10° increments while in 0° of F/E. A tiltable, adjustable-height table (Part 50642, Förbandsmaterial AB, Partille, Sweden) combined with calibration fixture (Greenleaf Medical; Palo Alto, CA) was used to repeatedly position each subject's forearm and wrist in the known pronation/supination (P/S), flexion/extension (F/E) and radial/ulnar (R/U) angles. To ensure the repeatable repositioning of the subject's hand, outlines of the hand were traced on the base of the calibration fixture for the various R/U positions and the analogue F/E scale settings on calibration fixture were noted for each F/E position.

The wrist angles used to position the wrist in the calibration fixture were considered the "Gold Standard" and the wrist angles measured by the goniometers the independent variable. The order that the goniometer systems were tested and the pronation/supination positions were randomised across subjects. With the summary data from the eight subjects, the mean angles were calculated.

Results

Figure 1 shows the effects of pronation and supination on the two goniometer systems. Non-parallelism to the vertical identity lines in Figure 1 indicates the presence of R/U crosstalk. As shown in Figure 1, System A was prone to more R/U crosstalk than System B. With System A, the R/U crosstalk was largest in 90 P, reduced in 45 P, minimal in 0 N and then increased in the opposite direction in 45 S. With System B, the R/U crosstalk was small and relatively constant over the various P/S positions.

Non-parallelism to the horizontal identity lines in Figure 1 indicates the presence of F/E crosstalk. F/E crosstalk was present with both goniometer systems. The F/E crosstalk tended to be parabolic with System A and was largest in 90 P, minimal in 45 P and 0 N and moderate but in the opposite direction in 45 S. With System B, the F/E crosstalk monotonically increased from 90 P to 45 S.

The horizontal and vertical distances from the origin of the identity lines to the origin of the goniometry data in Figure 1 indicate F/E and R/U offset errors. Depending on the P/S position, both goniometer systems tended to overestimate the amount of extension. In general, System B was prone to greater F/E offset errors but followed the same trends as System A. R/U offset errors were roughly equal but opposite in direction between the systems during P/S and gradually increased from a minimum in 90 P (the calibration posture), to maximum in 45 S.

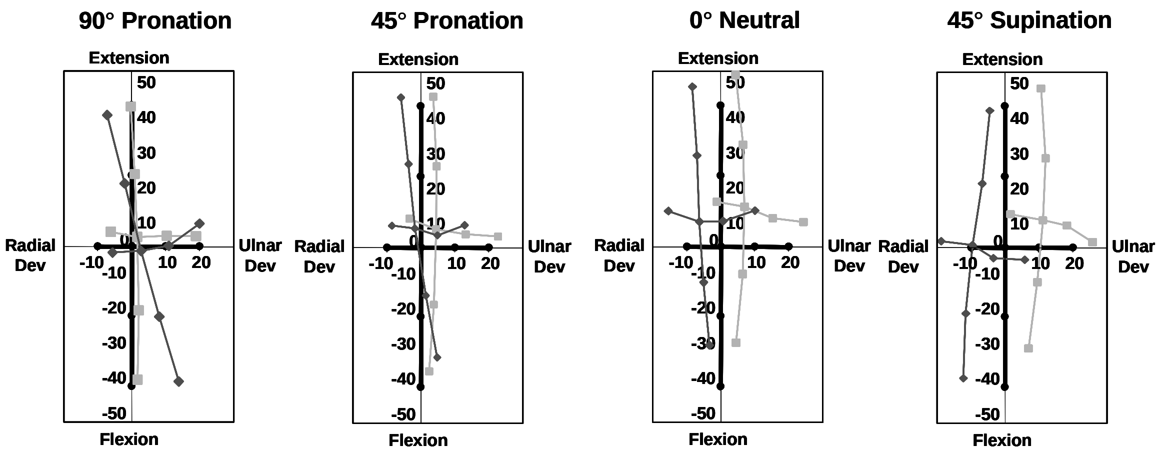

Figure 1 - The effects of pronation and supination on measurement accuracy. The bold black identity lines indicate the actual movements; the dark gray lines with the diamonds, the angle measurements from System A; and the light gray lines with squares, the angle measurements from System B.

Discussion

The main finding of this study is that forearm pronation/supination affects wrist angle measurements and that there were both some similarities and differences between goniometer systems in measurement accuracy and error patterns. The combination of these similarities and differences can be used to identify differences between goniometer systems which may lead to improvements in goniometer design and use.

Both goniometer systems were subject to crosstalk measurement errors with the errors being a function of P/S position. System A was prone to more R/U crosstalk compared to System B.

F/E crosstalk was also present with both goniometer systems and was shown to vary with P/S position. The transducers in System A and B are identical in manufacture and design but are located and oriented on the wrist differently. System B was designed so its two transducers reside over what is believed to be the two separate, non-orthogonal, wrist movement axes for F/E and R/U deviation. As a result of these differences, it can be expected that there may be differences in crosstalk and error patterns between systems. In general, this was the case. System A was prone to more R/U crosstalk than System B, whereas the differences in F/E crosstalk were less substantial.

Both goniometer systems were subject to offset errors, with the errors being a function of P/S position. However, there were both similarities and differences between the goniometers systems in the error patterns. F/E offset errors were similar between the goniometer systems in both magnitude and direction. However, R/U offset errors were roughly equal in magnitude but opposite in direction. The similarity in the F/E error and dissimilarity in the R/U error is likely to be due how the transducers reside over the wrist. The F/E transducers for both systems resided in a similar location on the wrist over the third metacarpal, whereas the R/U transducers were in different locations, with the R/U transducer on System B being more radially situated compared to System A's. The fact that the R/U offset errors were equal and opposite indicates that a more intermediate placement of the R/U transducer may be optimal for reducing R/U offset errors.

Goniometer crosstalk has been identified by others as an important and substantial source of measurement error. Our results tend to indicate that crosstalk is most likely to be a function of how the goniometer transducers are situated and move over the wrist relative to the wrist movement axis. Offset errors were prevalent with both systems and dependant on P/S position.

In summary, by comparing the two goniometer systems, important differences have been identified. Some of these differences may used to help direct future studies in order to further the understanding of goniometry and ultimately lead to improvements in goniometer design and use.

Acknowledgements

The authors wish to thank Alexander Areskoug, of the National Institute for Work Life, Göteborg, Sweden, for his important contribution with the collection of the measurements.

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Are the physical demands in work life too high?

What are the exposures and who are at risk?

Karlqvist L[(1)], Leijon O[(2)], Härenstam A[(1)] , Schéele P[(2)] and the MOA Research Group

(1) National Institute for Working Life, Stockholm, Sweden, e-mail: lena.karlqvist@niwl.se
(2) Division of Occupational Health, Department of Public Health Science, Karolinska Institutet, Stockholm, Sweden.

Intoduction

Heavy physical load at work is a potential risk factor for many different diseases, such as cardiovascular and musculoskeletal diseases(1-2). A positive relationship between physical capacity and physical work load among young workers has been documented, but in studies among middle-aged and elderly workers who have had physically strenuous jobs during their careers, a negative relationship between capacity and physical activities at work has been observed(3). Training effects may be attained within some weeks or months, but negative effects due to high strain and frequent overload over years may take more time to develop(4). The primary aim of this study was to investigate the correspondence between physical demands in work life and the physical capacity of the individual. A secondary aim was to identify working and living conditions and life style factors associated with the excess of metabolic level and the characteristics of the individuals at risk.

Methods

The present study was part of the Swedish MOA study (Modern work and living conditions for women and men. Development of methods for epidemiological studies.) Participants were 203 men and women at 80 work sites in public and private enterprises. The selected sample covered 85 occupational titles where approximately 1/3 worked with each of "*people*", "*things*" and "*data*(5). Information about external physical activity (intensity, frequency and duration) was obtained by an interview method(6) and translated into TWA-MET(7). The aerobic power of each individual was measured and maximal oxygen consumption was estimated(8). Physical capacity was obtained by tests of muscle endurance in arms, abdomen and legs as well as hand strength, balance, coordination and hand/finger precision. Information about work exposures and leisure time activities was obtained by interviews(6), observations, technical measurements and questionnaires. In the data treatment and analysis gender specific calculations have been used. Variables that showed statistically significant differences ($p<0.05$) between those who exceeded their metabolic level and the remaining subjects in univariate analysis were used as determinants in stepwise logistic regression models for excess of metabolic level.

Results

During work 27% of the men and 22% of the women exceeded their metabolic level according to the literature(9). Statistically significant differences were observed between those who exceeded their metabolic level, group A, and the remaining subjects, group B, regarding:
a) exposures at work: awkward work postures, manual handling, high %HRR, routine work and little stimulation; men had less time-bound work and women more and women also had less influence on the work situation, less creative work, more hindrances at work and more

irregular work hours; both men and women worked in environments with high chemical-physical exposures and measured high noise levels (Table 1).

b) exposures during leisure time: high %HRR for the men.

c) physical function and life style factors: less muscle endurance in legs, less balance and less VO_2 max; more of the men drank high alcohol beer at least once a week and were defined as overweight (WHO); the women had less endurance in abdomen, less coordination and a higher BMI.

Those who exceeded their metabolic level during paid work were mainly blue-collar workers: 76% of the men and 90% of the women. Examples among the men were construction workers, house painters, truck drivers and cleaners, i.e. *thing* workers. Common occupations among the women were mainly nurses´ aides but also kitchen staff, waitresses and cleaners (*people* and *thing*). No women in this group worked with *data.* Most of the men who exceeded their metabolic level worked in male dominated occupations (68%). More of the women who exceeded their metabolic level belonged to the low-education group (57%) and a majority had low wages (71%). Examination of self-reported health status showed that women who exceeded their metabolic level reported poorer general health, worse psychological well-being and more musculoskeletal symptoms than the remaining group. No such differences were seen among the men.

The stepwise logistic regression model for excess of metabolic level and

1) ergonomic-physical exposures at work, 2) psychosocial exposures at work and 3) chemical-physical exposures at work showed significance for the men in high %HRR and more routine work. For the women the results showed significantly more standing/walking postures, more hindrances and little skill discretion (Table 2). Clear statistically significant determinants in the final model were:

a) for the men: more routine work and more consumption of high alcohol beer

b) for the women: more standing/walking postures, little stimulation at work and less muscle endurance in abdomen.

Table 1. Some of the exposures at work measured by interview, observations and technical measurements among those who exceeded their metabolic level (25 men, 21 women = group A) and the remaining men and women (69 men, 73 women = group B). Mean and (range).

Work	Men		Women	
Mean (range)	Group A	Group B	Group A	Group B
Standing/walking hours/week	28*(6-44)	16 (1-40)	30*(5-43)	14 (0-44)
Hands above shoulders hours/week	3*(0-17)	1 (0-8)	2*(0-9)	1 (0-7)
Hands below knee height hours/week	4* (0-13)	1 (0-5)	4* (0-24)	1 (0-6)
Turned/flext body in standing hours/week	19*(0-39)	8 (0-35)	20*(0-38)	7 (0-37)
Observed manual handling,>1kg (PEO) %	11*(0-65)	4 (0-36)	5* (0-17)	2 (0-22)
Heart rate range (HRR), heart rate recorder %	30*(12-43)	20 (6-36)	22*(16-34)	17 (7-38)
Routine work %	61*(10-100)	29 (0-86)	44*(1-100)	25 (0-90)
Time-bound work %	12*(0-100)	30(0-100)	46*(0-100)	16 (0-100)
Measured noice level dB	81* (72-102)	78 (68-91)	78* (71-91)	75 (67-87)

***** indicate significant differences ($p<0.05$) between group A and group B

Table 2. Remaining work determinants when adding significant leisure time exposures in the logistic regression model for excess of metabolic level among men and women. Odds ratios and 95% confidence intervals.

Remaining factors		Men	Women
%HRR at work		1.10 (1.10-1.22)	
Routine work	%	1.05 (1.02-1.08)	
Standing/walking postures	hours/week		1.13 (1.06-1.21)
Skill discretion	index		0.78 (0.64-0.96)
Hindrances	index		1.36 (1.03-1.79)

Discussion

Twenty-seven percent of the men and twenty-two percent of the women exceeded the recommended metabolic level during work(9). Work exposures were strongly related to the excess of metabolic level. This was more evident among the women. For men life style factors also played an important role.

Awkward work postures, manual handling, high %HRR, routine- and time-bound work and little stimulation at work are key factors which about a quarter of the work force are exposed to. Many women also had jobs with little influence, more hindrances and irregular work hours. Men and women worked in environments with high chemical-physical exposures and high noise levels. Mainly blue-collar workers had these exposures and most of the men worked in male dominated occupations and women had low wages. Health status among the women was poor. Physical fitness was low among both the men and the women and this may reflect the situation of the general population.

Conclusions

This study indicates that physical demands in work life of today are high. This is reflected in a mismatch between the individual´s physical capacity and the physical demands of the work for a quarter of the population.

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Working technique, wrist movements and muscular load - An exposure profile among newspaper editors

Lindegård A [1], Wahlström J [1], Hagberg M [1], Hansson G-Å [2], Wigaeus Tornqvist E [3]

[1] *Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg, Sweden, e-mail: agneta.lindegard@ymk.gu.se*
[2] *Department of Occupational and Environmental Medicine, University, Hospital, Lund, Sweden*
[3] *Program for Ergonomics, National Institute for Working Life, Solna, Sweden*

Introduction

The use of computers has increased rapidly during the last 15 years. In Sweden 68% of the working male population and 63% of the working female population use a computer in their ordinary work (1999). Previous studies have indicated associations between several factors related to computer work and neck and upper extremity disorders, for instant duration of mouse use, work-place design and individual working technique.

The aim of this study was to evaluate the impact of work technique and ongoing symptoms from the neck and upper extremity respectively, on physical exposure and strain in an occupational group with similar working conditions and work tasks.

Methods

Thirty-two employees in the editorial department of a Swedish newspaper, 18 women and 14 men were included in the study. Median age for the men was 44 (range 26-57) years and for the women 43 (range 28-55) years. All subjects worked at least 50% of their VDU working time with editing work tasks. At first the subjects answered a questionnaire and then equipment for measuring muscular load, and wrist postures and movements were applied. To characterize muscular load the muscle activity in four different muscles were assessed with electromyography (EMG). The four muscles examined were: extensor digitorum (ED) on the side operating the computer mouse, extensor carpi ulnaris (ECU) on the same side and the right and left trapezius (R trap, L trap). The neck flexion/extension, shoulder flexion/extension, shoulder abduction, elbow flexion and trunk flexion/extension were measured with a manual goniometer. Perceived exertion and comfort were also assessed.

The subjects individual working technique were assessed by an experienced ergonomist according to an observation protocol. Nine items were assessed and a total score was calculated. According to this score the subjects were divided into two groups one with a good working technique and one with a poor working technique.

In the analyses comparisons were made between subjects with a good working technique (n=11) and subjects with a poor working technique (n=11), and between subjects with ongoing symptoms (n=17) and subjects without ongoing symptoms (n=14) from the neck and upper extremities.

Results

Subjects with symptoms showed a tendency towards higher muscular load than symptom free subjects (figure1). The symptom group tended to work with less extension and a greater range of motion in extension/flexion in the wrist than the symptom free group. Subjects in the symptom group worked with an upright trunk position while the symptom free subjects worked with trunk extension.

When comparing subjects with an observed good working technique to subjects with a poor working technique differences in muscular load were observed both in the forearm and in the shoulder (figure 2).

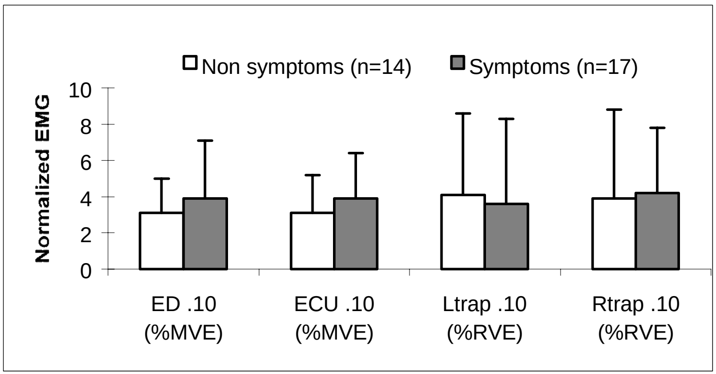

Figure 1. Muscle activity (10th percentile of the APDF) in forearm and shoulder grouped by subjects with or without symptoms, presented as group means and SD. ED= extensor digitorum, ECU= extensor carpi ulnaris, Ltrap= left trapezius, Rtrap= right trapezius.

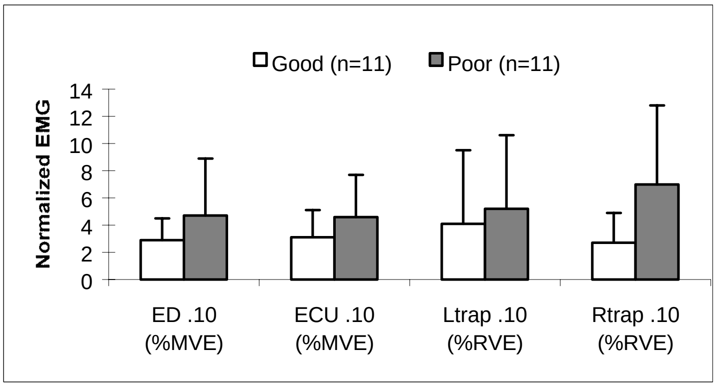

Figure 2. Muscle activity (10th percentile of the APDF) in forearm and shoulder grouped by good and poor work technique, presented as group means and SD. ED= extensor digitorum, ECU= extensor carpi ulnaris, Ltrap= left trapezius, Rtrap= right trapezius.

Discussion

In previous studies work technique during VDU work has shown an impact on the occurrence of musculoskeletal disorders (1,2). Individual work technique has also in a previous experimental study shown to be related to muscular load and also that the trapezius muscle is the most sensitive muscle for detecting differences in muscular load during VDU work (3). This study confirmed this result and added that a good work technique also reduced the load on the forearm.

The results of this study also indicated that assessment of work technique according to the observations protocol for VDU-work provided sufficient information to suggest changes towards a better working technique in order to reduce the risk for musculoskeletal disorders of the neck and upper extremities.

Conclusion

Editors with a good working technique had a lower muscular load compared to editors with a poor working technique in the trapezius and forearm extensor muscles. No other pronounced differences between subjects with good and subjects with poor working technique were observed, when performing similar work under similar working conditions.

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Can better exposure assessment resolve the uncertainties about EMF cancer risks?

Bowman JD,[1] Kromhout H,[2] Leonowich JA,[3] Yost MG [4]

[1] *National Institute for Occupational Safety and Health, Cincinnati, Ohio, USA, e-mail: JBowman@cdc.gov*
[2] *Utrecht University, The Netherlands*
[3] *Pacific Northwest National Laboratories, Richland, Washington, USA,*
[4] *University of Washington, Seattle, Washington, USA*

The evaluation of potential health effects from electric and magnetic fields (EMF) is a major challenge for the occupational and environmental health sciences. EMF from electric power has been associated with leukemia risks in children and workers, but these epidemiologic findings have been controversial. Now EMF cancer risks from mobile phones are being studied, while magnetic resonance imaging and many new wireless technologies need to be evaluated.

This roundtable will discuss the challenges of assessing EMF exposures across the frequency spectrum: static fields, extremely low frequency (ELF), very low frequencies (VLF), radio frequencies (RF), and microwaves. Is it enough to assess exposures with the metrics of the ICNIRP guidelines and TLVs (Table 1), or should we be measuring EMF characteristics like modulation or polarization, which the exposure guidelines consider irrelevant to health effects? Can evaluating exposure and dose metrics based on unproven biophysical mechanisms help avoid the uncertainties which now surround cancer risks from ELF fields?

Table 1. Metrics in exposure guidelines of the International Commission for Nonionizing Radiation Protection (ICNIRP) and the Threshold Limit Value (TLV®) committee (1,2).

Frequency range	Biomechanism	Dose metric	Exposure metrics*
ELF (3-3000 Hz)	Neurological effects of induced currents	Current density in the CNS	$dB/dt = 2\pi\nu B\nu$ & E-field magnitude
VLF / LF (3-100 kHz)	Neuromuscular stimulation	Current density in excitable tissues	H2, E2, induced currents, & contact currents
RF / microwaves (100 kHz–10 GHz)	Tissue heating	Specific absorption rate (SAR)	Same metrics as above + power density

*All EMF magnitudes are root-mean-squared (RMS)   CNS = central nervous system
ν = frequency   B = magnetic flux density   H = magnetic field strength ($B = \mu_o H$)

Evaluating Health Risks from New EMF Technologies

EMF exposures are a pervasive and growing consequence for millions of people of the new electronic technologies: the wireless office, mobile Internet hookups, personal tracking systems, etc. Of all the new technologies, mobile phones (*i.e.* cellular phones) are receiving the most intense scrutiny at the moment. Their popularity (over 500 million users worldwide) combined with the power transmitted to the brain (SARs within an order of magnitude of the exposure guidelines) creates the biggest potential for public health problems.

Methods for these risk evaluations are well established: comparisons with exposure guidelines, dosimetry models, cellular experiments, animal assays, and epidemiologic studies.

All of these methods are currently being used for the evaluation of mobile phones in well-funded research programs underway in Europe, the U.S., and other countries. Other new EMF emitters have been researched to a more modest degree, but many new communication and medical technologies have only been evaluated by comparing their emissions to health guidelines.

A question mark over these EMF risk evaluations is the continuing struggle to resolve the carcinogenicity of the oldest and most widespread EMF – the fields from AC electric power. Epidemiologic data shows that increased risks of brain cancer and leukaemia are associated with ELF magnetic fields at least three orders of magnitude below the exposure guidelines.* On the other hand, animal cancer assays have been largely negative. Laboratory and theoretical mechanism studies give evidence for biological effects from ELF-EMF found in some workplaces,† but not for the magnitudes associated with cancer. An U.S. government evaluation of this evidence (3) found ELF-EMF to be a "possible carcinogen" (IARC category 2B), which clearly presents regulatory and scientific challenges.

This ELF history is troublesome for other EMF risk evaluations because the power transmitted to the body by the ELF fields associated with cancer is at least twelve orders of magnitude below the health guidelines for RF/ microwaves. †† Such calculations were used 20 years ago to claim that ELF fields could not possibly have any health effects. If ELF-EMF turns out to cause cancer at these minuscule SARs, are the RF/microwave guidelines adequate for evaluating mobile phones and other new EMF technologies?

Table 2. Alternative exposure metrics for ELF magnetic fields (4)

	Short time scale (< 100 msec)	Long time scale (8-24 hr.)
Initial epidemiologic studies	RMS vector magnitude in the ELF frequency band	Time-weighted average (TWA)
Empirical alternatives	Static field magnitude, total harmonic distortion, polarization, etc.	Geometric mean, maximum, standard deviation, time above threshold, etc.
Biologically-based alternatives	Static/ELF resonances, induced body currents, free radical metric, etc.	Rate-of-change metric, toxicokinetic index

Exposure Assessment's Role in EMF Risk Evaluation

Once a study considers health risks at EMF levels below the guidelines, the established dose and exposure metrics (Table 1) are not necessarily valid, and the entire exposure assessment must be re-considered. The first wave of ELF epidemiologic studies chose an exposure metric (Table 2) that was easily measured and valid for the fields from most AC sources. This convenient metric came into question when the epidemiological results appeared contradictory, which might be due to exposure assessment errors relative to the "true" (but unknown) dose metric.

To move forward, ELF researchers started testing alternative metrics (Table 2). The empirical alternative metrics are taken from statistics or physical field characteristics. The

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* Significant risks reported by epidemiologic studies for 8-24 hr TWA B-fields>0.3 μT (3), but ICNIRP's ELF guidelines are B ≈ 80-100 μT (general public) and 400-500 μT (workplace) (1)

† "There is no controversy" about cellular effects from B-fields > 100 μT (3)

†† SAR = (current density)^2 / conductivity / tissue density ≈ 10^{-13} W/kg for 0.3 μT magnetic fields at 60 Hz, where the current density in the brain is determined from dosimetry models (5). ICNIRP's RF/microwave guidelines are 0.08W/kg (general public) and 0.4 W/kg (occupational).

“biologically-based” exposure metrics are derived with varying degrees of rigor from theoretical and laboratory evidence on biophysical mechanisms. Alternatives to the TWA derive from signal enhancement mechanisms (*e.g.* temporal coherence), and can often be calculated from the time series of ELF magnetic field magnitudes, which are stored by the present generation of data-logging gaussmeters. Alternatives to the ELF vector magnitude generally come from transduction mechanisms (*e.g.* induced body currents), and require more sophisticated instruments. A new 3-axis waveform monitor measures everything about a person’s ELF magnetic field exposure (6). These waveform data permit accurate biophysical modeling, and open up the possibility of empirical searches for stronger associations by neural networks (4).

For RF fields, many of the ELF alternative metrics may be valid, especially in the near field. One new feature of RF fields is the modulation of a carrier wave in communication applications. If biological structures can “demodulate” mobile phone radiation, then exposure frequencies are in both the RF band of the carrier wave and the lower frequencies of the modulation. For digital mobile phones, the modulation frequencies are in the ELF band, which suggests ELF biomechanisms may be operating at SARs far below the RF guidelines.

Questions for Discussion

- Should epidemiologic evaluations of new EMF technologies examine biophysical mechanisms and exposure metrics beyond those in the guidelines?
- Can the consistency of epidemiologic studies be improved by measuring exposure metrics derived from biomechanisms?
- Can epidemiologic studies reliably evaluate cancer risks from low EMF energies where the biological interaction mechanisms are speculative?
- What are the best strategies for assessing EMF exposures with its many dimensions (temporal, frequency, and spatial)?

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Exposure assessment for epidemiology and practice: Mind the Gap!

Quinn MM

Department of Work Environment, University of Massachusetts, Lowell USA
e-mail: Margaret_Quinn@uml.edu

Introduction

Much of the professional practice of exposure assessment has involved monitoring compliance with occupational exposure limits (OELs). The question motivating this work is: how does a workplace exposure compare with the OEL? However, there is growing evidence that OELs are not always protective of worker health and safety, especially for diseases such as cancer, asthma, or reproductive effects (14). In response to the evidence that many OELs are inadequate, research efforts have developed to characterize exposure independent of the question of compliance (8,10,4,9,6).

Exposure assessment research has produced very detailed methods and results that are interesting but not always easy to translate into practice, especially for practitioners in workplaces with limited resources. As research and practice advance, there is a risk that they will diverge to the extent that they can no longer inform each other. We risk having detailed research methods with a limited ability to apply them towards improving working conditions. In turn, we risk disconnecting from the practice that guides the relevant questions for research.

Methods

This paper presents a framework for the types of exposure assessment methods that have developed in recent years and asks what aspects of this research can be used to inform practice. The conceptual models and methods for data collection and analysis for each type of research are identified and recommendations are made for how the models and methods can be used by practitioners. A particular goal is to help practitioners understand how to go beyond compliance to provide improved measurement data that are useful both for practice and for research, to identify workplace factors that are determinants of exposure and of work-related illness and injury, and to continually improve the control of these exposures (17). The presentation limits its scope to assessment of airborne exposures, although many of the principles discussed also apply to ergonomic and physical exposure assessment.

Results

Exposure Assessment studies are grouped into four broad research areas, each with an underlying conceptual model and methods. These are described in detail in the paper:

1. Characterization of the distribution of exposure measurements over time and within and among jobs or workers (12,13,5).
2. Identification of workplace determinants of exposure. The determinants may be assessed at different levels of the workplace such as those related to technological and physical factors, those related to psychosocial factors, or those related to economic and social factors (2).
3. Evaluation of jobs and tasks to determine how the activities performed by a worker contribute to exposure (1,11).

4. Quantification of the amount of exposure delivered to a target tissue and its time course of action with a particular disease process (15,16,3,7).

Discussion and Conclusions

Each of these research areas has advantages and limitations for professional practice. These are discussed in the paper. In addition to specific methods that can be derived from each type of research for professional practice, several overarching conclusions are drawn that relate to making real improvements in the work place:

1. Exposure assessment research risks taking for granted that the exposures being studied must exist. The top of the hierarchy of controls in professional practice is substitution and elimination. We should question why an exposure exists and describe the exposures in a way that leads to the development of controls measures, including elimination.
2. Exposure assessment research should identify and evaluate determinants of exposure for which work place interventions are possible.
3. Exposure assessment research should quantify the degree of uncertainty in exposure estimates so that we know how certain we can be about the consequences of intervention or lack thereof. This will assist in precautionary actions by practitioners to improve health and safety.
4. It is important to quantify the aspects of exposure that are most closely related to an occupational disease so that effective monitoring and controls can be implemented.
5. At the same time, researchers should not lose the broader context in which specific exposures occur. Practitioners have to control exposures in a complex environment that incorporates many factors at different physical, psychosocial, and social/economic levels. It may be that the exposures and related occupational health problems are a function of many factors. The results of research that uses multilevel modeling of exposures and exposure determinants may assist practitioners to understand the relationships among workplace factors that exist at different levels.
6. Exposure assessment research papers should describe the broader workplace context in which the exposure of interest occurs. For example, the existence of other exposures not being studied should be noted as well as prominent psychosocial, social and economic factors. When possible, qualitative and quantitative exposure data should be linked.
7. Exposure assessment research papers should include recommendations about how the methods and findings might lead to practical applications to improve workplace health and safety.

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High molecular weight sensitizers: how much more progress do we need?

Dick Heederik

Division of Environmental and Occupational Health. Institute for Risk Assessment Sciences. Universiteit Utrecht, Utrecht, The Netherlands, e-mail: d.heederik@vet.uu.nl

The use of immuno-assays has facilitated the measurement of High Molecular Weight Sensitizers, usually protein molecules, in the picogram and nanogram per cubic meter range. This made evaluation of exposure response relationships possible for several occupational groups such as for bakery workers, with exposure to wheat allergens and fungal α-amylase, laboratory animal workers exposed rat and mouse urinary proteins. This development is paralleled by similar observations in studies on effects of exposure to domestic allergens such as house dust mites and cats. In addition, several hygiene studies have been undertaken to evaluate exposure determinants of occupational and domestic allergen exposure. Exposure response relationships have been observed for sensitisation, but also for upper and lower respiratory symptoms in several independent studies. There is now sufficient evidence to consider application for risk assessment purposes, which might result in exposure standards. However, there is no agreement on what endpoint should be considered in risk assessments and there is no agreement on the approach that should be applied in case of high molecular weight sensitizers. Apart from this specific application of recent research finding, several issues need to be studied and resolved. For instance, the risk of sensitisation has been suggested to be modified by other exposures such as endotoxins and chemical agents, although it is not clear if these effects are always relevant in case of occupational exposures. However, risk assessments and resulting preventive actions might be complicated if such interactions are present.

The major developments that occurred over the last years will be critically reviewed and some important research issues for the coming years will be discussed.

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Exposure assessment for epidemiology and practice- similarities and differences

Westberg H [(1)], Stenzel M [(2)]

[1.] *Department of Occupational and Environmental Medicine, Örebro Medical Centre Hospital, Örebro Sweden, e-mail: hakan.westberg@orebroll.se*
[2.] *OxyChem, Dallas, USA*

Aims

Exposure assessment, being one of the key element in risk assessment, is used for several purposes. Compliance determinations for comparison of measurement data with different types of occupational exposure limits are dominating, but assessment of exposures in prospective surveillance and monitoring programmes are important. In epidemiology exposures are equally important for calculation of dose measures used in dose response analysis in. Why aren't all chemical agents sampled for every worker over time? This would be the case if all occupational settings were nuclear plants (!), all personal would be monitored for their whole working life. Luckily enough, this is not true for occupational settings. Exposure assessment involves accounting for and description of uncertainties based on sampling, analytical and selection biases. This round table discussion will highlight out some issues of common interest for assessment in epidemiology and practice. What are our common and different grounds?

Qualitative exposure measures

Detailed knowledge about the chemicals and the composition of chemical products in use are the basis for all types of exposure assessments as well as the critical routes of exposure. The presence of contaminants as well as the physical state of the agents must be considered when exposures are assessed qualitatively. In addition, knowledge about the processes, ventilation, personal protective equipment and other determinant factors, including job titles and tasks must also be included (. The ambitions and necessity for identification are equally important for epidemiology, monitoring and compliance purposes. For compliance and cross sectional epidemiological studies the conditions for proper the assessments are much alike, for the corresponding retrospective exposure assessments they are equally necessary but depending on the quality of historical company records or comparable knowledge.

Quantitative exposure measures

In epidemiology sometimes the paucity of historical measurement data calls for using proxies like ever/never employed, department or job title affiliation for certain time periods. Contrast between exposed groups would be the overall goal.

When job titles are used, differences in exposure levels are assumed between the job titles or grouping of job titles used in the dose-response analysis. For descriptive purposes this would be acceptable, but looking for inferences involving job title as an exposure measure certainly need further analysis.

For compliance and surveillance as well as epidemiology with quantitative air concentration data the job titles are merely used to form homogenous or similar exposure groups and are not used as a basis for decisions on exposures and risks.

For compliance or surveillance purposes similar exposure groups are defined and representative samples are taken for comparison with long- or short-term occupational exposure limits. For regulatory purposes, compliance and the frequency of further measurements are decided upon are based on data standardised by using the the OEL (EN 689 Workplace atmosphere, NIOSH decision scheme). When both the short and long term OELs are sufficiently low, no further measurements are carried out unless significant changes in the use of raw material, products or processes are due to changes. Data are also used to refine the grouping in order to reduce variability within the groups and the number of workers sampled for decision making. In epidemiology, a certain minimum number of measurement data are preferred for each similar or homogenous exposure group, on a yearly basis exists. However, refining quantitative data for grouping within job titles or homogenous, similar exposures groups are also performed to reach maximum contrast between the groups for further analysis of dose-response

Missing data in epidemiological studies are estimated by statistical modelling or deterministic approaches using existing measurements. Determinant variables important for exposure variability are considered. Job title, department, process emissions, enclosures, distance to operations, mechanical and natural ventilation, other department activity, weather and climate conditions are included. Based on analysis of within and between group variability the exposure groups for the models are considered.

In sampling for compliance purposes factors of importance for variability of concentration levels are registered during sampling, much the same as needed for the epi studies, i.e. processes, tasks and engineering controls, personal protective equipment. However, they are used for justifying the measurement situation as not to deviant from the normal situation or stating potential selection biases. i.e. internal validity. The possibility of using measurement data for other settings in preliminary assessment procedures are also considered, i.e. external validity.

Areas of discussion

Identification processes- do we have different demands on the type of data needed for the compliance and epidemiological purposes? Minimum standard or request on company records?

- Formation of homogenous, uniform or similar exposure groups?
- Contrast between exposed groups versus description of exposure within a job title?
- Quality and quantity of measurement data in surveillance programmes and epi needs for exposure assessment in the epidemiological studies?
- Compliance and decision schemes monitoring- usefulness for epi or other purposes.

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Exposure to lead particles with different size characteristics, generated in four industries

Donguk Park [(1)], Namwon Paik [(2)]

[(1)]Department of Environmental Health, Korea National Open University, 169 Donsungdong Jongroku, Seoul, Korea, 110-791 e-mail: pdw545@mail.knou.ac.kr
[(2)]Department of Environmental Health, School of Public Health, Seoul National University, 28 Yunkeun-Dong, Chongro-Ku, Seoul, Korea, 110-799, e-mail: nwpaik@snu.ac.kr

Introduction

Permissible exposure limit (PEL) for lead (50 µg/m^3) was based on a model of the airborne lead concentration (PbA) – blood lead (PbB) relationship, modified by the MIT Center for Policy Alternatives (CPA) to include the effects of particle size and job tenure. The CPA assumed that when a worker is exposed to PbA, the first 12.5 µg/m^3 of it consists of lead particles ≤ 1 µm in aerodynamic diameter (AD) and the remaining PbA consists of particles ≥ 1 µm (1). CPA's assumption has been criticised by several studies. Froines et al. (3) reported that mean PbB levels predicted from the actual size distribution of lead particles was higher than that found in the PEL. Tsai et al. (9) concluded that concentrations of lead particles ≤ 1 µm increased along with increasing PbA concentrations. A better approach to resolving this differences would be to perform a large empirical study which correlates actual PbB and PbA concentration characterized by particle sizes in different lead work environments.

The specific objectives of this study was to examine whether the current occupational health standard, as PbA, based on CPA assumption, would be effective for reducing workers' body burden of lead.

Methods

A total of 117 worker's exposure to airborne lead particles was investigated at workplaces of 4 different industries in Korea. Mass median aerodynamic diameter (MMAD) and percentage of lead size particle as fractions of PbA concentration were determined by the use of 8 stages cascade impactors (Model 298, Anderson sampler, Inc, USA) worn by the workers. PbB levels of 102 workers who matched airborne lead samples were also examined by Zeeman effect graphite furnace atomic absorption spectrometry (Spectra AA-300/400 Zeeman, Varian, Australia, Pty Ltd). Since 1995, our laboratory has been participating in the Proficiency Analytical Testing (PAT) Program of the U.S. National Institute for Occupational Safety and Health (NIOSH)/American Industrial Hygiene Association (AIHA). The results have been all within the reference ranges, indicating that our lead measurements are relatively accurate.

Results

Lead particle sizes in secondary lead smelting and radiator manufacturing plants with high temperature operations was significantly finer than those in battery manufacturing and lead powder manufacturing operations (see Table 1). Scheffe's pairwise comparison showed that the fraction of respirable and lead particle ≤ 1 µm to PbA in the secondary smelter furnace and radiator soldering operations was significantly higher than those in other two industries ($p=0.0001$). Unlike the relationship that concentrations of fine lead particles ≤ 1 µm increased slowly, relative to increases in PbA concentrations except secondary smelting, concentrations of respirable lead particles increased proportionately with increases in PbA concentrations, as presented in Fig 1. In addition, respirable lead concentration significantly reflected the variation in the PbB level with higher R^2 than that of PbA as shown in Table 2 (R^2=0.35, p=0.0001)

Table 1. MMAD, PbA concentrations and average fractions of respirable particles and particles ≤ 1 μm in PbA by industry (a: respirable particle defined by OSHA, b: respirable particle (RPM) by ACGIH)

Industry	Sample No.	MMAD, μm	PbA, μg/m^3 GM(GSD)	Average Fraction in PbA(SD), %	
				a	b
2^{nd}ary lead smelting	6	1.6	575(1.7)	24.5(23.8)	43.3(25.6)
Radiator	42	1.3	19(2.1)	41.3(19.4)	48.9(22.5)
Battery	44	14.1	355(4.7)	5.3(6.4)	10.9(5.7)
Lead powder	25	15.1	355(4.7)	5.3(6.4)	16.5(10.7)
Total	117	5.8	118(7.1)	19.1(21.8)	27.5(23.5)

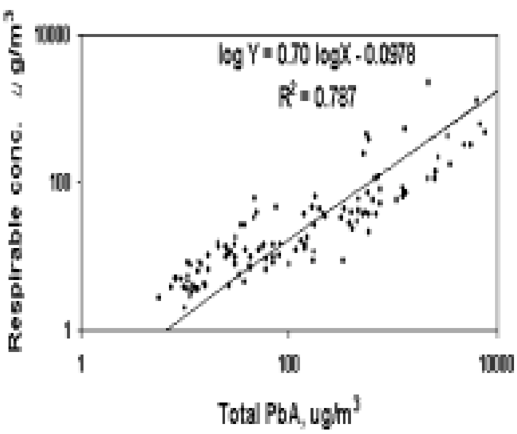

Figure 1. Relationship between PbA and respirable lead concentration defined by ACGIH

Table 2. Comparison of simple linear regression analyses for predicting blood-in-lead (PbB) by PbA concentrations characterized by particle size([a] respirable particle defined by OSHA, [b] respirable particle (RPM) by ACGIH)

Independent variable, μg/m3	Coefficient	Intercept	SE	R2	P
Log (PbA),	2.85	18.86	3.24	0.26	0.0001
a) Log (lead particle ≤ 1 μm)	32.81	-89.29	4.52	0.35	0.0001
b) Log (respirable lead)	28.59	-82.65	4.02	0.35	0.0001

Discussion

The nature and size of the lead particles will have significant implications for the distribution of blood lead values (4). Because lead fumes generated from high temperature operations can be easily absorbed into the body as compared to coarser lead particles, the fumes may lead to an elevated PbB level.

The CPA assumed that there was no deposition in the alveolar region of particles ≥ 1 μm. It is generally accepted, however, that there is deposition of particles with AD in the range of 1-10 μm (3,5). Our finding indicated the fraction of respirable lead particles contributes significantly to PbA concentrations, particularly in high temperature operations, and varies inversely with the PbA concentrations, especially at concentrations below 50 μg/m^3.
The R^2 associated with respirable lead particle concentration increased approximately 10 % over that attributable to only the PbA, even though all lead concentration was found to be significantly associated with PbB level, concentration (see Table 2).

Welding, sand blasting, rivet busting, burning lead-painted structure, and demolition work that generate fine lead particle have all been reported to cause elevation in PbB levels in labors and iron workers (Rae et al., 1991; Forst et al., 1997; Sokas et al., 1997). Recently, Reynolds et al.(1999) reported that participants who had 'ever' worked in demolition, burning paint and metal who welded outdoors had higher PbB levels than those who had done none of these activities. These results including our findings indicated that worker exposure to lead might not be effectively monitored by sampling of PbA alone, in particular, in high temperature operations that small lead particles like fumes occupy a significant proportion of the PbA

Conclusions

This study concluded that the occupational health standard for lead should be modified by including an assessment of respirable lead particles that reflect size-selective nature of aerosol sampling as well as PbA concentrations to monitor the diverse size characteristics of lead particles in various operations and types of industry.

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Exposure assessment for complex mixtures-the example of asphalt fume

Herrick, R.F. [1], Rinehart, R.D.[1,2], McClean, M.[1] , Weker, R. [1], Sapkota, A. [1], Christiani, D. [1]

[1] Harvard School of Public Health, USA, herrick@hohp.harvard.edu
[2] US Occupational Safety and Health Administration

Introduction

Studies that attempt to evaluate associations between exposure and response require the assessment of the characteristics of exposure that may be biologically relevant for the outcome of interest. For example, epidemiologic studies have demonstrated excess cancer risk among workers employed as roofers and highway workers, but the likely cause of this cancer risk has not been unequivocally established due to the limitations in exposure assessment. The excess cancer risks seen in roofers and pavers may be the result of polycyclic aromatic hydrocarbon (PAH) exposures from asphalt (bitumen), but this association may be confounded by exposure to other components in the complex mixture that comprises asphalt fume. In addition, these workers are exposed to PAH from other sources including coal tar pitch, cigarette smoke, or diet.

In animals, the DNA binding capacity of PAHs has been found to correlate fairly well with carcinogenic potency. The goal of this exposure assessment is to characterize three steps along the exposure-dose- response pathway. This starts with measurement of inhalation and dermal exposure to the complex mixture that comprises asphalt fume, to measurement of the urinary excretion of a metabolite(1-hydroxypyrene) of pyrene (a prominent component of the mixture), to measurement of a DNA adduct reaction product of the 4-ring and larger PAH fraction of the asphalt fume. The exposure assessment challenge is to devise a strategy which will correctly identify and quantitate the biologically significant component of the complex mixture that may form DNA-PAH adducts, as well as to characterize the relative contribution to total dose from each of the several possible PAH sources. The exposure assessment was conducted in conjunction with a 1-year longitudinal study of PAH-DNA adduct levels in asphalt-exposed workers.

Methods

In this research, we have assembled a population of approximately 50 roofers and highway pavers. We sampled each worker on three consecutive workdays under normal working activities, measuring inhalation exposure to PAH. Small adhesive pads were worn on the wrist to estimate PAH skin contamination. In addition to the environmental measurements, each worker provided three urine samples per day over three days to measure the excretion of 1-hydroxypyrene as a marker of pyrene exposure. We also obtained information on smoking, diesel exhaust exposure, and diet.

Results

We found that roofers generally had higher and more variable exposures than pavers. The bedtime 1-hydroxypyrene levels were the most strongly associated with the personal samples of daily inhalation and dermal exposure. These levels were clearly associated with exposure to pyrene (and other PAHs) on the job. In cases where exposure was to asphalt only, 1-hydroxypyrene excretion was about an order of magnitude lower than for workers exposed to coal tar pitch (from 0.1 - 1μmol/mol creatinine compared to 1 - 10μmol/mol creatinine). The effect of old coal tar pitch roofs at roofing sites was highly significant and contributed largely to the intensity and day-to-day variation in roofers' exposure. The amount of recycled asphalt pavement in road paving significantly influenced exposures among pavers. The exposure information for each worker-day was linked with the changes observed in PAH-DNA adduct levels over the work year, verifying the exposure metric as a predictor of the biologically significant dose.

Discussion

This research illustrates a strategy for measuring the characteristic of exposure that may be associated with the health effect of interest. In this case, the evaluation of the polycyclic aromatic compounds in the extremely complex mixture that comprises asphalt fume provides an exposure measure that is associated with the damage to genetic material represented by the PAH-DNA adducts. These findings provide the basis and rationale for a set of intervention strategies to reduce exposure, and possibly the cancer risk among workers exposed to asphalt fumes. The approach of focusing the exposure assessment on the characteristic of exposure that may be relevant to the health effect outcome can be generalized to studies of other complex mixtures.

Determinants of chlorpyrifos exposures and urinary 3,5,6-trichloro-2-pyridinol levels among termiticide applicators

Hines C J [(1)], Deddens, J A[(1)]

[1.]*National Institute for Occupational Health and Safety, 4676 Columbia Parkway, R-14, Cincinnati, OH, 45226, USA, e-mail:* chines@cdc.gov

Introduction

Chlorpyrifos is an organophosphorus insecticide widely used in the United States to control structural termites. It is metabolized in the liver to chlorpyrifos oxon, which is further detoxified to 3,5,6-trichloro-2-pyridinol (TCP) and excreted into the urine. The mean urine elimination half-life of TCP in humans after administration of oral and dermal doses of chlorpyrifos has been estimated to be 26.9 h (2). The aim of this study was to identify significant determinants of chlorpyrifos exposure and urinary TCP that could be used to build predictive exposure models.

Methods

Personal air and first morning urine samples were collected on multiple days within one week for 41 termiticide applicators. Information about chemicals, tasks and personal protective equipment was recorded for each treatment job performed. Air samples were collected and analyzed for chlorpyrifos according to NIOSH Method 5600 (1). Urine samples were analyzed for TCP by gas chromatography with mass-selective detection. Linear models were built by stepwise regression using PROC MIXED in SAS v. 612 (SAS Institute, Cary, NC). Dependent variables were highly skewed and a natural log transformation was applied. For TCP, two models were developed; the first, used both air and work factor data, and the second, used work factor data only. Covariate values from the day the air sample was collected were used in air models and values from days preceding urine collection were used in urine models. Akaike's Information Criterion was used to compare model fit. Standard maximum likelihood estimation methods were used. Within- and between- worker variance components were estimated from the random effects portion of the models.

Results

During the 202 applicator-days monitored, 415 treatment jobs were performed. Full-shift chlorpyrifos exposures ranged from <0.048 to 110 $\mu g/m^3$ (n=184), with a geometric mean (GM) of 10 $\mu g/m^3$. Urinary 3,5,6-trichloro-2-pyridinol (TCP) levels ranged from 9.42 to 1960 µg/g creatinine (n=271) and varied significantly by day of the week (GM range: 169-262 µg/g creatinine). Models were built for airborne chlorpyrifos and urinary TCP (Tables 1 and 2, respectively). In the air model, the within- and between-worker variance components, expressed as geometric standard deviations, were 2.2 and 2.3, respectively. In urine models A and B, the within-worker variance components were each 1.4, and the between-worker variance components were 2.3 and 2.4, respectively.

Table 1. Chlorpyrifos regression model. Compound symmetric covariance structure assumed. β=regression coefficient, SE=standard error, CPFS=chlorpyrifos (n=184 applicator-days, 37 workers). Dependent variable: ln(chlorpyrifos, $\mu g/m^3$).

Model	β	SE	p-value
Intercept	1.715	0.171	<0.001
Minutes CPFS applied	$5.776\ 10^{-3}$	$1.582\ 10^{-3}$	<0.001
Enclosed crawl space treated (yes/no)	0.608	0.135	<0.001

Table 2. TCP regression models. First order autoregressive covariance structure assumed. β= regression coefficient, SE=standard error, DF=degrees of freedom, CPFS=chlorpyrifos (Model A: n=173 applicator-days, 35 workers); Model B: n=194 applicator-days, 39 workers). Dependent variable: ln(TCP, μg/g creatinine).

Model	β	SE	p-value
A. Air Concentration in Model			
Intercept	5.145	0.183	<0.001
Day of the week (4 DF test, p=0.041)			
Tuesday	-0.185	0.114	0.107
Wednesday	-0.190	$7.213\ 10^{-2}$	0.009
Thursday	-0.119	$6.541\ 10^{-2}$	0.072
Friday	$5.470\ 10^{-3}$	$5.164\ 10^{-2}$	0.916
Saturday	0		
ln(CPFS air conc., $\mu g/m^3$)	0.102	$2.363\ 10^{-2}$	<0.001
ln(CPFS air conc., lagged 1 day, $\mu g/m^3$)	$6.144\ 10^{-2}$	$2.442\ 10^{-2}$	0.013
Commercial structure, time-weighted[a]	0.183	$9.012\ 10^{-2}$	0.044
B. Air Concentration Not in Model			
Intercept	5.333	0.157	<0.001
Day of the week (4 DF test, p<0.001)			
Tuesday	-0.327	$7.405\ 10^{-2}$	<0.001
Wednesday	-0.227	$6.632\ 10^{-2}$	<0.001
Thursday	-0.148	$5.865\ 10^{-2}$	0.013
Friday	$-5.562\ 10^{-3}$	$4.551\ 10^{-2}$	0.903
Saturday	0		
Minutes CPFS applied	$1.953\ 10^{-3}$	$5.152\ 10^{-4}$	<0.001
Minutes CPFS applied, lagged 1 day	$1.475\ 10^{-3}$	$5.073\ 10^{-4}$	0.004
Enclosed crawl space (yes/no)	0.109	$3.803\ 10^{-2}$	0.005
Commercial structure, time-weighted[a]	0.170	$8.630\ 10^{-2}$	0.050

[a] each job weighted by minutes of CPFS applied. Expressed as a proportion (0-1).

Discussion

Several significant determinants of chlorpyrifos air exposure and urinary TCP were identified. The highly significant association between duration of chlopryrifos application and increased levels of chlorpyrifos in air and TCP in urine may be related to the manual application of chlorpyrifos-containing solutions using open delivery systems (e.g. hoses or injection rods). The association between duration of chlorpyrifos application, lagged one day and increased TCP levels is consistent with the urinary elimination half-life of TCP, i.e. TCP levels in the urine should reflect chlorpyrifos exposure over 2-3 days. Treating an enclosed crawl space is most likely an important predictor of increased airborne chlorpyrifos exposure because these spaces have limited access and therefore, poor natural ventilation. In both TCP models, treatment of a commercial structure, weighted by the number of minutes of chlorpyrifos use, was a determinant of increased TCP levels. The explanation for this association is not readily apparent.

We were not able to show an association between respirator or glove use and TCP levels, nor did we find a significant interaction between respirator or glove use and minutes of chlorpyrifos application, a highly significant predictor of TCP in Model B. Applicators were approximately four times as likely to wear a respirator, and approximately two times as likely to wear gloves when treating enclosed crawl spaces as compared to treating other spaces. The preferential use of respirators in enclosed crawl spaces as compared to other spaces is most likely related to regulatory requirements.

Conclusions

Significant determinants of airborne chlorpyrifos exposure and TCP levels included the duration of chlorpyrifos application and the type of space treated. In the TCP models, day-of-the-week and the chlorpyrifos air concentration were also significant determinants. These findings suggest that control measures aimed at reducing chlorpyrifos air exposures, especially in enclosed crawl spaces, (e.g. portable mechanical ventilation) or changes in application technique that reduce the duration of chemical handling, would lead to lower TCP levels in the body.

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Children's pesticide exposure associated with agricultural spraying: report of a longitudinal biological monitoring study

Fenske R(1), Lu C(1), Koch D(1), Jolley L(1)

[1.] *School of Public Health and Community Medicine, University of Washington, Seattle, WA, 98195, e-mail: rfenske@u.washington.edu*

Introduction

Young children are believed to be exposed to pesticides through diet, drinking water, and residential or school pest control activities. However, the widespread use of pesticides in farming suggests that children who live in agricultural communities may be exposed through additional pathways. Recent studies have demonstrated higher concentrations of agricultural pesticides in house dust from homes that are in close proximity to pesticide-treated farmland, or where parents work with pesticides (1). Children in these homes tend to have higher pesticide metabolites in their urine. However, such studies have normally been conducted during the active spraying season. It is not clear whether these elevated concentrations occur year-round, or only during peak periods associated with agricultural spraying. This study was designed to follow children throughout an entire year, and to determine their temporal exposure through biological monitoring.

Methods

Forty-four children ages 2 to 5 were recruited from a Women, Infants, and Children (WIC) clinic in central Washington state to participate in this longitudinal study. The study area is a major tree fruit production region in the state. Children were asked to provide urine samples on a biweekly basis for one year. The study extended over 21 months, and the range of samples collected from the children was 16 to 26. The urine samples were analyzed for the six dialkyl phosphate (DAP) metabolites that can be produced by organophosphorous pesticides. Three of these metabolites contain dimethyl groups (dimethyl phosphate, dimethyl thiophosphate, and dimethyl dithiophosphate), and three contain diethyl groups (diethyl phosphate, diethyl thiophosphate, and diethyl dithiophosphate). The dimethyl and diethyl metabolite concentrations were converted to their molar concentrations (µmol/L), and summed to produce a single dimethyl or diethyl DAP concentration for each sample. Log concentrations were analyzed with a general linear regression procedure.

Results

Elevated DAP concentrations were found in months when organophosphorous pesticides were sprayed in the region's orchards. As indicated in Table 1, the geometric means of both dimethyl and diethyl DAPs for urine samples collected during the spray months were significantly higher than those collected during the non-spray months ($p=.009$ for dimethyl, and $p=.018$ for diethyl DAP). A child's gender also affected exposure, but not age or parental occupation. Elevated DAP concentrations were found in male children, a result that is not consistent with other published studies, and which warrants further investigation.

Table 1. Effect of agricultural spraying on dimethyl and diethyl dialkylphosphate concentrations (μmol/L) in young children in an agricultural community over a 21 month period.

Dialkylphosphates	N	Geometric Mean	Geometric Std. Dev.
Dimethyl			
Overall	972	0.08	2.5
Spray months	275	0.10 [a]	2.7
Non-spray months	697	0.07 [a]	2.5
Diethyl			
Overall	972	0.036	1.6
Spray months	119	0.049 [b]	2.0
Non-spray months	853	0.035 [b]	1.5

[a] Significantly different: p=.009

[b] Significantly different: p=.018

Discussion

This study is unique in its characterization of long-term organophosphorous pesticide exposure for children living in an agricultural community. This study did not focus specifically on the pathways by which children receive exposure from agricultural spraying. Previous work has suggested that proximity to treated fields and parental involvement with pesticides at work can contribute to elevated biological levels in young children. The role of pesticide drift from agricultural spraying requires further investigation.

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Identifying the biomarker for non-invasive biomonitoring benzidine-based dyes manufacturing workers by ^{32}P-postlabeling and GC/MS-SIM

Lee, J. H. and Shin, H. S.

Department of Environmental Education, Kongju National University
182 Shinkwan, Kongju, Chungnam, 314-701, South Korea
e-mail address: ejhl@knu.kongju.ac.kr

Introduction

Benzidine-based dyes are largely classified as direct dyes, since they may be directly to fabrics or other substrates without pretreatment or without subsequent processes that firmly attach the dyes to the substrate (mordanting)(6). Then it is recognized as potential human carcinogens and showed an association between benzidine-based dyes exposure and bladder cancer in workers, because all of the benzidine-based dyes was metabolized in animals to the carcinogen, benzidine(3). The enzyme is azoreductase which was found in both animals and humans(3). Yoshida et al.(8) and Yoshida & Miyakawa(9) reported epidemiological studies that exposure to benzidine-based dyes produces cancer in humans. In spite of its high potential carcinogenicity, many workers in South Korea are exposed with benzidine-based dyes because Korean Occupational Safety and Health Law(KOSHL) permits to manufacture and use them under some regulatation(1,4).

So we need to develop non-invasive biomonitoring method that easily find the high risk workers being exposure benzidine-based dyes. Then this study identify the biomarker in exfoliated urothelial cells of benzidine-based dyes manufacturing workers by ^{32}P-postlabeling and GC/MS-SIM.

Method

Exfoliated urothelial cells were used as the samples of non-invasive biomonitoring. Firstly urine was submitted from 33 workers in 3 benzidine-based dyes industries, and then separated exfoliated cells from urine. Biomarker was identified by analyzing DNA adducts by ^{32}P-postlabeling method (7,2) and GC/MS-SIM. Figure 1 is the schematic procedures of their experiment, and Table 1 is the analytical conditions of GC/MS-SIM for analyzing benzidine-DNA adducts.

Results

The characteristics of workers submitted urine samples is Table 2. Their average age, average working years and smoking persons are 41.9±11.1yrs, 8.7±5.5yrs and 25(32.0%)persons, respectively. Six kinds of DNA adducts were analyzed from their exfoliated urothelial cells, but only one adducts(a1) was predominated and commonly formed in all workers(Figure 2). Relative adducts level(RAL) of a1 was 73.2×10^{7} which was significantly higher than that of the others(Figure 3). The coefficient and slop of regression curve between RAL of a1 and working years of workers exposed with benzidine-based dyes were 0.548 and 6.922($p<0.05$), (Figure 4). DNA adduct of benzidine is N-(3'-phospho-deoxyguanosin-8-yl)-N'-acetylbenzidine (5). In the mass spectra of benzidine by GC/MS, along derivatization of benzidine-DNA adduct with trifluoroacetyl anhydride(TFA), benzidine-TFA is at m/z279 and benzidine-diTFA is at m/z

376 as base peak. In a chromatogram using secondary ion mass(SIM) the benzidine-di-TFA is shown at m/z 376. A chromatogram of a DNA adduct is isolated from the sample by GC/MS-SIM at m/z 376. It is shown that the DNA adduct isolated from exfoliated urothelial cells of workers exposed to benzidine-based dyes is benzidine-DNA adduct as N-(3'-phospho-deoxyguanosin-8-yl)-N'-acetylbenzidine.

Table 1. Analytical conditions of GC/MS-SIM for analyzing benzidine-DNA adducts

Subjects	Analytical Conditions
Column	HP-5MS(cross-linked 5% phenylmethylsiloxane 50m×0.25mm I.D.×0.25μm F.T.)
Carrier gas	He at 0.8 ml/min
Split ratio	1/30
Injection port temp.	280°C
Transfer line temp.	300°C
Oven temp. program	Initial temp. and time : 80°C and 0min Rate : 20°C/min Final temp. and time : 300°C and 5min
Scan mode (Solvent delay : 2.0min)	Mass range : 405 ~ 500 m/z
SIM mode (Solvent delay : 2.0min)	Group : 1 Start time : 2.0min Selected ions m/z : 279, 376

Table 2. Demographic characteristic of workers submitted the urine samples

Mean±S.D

Industry	No. of Workers	Age	Smoking		Sex		Working years	Unine Vol (ml)
			Yes	No	Mr	Mrs		
A	7	31.7±8.0	7	0	7	0	5.3±4.1	262±115
B	18	47.7±7.2	12	6	17	1	10.7±5.4	328±109
C	8	39.5±11.5	6	2	8	0	7.3±5.4	204±80
Total	33	41.9±11.1	25	8	32	1	8.7±5.5	284±114

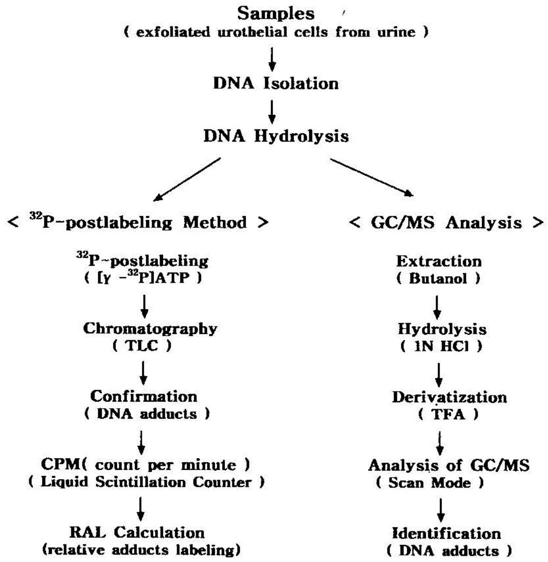

Fig. 1. Schematic procedures of ^{32}P-postlabeling method and GC/MS-SIM analysis for identification of Carcinogen-DNA adducts.

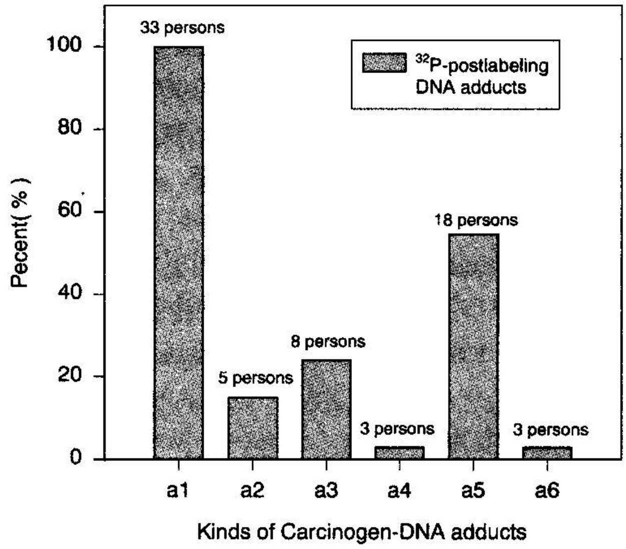

Fig. 2. The incidence rates of each Carcinogen-DNA adduct formed in exfoliated urothelial cells of workers exposed with benzidine-based dyes.

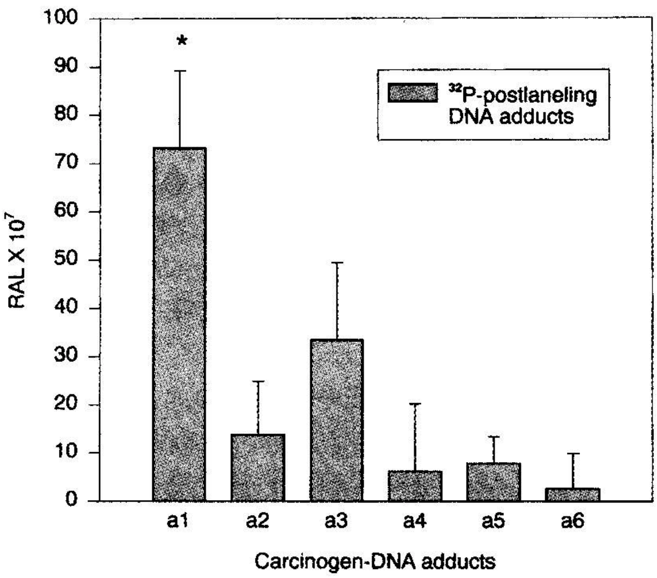

Fig. 3. The RAL levels of each carcinogen-DNA adduct formed in exfoliated urothelial cells of workers exposed exposed with benzidine-based dyes.
Error bars show standard errors.
*Significantly different from others.

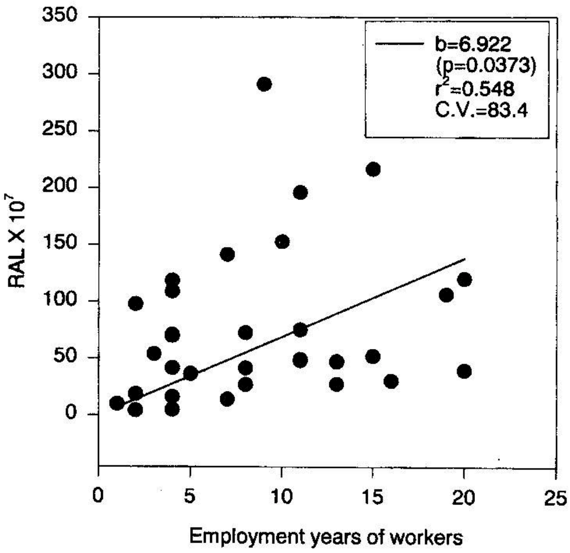

Fig. 4. Correlation between RAL levels of DNA adducts(a1) formed in exfoliated urothelial cells and empolyment years of workers exposed with benzidine-based dyes.

Conclusion

All workers exposed with benzidine-based dyes were commonly formed one DNA adduct into significantly high levels in exfoliated urothelial cells. It chemical formula is similar with benzidine-DNA adduct, such as N-(3'-phospho-deoxyguanosin-8-yl)-N'-acetylbenzidine. So we can do monitoring the workers with exfoliated urothelial cells by analyzing above DNA adduct as biomarker for preventing bladder cancer causing the exposure of benzidine-based dyes.

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Exposure and uptake of polycyclic aromatic hydrocarbons from oils in engine rooms on ships

Nilsson R [(1)], Nordlinder R [(2)], Ahlqvist J-O [(3)], Morgan U [(3)]

[1.] *Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg, Sweden, e-mail: ralph.nilsson@ymk.gu.se*
[2.] *Present address: IVF, Mölndal, Sweden*
[3.] *Hamn- och rederihälsan, Göteborg, Sweden*

Introduction

Studies from several countries have shown an increased incidence of cancer, especially cancer of the lung and urinary bladder, among engine room personnel on ships. Tobacco smoking, exposure to asbestos and polycyclic aromatic hydrocarbons (PAH) from oils, soot and engine exhaust could be possible causal factors. Marine diesel oils may contain more than 10% PAH and lubricating oils could be contaminated with PAH from combustion products. Several PAH are known carcinogens and mutagens. In addition to inhalation there could also be a considerable dermal uptake. A metabolite of pyrene, 1-hydroxypyrene could be used as a biomarker for exposure.

The main aim was to study inhalation and dermal exposure to PAH from oils. We also wanted to study the exposure during different work operations and the possibilities for prevention.

Methods

The study group consisted of 36 subjects exposed to oils and 25 controls working on four RoRo-ferries and five passenger ferries.

The extent and duration of skin contact with different types of oils was assessed with an observation scheme. Stationary and personal measurements of oil mist and hydrocarbons in air were also performed and the content of PAH in samples from different types of oils was analysed with GC-MS.

The subjects were followed for 24 hours with repeated urinary samples which were analysed with HPLC for 1-hydroxypyrene.

Results

The concentrations of oil mist in air were generally low (<0.1 mg/m^3) but concentrations up to 2.2 mg/m^3 during short time periods (15 minutes) could occur. The concentrations of total hydrocarbons in air were also low (mean 2.0 mg/m^3, range 0.1-11.0 mg/m^3).

The concentrations of PAH were higher in fuel oil and marine diesel oil than in lubricating oils, table 1. The PAH content of unused lubricating oil, hydraulic oil, and heating oil was low while it was relatively high in gas oil (1450 ppm).

Table 1. The concentrations of total PAH, pyrene and benzo(a)pyrene (BaP) in different types of used lubricating oils, fuel oil and marine diesel oil.

Type of oil	Total PAH ppm	Pyrene ppm (% of tot.PAH)	BaP ppm (% of tot.PAH)
Lubricating oil, main engine	90	12 (13%)	3 (3.3%)
Lubricating oil, auxiliary engine	59	8 (14%)	2 (3.4%)
Fuel oil (HFO)	834	37 (4%)	8 (1.0%)
Marine diesel oil	1176	39 (3%)	2 (0.2%)

The post-shift urinary samples had the highest concentrations of 1-hydroxypyrene and the results of these analyses are shown in table 2.

Table 2. 1-hydroxypyrene (1-OHP, nmol/mol creatinine) by exposure category and smoking habits.

Category	n	1-OHP mean	1-OHP min	1-OHP max
Exposed	36	95	5	390
Smokers	10	123	6	240
Non-smokers	26	85	5	390
Controls	25	70	3	310
Smokers	1	223	223	223
Non-smokers	24	64	3	310

Those who had been exposed to oils on their skin had higher mean urinary concentrations of 1-hydroxypyrene and smokers had higher levels than non-smokers but there was a considerable variation between the subjects.

Most subjects had been exposed to oils, mostly lubricating oils, on their hands. More extensive contamination with oils could occur during certain work tasks, such as work in the crankcase, but protective clothing were worn during these operations. The ratings had higher exposure than the officers. The highest exposures occurred during greasing and maintenance of the engines. Exposure to soot caused high excretion of 1-OHP in urine (322 nmol/mol creatinine, not included in the table).

Discussion

Dermal exposure to oils is probably a more important source of exposure to PAH in modern engine rooms than inhalation of oil mist during normal conditions. Fuel oils, diesel and gas oils had higher content of PAH than lubricating oils but the relative concentrations of pyrene and benzo(a)pyrene were lower in the fuel oils. The concentrations were generally lower than has been reported previously.

Conclusions

The contribution of PAH from occupational exposure seems to be lower than from tobacco smoking but both may contribute to the increased cancer risk among engine room personnel.

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Exposure profiles for practical use

Winkel J [1], Burdorf A[3]

[1.] *Programme for Production Ergonomics, School of Technology and Society, Malmö University, Sweden, e-mail: jorgen.winkel@ts.mah.se*
[2.] *National Institute for Working Life, Sweden*
[3.] *Erasmus University, Rotterdam, The Netherlands*

Introduction to the workshop

Practical ergonomic interventions in working life still seem to have a poor impact on the occurrence of occupational musculoskeletal disorders (1). There may be many reasons to this. One of these may be the small amount of practical information delivered by the ergonomic epidemiological research. This, in turn, seems partly to be related to exposure assessment issues.

Ideally, each exposure assessment strategy presents information on amplitude, frequency, and duration of the exposure. Collection of exposure data as a function of time prompts for analytical methods reducing the available amount of data into a limited number of exposure indices that sufficiently capture the exposure at work.

However, it may be questioned if such exposure profiles are practical as a basis for ergonomic interventions. The practitioner may rather focus on exposure data related to the working situation. Furthermore, most company interventions concentrate on technical and organizational development often with ergonomic spin-off effects. To what degree is the information obtained from ergonomic epidemiological research applicable in this context?

The aim of the workshop is to discuss how risk information from ergonomic epidemiological research can be linked together with the needs in practical ergonomic interventions. As a basis for this discussion it is suggested that epidemiological studies provide more clear guidance regarding necessity and level of intervention required to arrive at safe workplaces.

On this background Dr. P Ørbæk discusses the prevalent scope of ergonomic epidemiological research. After that Dr. P Buckle presents the scope of information needed in practical ergonomic interventions in working life. The workshop is concluded by a plenum discussion.

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The risk information we get - or do not get - from epidemiological studies

Ørbæk P[(1)]

[1.]Department of Occupational and Environmental Medicine, Lund University Hospital, Lund, Sweden, e-mail: palle.orbaek@ymed.lu.se

Introduction

Mechanical and mental load are both emphasized to be of importance for the pathogenesis of musculoskeletal troubles (1). Both are mostly 'measured' by use of self-reports, which for mechanical exposures imply that individual information is obtained on ordinal scales with a few response steps. This gives methodological problems concerning the establishment of the relative importance of these two aspects, which is essential for prevention. Pain from the shoulder and neck region occur frequently and will be the focus of this discussion (2, 3).

Index

Since shoulder-neck pain may originate from several local structures, a wide range of data is required for estimating mechanical exposure (4, 5). When studying relationships between complex exposure and the development of pain, index constructs are essential for including most of the information in the analysis. A questionnaire comprising several single items is the most feasible method to obtain exposure data in large populations (6) but the preventive actions that could be taken by use of these data is less documented.

Indices have usually good face validity, i.e. intuitively reasonable content of both the single items and the index construct (7). The test-retest reliability of single items and index should be documented, at least as 'good', i.e. Kappa >0.6. If several indices are used, each index should mirror exclusive constructs, and single items should only be used in one index. The internal consistency as measured by Cronbach's alpha should not be less than 0.6 and preferably at least 0.8 (8).

Furthermore, the distribution of the index scores should reveal both a conceptually clear and statistically feasible zero-level of exposure. For calculation of exposure-effect relationships with good statistical power, the index scores should be dividable into at least four strata, each including a sufficient number of subjects. Finally to be useful for preventive actions the construct validity, i.e. convergence with other measurements of workloads that are possible to change and known to be part of the pathogenic pathway should be demonstrated.

Outcome

The idea to establish occupational exposure limits puts demand on the outcome measurements in particular regarding the specificity of the pain location, which has not been much considered in previous epidemiological studies of work related musculoskeletal pain (9). Inclusion of subjects with more than one pain area as cases of localized pain in epidemiological studies with preventive purpose might be problematic due to possible bias in pain perception introduced by the physiological nociceptive mechanisms. If such data are not collected in epidemiological studies on causes of musculoskeletal pain, this will at best introduce unnoticed effect modifications. At worst, potential confounding may occur. Examples of the spinal and peripheral neurophysiological mechanisms are pain memory, peripheral and central sensitization, recruitment of silent nociceptors, wind-up mechanisms, long-term potentiation and decreased pain inhibition (5).

Convergence

Self-reported exposures should be interpreted in the field of psychometrics, i.e. they mirror perceptions from the structures the questionnaire items aim at. This notion may imply that asking about a certain position or time span does not give answers that directly could be understood as compatible with external observations of these factors. Items or indices shown to be risk factors may not correlate very well with external observations or measurements (10, Balogh et al. in preparation). Self-assessments of exposure seem to be biased against higher levels than the true ones when the subjects experience pain from the musculoskeletal system. This will imply flattening of an observed exposure-effect relationship if the outcome is correctly established. However, established exposure assessment methods might also show problematic high variance when applied in real production systems (11).

To further understand self-assessed data on exposures shown to be risk factors for musculoskeletal disorders, it is for preventive purposes necessary to analyze the meaning of these with regard to external and changeable information of the interaction between man and work-systems. Examples of methods are physiological monitoring of heart rate or muscle activity, external observations, and measurements of cycles and angles of movements et cetera. When assessing exposure factors, the precision of the methods is essential (12). Misclassification might even make it impossible to demonstrate positive effects of interventions (13, 14).

Conclusion

Although the literature comprise well performing exposure indices with good psychometric properties and relationships to musculoskeletal outcomes, they fail to give preventive information when the observed population is homogenous. This calls for future studies aiming at establishment of knowledge about what subjects, who self-assess their exposure to be at risk levels actually tell us by their reports. Such studies might give technical and organizational knowledge that eventually can be used for more specific preventive actions to be taken by workplace designers and motivate executive managements to order redesign measures to keep the workforce fit and highly productive. In future investigations of possible causal relationship between repetitive low force musculoskeletal load and the development of localized pain it is also necessary to assess the subjects total pain load. Focus on the primarily interesting pain location only, is not sufficient. The key to prevention is specificity concerning both exposure and outcome measurements.

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Can exposure profiles derived from epidemiological studies inform practical ergonomic interventions?

Buckle, P [(1)]

[(1)] *Robens Centre for Health Ergonomics, EIHMS, University of Surrey, Guildford GU2 7TE*
p.buckle@surrey.ac.uk

Introduction

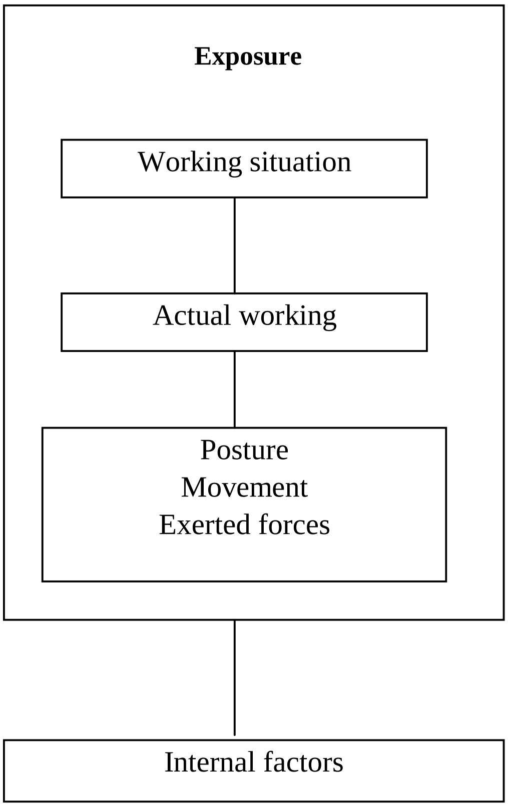
Epidemiological studies, using appropriate criteria for causality, have established a strong positive relationship between the occurrence of some musculoskeletal disorders and the performance of work (1), especially where high levels of exposure to work risk factors were present.

Consistently reported risk factors requiring consideration in the work system include: posture (notably relating to the shoulder and wrist), high force applications at the hand, biomechanical loading on the spine, exposure to vibration (at the hand and whole-body), direct mechanical pressure on tissues, effects of a cold work environment, work organisational and psychosocial issues. However, there is a limited understanding of interactions between these variables. This means that exposure-response relationships are difficult to deduce.

The concept of exposure

The concept of exposure can be described in the following model adapted from (2). Figure 1 shows the exposure or work requirements operationalised as the working situation, the actual working method, and posture, movements and exerted forces.

Figure 1.



The working situation is characterised by work demands and job decision latitude. The latter is defined as the extent of autonomy and opportunities for workers to improve (or to make worse) the working situation by altering the work demands. The working situation is, therefore, characterised by the organisation of work (work organisation factors) and the perceptions held by workers regarding the way the work is organised (psychosocial work factors).

The working situation constructs the way a worker performs the work activity. This can be affected by individual characteristics such as anthropometry, physical fitness, age, gender, and previous medical history.

The method that an individual worker adopts will affect the level, duration and frequency of exposure to work postures, executed movements and the forces exerted. This will affect the internal factors previously discussed.

Work organisation, production rates and the time taken to perform a work task affect the frequency and duration of force exertions. In some instances, the time taken for a process change can determine soft tissue recovery times. The postures adopted in the workplace are affected by the design of work equipment, the location of objects, the size and shape of handles and the orientation of objects.

Data related to the working situation and the method of actual working are often the main focus of interest for ergonomists when designing and implementing work system interventions. Few epidemiological studies collect such data.

Conclusion

The majority of epidemiological studies consider exposure profiles with the aim of further clarifying our understanding of the *causation* of musculoskeletal disorder. They have traditionally focused on those variables of posture, movement and physical force applications. Exposure profiles required for practical workplace implementation would additionally require data relating to those factors derived from the working situation (as described above), and in particular work organisational factors.

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An evaluation of a dose rate parameter in occupational radiation epidemiologic studies

Taulbee TD [1], Spitz HB [1], Neton JW [1], and Chen PH [1]

[1.] *Health-Related Energy Research Branch of the United States National Institute for Occupational Safety and Health, Cincinnati, Ohio USA, email: tgt4@cdc.gov*

Introduction

Risk estimates for occupational radiation exposure are primarily based upon studies of atomic bomb survivors and other persons who received instantaneous or acute radiation exposure. In contrast, occupational radiation exposure tends to be received at a low intensity and in a fractionated or protracted manner.

Multiple studies of animals have clearly demonstrated that fractionated and low intensity exposure to gamma radiation results in a reduced rate of cancer incidence compared to acute exposures (8,5,7,2). The International Commission on Radiological Protection (ICRP) has developed the Dose and Dose Rate Effectiveness Factor (DDREF) to accommodate the observed decrease in cancer incidence associated with fractionated gamma exposures. Although the ICRP (3) recommends a value of 2 for the DDREF, they also recognize that this value is somewhat arbitrary and in need of additional validation.

The United States National Institute for Occupational Safety and Health (NIOSH) is conducting an Occupational Energy Research Program to investigate health effects in workers who are exposed to radiation. In this analysis, we compare the conventional dose rate calculation to a new method, which is shown to be a better description of the intensity (dose rate) of the cumulative dose for epidemiological studies.

Methods

Monthly radiation dosimetry records for 360 workers from a current epidemiologic study were selected for this analysis. Of these workers, two hundred and eighty-four (284) had cumulative external radiation doses greater than 0.2 mSv. Workers with very low cumulative doses less than 0.2 mSv and three accidentally exposed workers, who received doses exceeding radiation protection limits, were excluded from this analysis. Thus, dosimetry records for 281 workers were evaluated with approximately 46% having cumulative doses greater than 10 mSv.

A new computational method for dose rate analysis was developed and compared to the cumulative average dose rate, a conventional method previously used in epidemiologic studies and analysis (1,6). The cumulative average dose rate is obtained by dividing an individual's cumulative dose by the length of time from first exposure to last exposure. The new method developed for this analysis is a "Dose Weighted Average" (DWA) which weights each monthly dose rate ($\dot{D}$) according to the fractional contribution (weight) of the monthly dose to the worker's lifetime cumulative dose (Equation 1). The weight (w_D) is the monthly dose divided by the total cumulative dose. As a result, monthly doses that contribute a greater proportion to the cumulative dose are weighted greater than multiple lower monthly doses.

$$DWA = \sum_i w_{D_1}\dot{D}_1 + w_{D_2}\dot{D}_2 + w_{D_3}\dot{D}_3 + ...w_{D_i}\dot{D}_i \qquad \textit{Equation 1}$$

Assuming that workers with similar cumulative doses do not necessarily have similar dose rates, an unbiased dose rate parameter should not be correlated with cumulative dose. For both the cumulative average and dose-weighted average methods, the

Spearman Rank correlation procedure was used to determine correlation between dose rate and cumulative dose across similar dose groups.

Results

The geometric mean dose rate calculated for these 281 workers was 0.10 and 1.28 mSv per month using the cumulative average and dose weighted average methods, respectively. The difference between these dose rates arises because the cumulative average method includes dose fractionation (time between exposures) that is explicitly excluded in the dose weighted average method. Figure 1 shows the distribution of dose rates for these workers using both methods versus cumulative dose and illustrates that workers with similar cumulative doses received their doses at different rates. In general, the dose rates calculated using the dose-weighted average method exceeded the cumulated average method and varied by an order of magnitude.

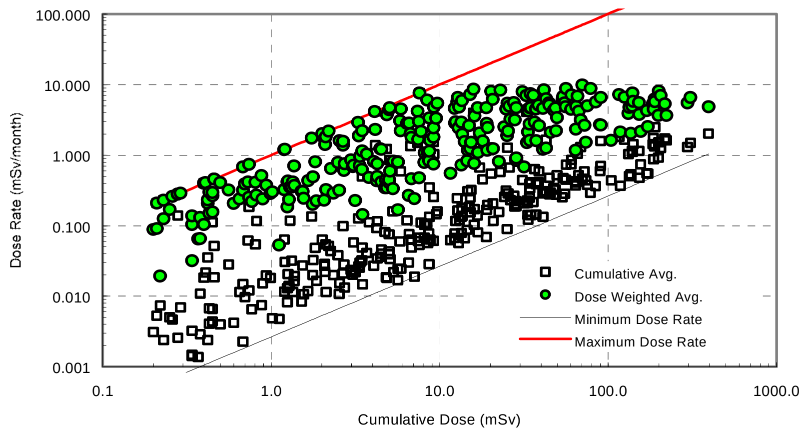

Figure 1: Comparison of the two dose rate computational methods and cumulative dose

The calculated dose rates for both methods were generally found to be log-normally distributed over most of the dataset, however, each produced a tail or compression of the log-normal distribution at the upper end. Kumazawa et al (4) noted this compression of the log-normal distribution among various radiological exposed occupations and developed a hybrid log normal distribution function to fit the data. The compression was attributed to the removal of individuals from the workplace as they approached the occupational exposure limit. While this distribution function was developed for annual dose limits, it also appears to be relevant to exposure rate limits. The effect of occupational limit was observed in Figure 1 in which workers were limited to a radiation exposure rate of 10 mSv per month.

Overall, the cumulative average dose rate method exhibited greater correlation with cumulative dose than the dose weighted average method (Figure 2). As cumulative dose increased, the cumulative average method becomes more correlated with cumulative dose. This trend would limit the utility of the cumulative average for high cumulative doses. The opposite trend was observed using the dose-weighted average, however, this method was more correlated at very low cumulative doses.

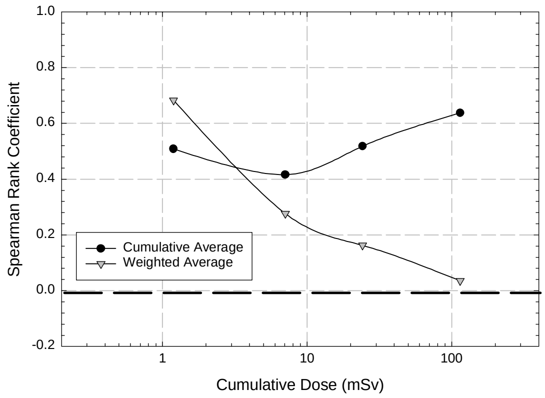

Figure 2: Correlation coefficient between dose rate and cumulative dose

Discussion

Although the cumulative average method is easy to calculate, the method results in an oversimplification that might hinder any observation of a dose rate and/or fractionation effect. Since this method combined fractionation with intensity, any potential effect of the intensity of the exposure cannot be evaluated independently. The dose weighted average method is a better relative measure of the intensity (dose rate) of exposure because it neglects periods of time between exposures. This method also puts greater emphasis on those dose rates, which are potentially more relevant to risk.

Conclusion

Currently the DDREF is used in risk estimates to account for decreased effects of radiation on human health due to fractionation and rate or intensity of exposure. In epidemiologic studies where detailed data are available, dose rate effects may be investigated. The dose-weighted average methodology discussed above was developed as a metric for these investigations. This dose rate parameter, when used in combination with cumulative dose in an epidemiologic study, might enhance our understanding of the health effects of radiation exposure and should be utilized in exposure assessments for occupational epidemiologic studies.

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Quantification of exposure to electromagnetic fields (EMF) in a case-control study of brain tumor in adults in the U.S.

Dosemeci M [(1)], Coble J [(1)], Stewart PA [(1)], Bowman JD [(2)], Yost MG [(3)], Kaune WT [(4)], Mantiply E [(5)], Linet M [(1)], Inskip P [(1)]

[1] *Division of Cancer Epidemiology and Genetics, National Cancer Institute, Rockville, MD, USA, e-mail: dosemecm@mail.nih.gov*
[2] *National Institute for Occupational Safety and Health, Cincinnati, OH, USA*
[3] *University of Washington, Seattle, WA, USA*
[4] *EM Factors, Richland, WA, USA*
[5] *U.S. Environmental Protection Agency, Montgomery, AL, USA*

Introduction

Some occupational case-control and cohort studies have reported increased risks of brain cancer and leukemia associated with employment in jobs linked with exposures to magnetic or electric fields. In early studies, these associations were based on only electrical-related jobs; however, various attempts have been made to quantify EMF exposure in recent epidemiological investigations (2). In this report, we present a new approach to quantify level of exposures to EMF in various ranges of frequencies, such as static magnetic fields (SMF: < 3 Hz), extremely low frequencies (ELF: 3-3,000 Hz), video display units (VDU: 15-30 KHz), and radio frequencies (RF: 30 KHz-300GHz).

Methods

A detailed questionnaire with lifetime work history information has been administrated to 782 cases and 799 controls (1). In addition, subject-specific information on EMF exposure was obtained using job-specific modules (i.e., integrated-questionnaires designed to obtain information on types of electrical equipment used, the distance from the electrical sources, and the frequency of exposure in a given time period) for potentially EMF-exposed subjects. Jobs in work histories were reviewed by an occupational hygienist shortly after the interview and further questions were asked to the subjects to clarify exposure information when needed. For ELF exposure assessment, we used type of electrical equipment and the proximity to the source in three categories (i.e., <3 feet; 3-6 feet; and >6 feet) to estimate the level of exposure intensity. We also used the frequency of exposure (i.e., hours per week) and the number of years worked at the exposed job. Two-way radios operated in offices, CB-radios in trucks and cars, and walkie/talkies were used as intensity variables for RF exposure assessment. Assessment of VDU exposure was based on use of computer or video monitor, while assessment of static magnetic field exposure was based on job titles associated with the use of electrical equipment operated with direct current, such as welding machine operators, forklift operators, or smelters.

From work histories of 1581 subjects, we had three types of exposure information for 8,750 unique jobs. First, we had general exposure information from work histories, such as job and industry titles, tasks or activities, and electrical tools or equipment used for every study subject. Secondly, for 61% of the jobs, we had job-specific module information on the use of electrical tools and equipment, and for 17% of the jobs, we had information from the follow-up interview to clarify the exposure conditions. From the module information, we developed quantitative estimates of ELF exposure using an algorithm with the following variables: (1) Intensity of

EMF produced by the electrical equipment or tools used; (2) distance from the equipment or tools; and (3) frequency of exposure. Thirdly, we developed several job exposure matrices (JEM) for EMF exposures for the various frequency categories using existing measurement data from the literature and our own experiences regarding to the jobs or industries. For ELF, we developed one semi-quantitative (JEM-1) and one quantitative (JEM-2) job exposure matrix. For jobs with information on work history only (n = 3,110), we used JEMs values and the descriptive data from job title, work place, activities, products, equipment and tools used, and calendar years of employment, plus literature data to develop quantitative exposure estimates. For the jobs with work history data and job-specific modules (n = 4,276), we used all the information listed in the work history data, plus algorithm results. For the jobs with information on work history, job modules, and responses to the follow-up interview (n=1,364), we used all the above data and the responses to the clarification questions. We also developed an exposure assessment software program to utilize all of the available information efficiently to reach the final quantitative estimate of exposure to EMF.

Results

We present examples for quantifying levels of exposure to ELF for three scenarios with different information sources:

Example 1:	Job with work history only
Job Title:	*Engineer*
Industry Title:	*Aircraft manufacturing*
Calendar Years:	*1950-1956*
Activities:	*Tested fuel control and electrical circuits*
Products Made:	*Carburetors and aircraft engine*
Chemicals Used:	*Stoddard fluid and JP4 Fuel*
Tools Used:	*Electrical test equipment*
JEM-1:	*Medium (3-4 mG)*
JEM-2:	*1.7 mG for Engineer*
FINAL ESTIMATE:	*3.0 mG*

Although the measurement-based JEM-2 suggested that the level of exposure to ELF should be 1.7 mG for engineers and 3.3 mG for electrical engineers, we assigned the final estimate to be closer to electrical engineers than unspecific engineers, because the subject used of an electrical test equipment for testing electrical circuits.

Example 2:	Job with work history and module information
Job title:	*Welder/grinder*
Industry title:	*Construction machine manufacturing*
Calendar Years:	*1973-1975*
Activities:	*Welding and grinding*
Products Made:	*Bulldozers, front end loaders*
Chemicals/Tool Used:	*Gasoline, hand grinder*
Electrical Equip. Used:	*40 hr/wk >3ft welding machine; 40 hr/wk >6ft generator*
JEM-1 :	*High (>5 mG)*
JEM-2 :	*20 mG*
Algorithm:	*5.0 mG without considering the grinding process*
FINAL ESTIMATE:	*13.7 mG*

JEM-2 suggested that the level of exposure should be 20.0 mG for welders. The algorithm was 5.0 mG. Because the subject did not report the use of grinder in the module, the estimated level of exposure calculated by the algorithm was lower than it should be, and we recalculated the algorithm result (i.e., 13.7 mG) with the information on grinder use.

Example 3:	Job with work history, module, and follow-up information
Job title:	*Production inspector*
Industry title:	*Boat Engine Manufacturing*
Calendar Years:	*1985-1990*
Activities:	*Examine engines and report results*
Products Made:	*Made 9-150 HP engines*
Chemical Tools Used:	*Solvents and Electrical test equipment*
Electrical Equip. Used:	*Hand-held test equipment 10 hr/wk*
Algorithm:	*1.4 mG*
Follow-up Que.:	*How much time did you spend in the engine area? Ans: 25 hr/wk*
JEM-1:	*Medium*
JEM-2:	*2.0 mG*
FINAL ESTIMATE:	*1.8 mG*

In the earlier review of responses, it was unclear how much time the subject spent in the production area, which he might be getting additional EMF exposure from other equipment in the production area. In the follow-up interview, the subject responded that he spent 25 hr/wk in the production area. JEM-2 suggested that the level should be 2.0 mG and the algorithm result was 1.4 mG. Since the actual time was longer than the one included in the algorithm, we increased the level to 1.8 mG to make it close to the JEM-2 value based on the response in the follow-up interview.

Discussion

We were unable to estimate subject-specific exposure levels using solely either semi-quantitative JEM-1 or measurement–based quantitative JEM-2, because they were developed as job-specific, and the assignment of exposure levels were generally averages of measured values for a limited number of samples. Subject-specific questionnaire information collected in this study suggested that the variability of exposure to EMF between different individuals with the same jobs could be substantial due to differences in work practices and frequency of exposure in a given period.

Conclusions

We found that descriptions of tasks or activities, responses to job-specific modules and follow-up interviews provided us with a significant amount of subject-specific exposure information to capture accurately the variability between workers holding the same job title.

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Measuring biologically-based exposure metrics for Extremely Low Frequency (ELF) magnetic fields with a personal waveform monitor

Bowman JD, [1] McDevitt JJ,[2] Breysse PN[2]

[1.] *Division of Applied Science and Technology, National Institute for Occupational Safety and Health, Cincinnati, Ohio, USA, e-mail: JBowman@cdc.gov.*
[2.] *School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, Maryland, USA*

Purpose

This study is a first effort to measure worker exposures to magnetic field metrics derived from biophysical mechanisms, using a new waveform capture monitor. The primary purpose was to test whether these biologically-based exposure metrics are significantly elevated in electrical occupations which had been associated with cancer. Secondarily, this pilot study tested the feasibility of using this new monitor in epidemiologic studies.

Background

Magnetic fields with extremely low frequencies (ELF = 3-3000 Hz) have been associated with increased risks of leukaemia and brain cancer in several well-done epidemiologic studies, but were only rated a "Possible Carcinogen" (IARC category 2B) by an U.S. government risk assessment (1).

One reason for the uncertainty has been inconsistencies in the epidemiologic associations between occupational EMF studies. Another has been that exposures have been measured with the RMS (root-mean-squared) magnitude of the ELF magnetic field vector (Figure 1). Although convenient to measure, the ELF magnitude has no direct relationship to any effects on biophysical processes.

A strategy for obtaining more consistent results from epidemiologic studies has been to measure exposure metrics derived from biophysical mechanisms (2). The mechanisms with the most empirical support are:

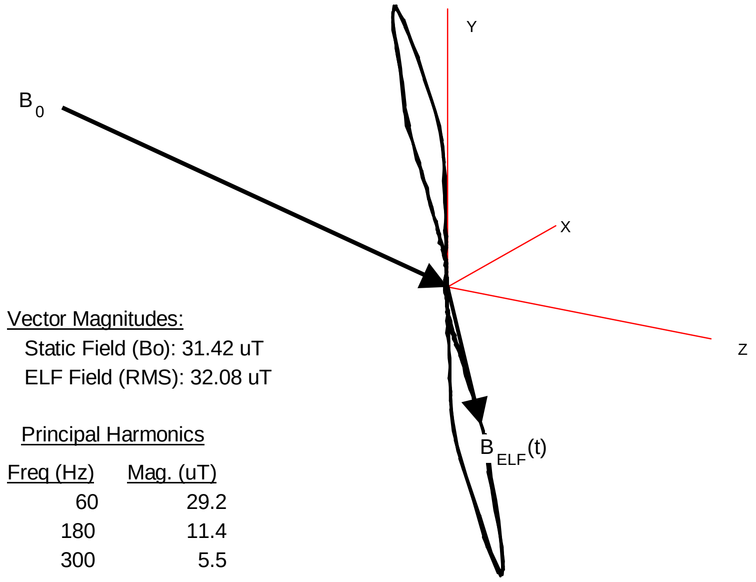
- Currents induced in the body by time-varying magnetic fields
- Changes in the free radical production rates
- Interactions with magnetosomes (biologic ferromagnetic crystals)
- Resonant interactions of excited-state ions in protein complexes

These hypothesized mechanisms lead to "biologically-based exposure metrics", such as the current density induced in the tissue where a cancer originates.

To measure exposures to these biologic metrics, this study used a new personal waveform capture monitor. By simultaneously digitizing the signals from three orthogonal magnetic field sensors with a 0-3000 Hz bandwidth, the Multiwave® System III (Electric Research and Management, State College, PA) totally captures the ELF and static field vectors over several 60 Hz cycles (Figure 1). The waveform data allows accurate biophysical modeling, and also provides all the field's physical parameters (ELF magnitude, frequency spectrum, etc.) (3).

As a first step towards health studies, we took Multiwave III measurements on electric occupations which have been previously associated with cancer (1). Biologically-based exposure metrics for the mechanisms listed above were then calculated with new software written to analyze Multiwave III data.

Figure 1. A three-dimensional trace of the ELF magnetic field vector $\mathbf{B}_{ELF}(t)$ and the static field vector $\mathbf{B}_o$ measured over five 60 Hz cycles by the Multiwave® System II near a transformer (3). Also shown are some physical characteristics calculated from the waveforms with Multiwave software.



Methods

Measurements were taken on workers recruited at Los Alamos National Laboratory, New Mexico, USA from the following occupations that previous studies had designated "electrical work" (1): electric lineworkers, electricians, welders, electronic technicians, and repairers of commercial and industrial electronic equipment. The number of electric workers and the sample of non-electric jobs was determined by a power calculation for the TWA magnitude of the ELF magnetic field. For at least half the work day, each worker wore a Multiwave III in a vest with its sensor located on the chest. In order to eliminate artifactual variations in the static magnetic field from the earth, the vest was made without metal fasteners, and kept the probe fixed to the worker’s body. Once a second, the Multiwave III took a measurement of 3-axis magnetic field waveforms within a 1/30 sec. window and a 0-3000 Hz bandwidth, and stored them as a time series on a PCMIA memory card. After monitoring, the Multiwave data was transfered to a PC for analyses. Graphing software for the Multiwave was used to check that valid data had been acquired. C++ software was written to calculate biologically-based metrics for the four mechanisms listed above and physical magnetic field characteristics directly from the waveform data. For each worker and metric, the software calculated summary metrics for the total monitoring period, *e.g.* the time-weighted average (TWA), maxiumum, first-order autocorrelation, etc. Finally, means tests were performed for each summary metric to determine whether the electrical occupations were more strongly exosed than the non-electric jobs.

Results

Thirty-eight partial-period personal samples were monitored in the 6 different job classifications. We calculated TWA exposures to the ELF magnetic field magnitude and the following biologically-based metrics:

- induced current density in the brain
- fullband intensity ($B_o^2 + B_{ELF}^2$) for the free radical mechanism
- ELF component perpendicular to $\mathbf{B}_o$ vector for the magnetosome mechanism
- for the ion resonance mechanism, the component of the electric dipole perpendicular to the impulse which put the ion into its first excited state

Table 1 gives an example of these results, compared to the TWA of the ELF magnetic field magnitude. Compared to the non-electric jobs, TWA exposures to both the induced brain currents and the ELF magnitude are significantly elevated in all electric occupations, plus electricians and welders. However, the elevation is more pronouced for induced brain currents (p=0.00003 for all electrical jobs) than for the ELF magnitude (p=0.00081).

Table 1. Means tests of the time-weighted averages for a biologically-based exposure metric and the ELF magnetic field magnitude in the electrical occupations compared to a sample of non-electrical jobs

Job Category (# of subjects)	Geometric Mean TWA (GSD†)	
	Induced brain current Density (μA/m^2)	ELF magnitude (μT)
Non-electrical (n=8)	0.08 (1.5)	0.08 (2.2)
Line workers (n=11)	0.21 (4.7)	0.25 (9.8)
Electronic repairers (n=8)	0.15 (2.7)	0.21 (2.7)
Electricians (n=5)	0.56 (3.1)*	0.71 (4.2)*
Welders (n=3)	0.47 (2.9)*	0.43 (3.0)*
Electronic technicians (n=3)	0.46 (14.9)	0.69 (18.3)
All electric jobs (n=30)	0.28 (3.8)*	0.33 (5.3)*

*p<0.05 compared to the non-electric jobs (log transformed) † GSD is unitless

Conclusions

This pilot study suggests that electrical jobs previously associated with brain cancer may be more highly exposed to the induced currents in the brain than to the ELF magnetic field magnitude measured in the epidemiologic studies. More importantly, this pilot study demonstrated the feasibility of measuring worker exposures to biologically-based metrics with the Multiwave III personal waveform monitor.

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Review of statistical modelling of exposures for an epidemiological study and exposure controls in asphalt paving industry

Burstyn I [1,2] and Kromhout H [1]

(1) Environmental and Occupational Health Group, Institute for Risk Assessment Sciences, Utrecht University, Wageningen, The Netherlands, e-mail: I.Burstyn@vet.uu.nl;
(2) Unit of Environmental Cancer Epidemiology, International Agency for Research on Cancer, Lyon, France.

"The order that our mind imagines is like a net, or like a ladder, built to attain something. But afterward you must throw the ladder away, because you discover that, even if it was useful, it was meaningless." -- Umberto Eco, The Name of the Rose.

Introduction

We will present an overview of how models of average exposure intensity to bitumen fume and benzo(a)pyrene among asphalt paving workers were constructed for epidemiological cohort study of European asphalt industry. Furthermore, we will demonstrate how exposure data retrieved for the epidemiological study was used to construct models aimed at identification of effective exposure controls.

Methods

Exposure models for epidemiological study: A comprehensive database of exposure measurements in the European asphalt industry was constructed for this study (3). Exposure measurement data (concentrations and supplementary information, including an identifier for repeated measurements within a person) were sufficiently comprehensive to construct predictive bitumen fume and benzo(a)pyrene exposure models among asphalt pavers using mixed-effect linear model methodology (4). We evaluated the predictive power of determinants of exposure that could be assessed retrospectively (through a questionnaire) in a historical cohort study. The effects of these determinants were adjusted for possible confounding by methods employed in the surveys that contributed to the exposure database (sampling strategy, sampling and analytical methods).

Exposure models seeking novel exposure control measures: Some exposure data sets retrieved for the epidemiological study had unique supplementary information that could be exploited in order to identify measures that can reduce exposure concentrations in workplace. Data from a two-year survey conducted in Norway contained very detailed documentation of production conditions (grade of bitumen and asphalt used, and emulsion use) and control measures. Mixed-effects linear models were used to select the strongest predictors of bitumen fume exposure in the Norwegian data. A data set from France contained information on the benzo(a)pyrene content of asphalt. This unique piece of information was used to study a relationship between the chemical composition of asphalt and airborne benzo(a)pyrene exposures.

Results

Exposure models for the epidemiological study revealed a declining time trend in exposures to bitumen fume and benzo(a)pyrene (4). Coal tar use was demonstrated to be the most important predictor of benzo(a)pyrene exposure, and its removal from production should be an effective benzo(a)pyrene exposure control measure (already implemented across Western Europe). Mastic laying, recycling asphalt surfaces, and indoor work were associated with some of the highest exposure levels in the industry. Adjustments for methods in each individual survey comprising the data set contributed significantly to the models. There were no differences between comparable paving operations among countries. Empirical models developed for the epidemiological study allowed us to estimate average exposure intensities for different scenarios that described past production conditions in each participating company. Such inferences required the knowledge of (a) relative exposure intensities among different determinants of exposure and (b) estimates of the magnitude of within-worker variance of exposure.

Empirical models aimed at identification of exposure controls revealed that the use of a specially designed basket that increased the distance between the source of exposure and the worker, in combination with ventilation of the screed of the paving machine, can reduce personal exposure to bitumen fume by about a factor of three (5). Paving machines can be retrofitted with this control measure. The use of softer bitumens and the lowering of application temperatures were conducive to controlling exposures. Different emulsion types were also associated with variability of bitumen fume exposure.

Through analysis of a separate sub-set of data from surface dressing (n=34), we found a strong dependency of personal airborne benzo(a)pyrene exposure on the benzo(a)pyrene content of the binder used in asphalt (slope=0.60, r=0.60) (2). We also discovered that the benzo(a)pyrene content of the asphalt binder strongly correlated with the benzo(a)pyrene content of non-bitumen additives to the binder (r=0.99, p<0.0001). This strengthened the notion that in order to decrease exposure to carcinogenic polycyclic aromatic hydrocarbons (PAH) during paving, one has to focus on controlling PAH content of non-bitumen additives to the asphalt mix. Coal tar was found not to be the only PAH-rich additive to asphalt.

Discussion

Empirical models of exposure can be used to identify determinants of exposure that are useful for either epidemiological or exposure control investigations. The mixed-effects model methodology can be used to infer exposure levels under different scenarios relevant to exposure assessment in epidemiological studies. Empirical models can also be applied to predict changes in exposure levels in response to the introduction of control measures. The manner in which a model was constructed depended primarily on its intended application. For example, in the epidemiological study we could only ascertain past production conditions in terms of crude general descriptions. Therefore, our models had to be such that they used these same categories (jobs, time periods etc) to explain exposure patterns. The patterns in exposure levels identified in such a manner did not necessarily lead to an explanation of why exposures changed, they simply described how they have changed. For example, we may not fully understand the cause of time trends in exposures, but nonetheless there is little doubt that they did exist.

Empirical models designed to identify exposure controls utilised more specific descriptions of production characteristics to explain variability in exposure levels. Such determinants of exposure were not useful in epidemiological exposure reconstruction. For example, bitumen quality, specific modifications of paving machines, and PAH content of non-bitumen additives to asphalt could not be ascertained retrospectively through questionnaires administered to companies enrolled in the cohort.

A crucial prerequisite to the use of exposure data for variety a purposes was rich supplementary data placing each measurement into the appropriate context, in terms of production conditions. That this supplementary information was not originally collected for exposure modelling is indicative of the wealth of information that might lie hidden in reports compiled by occupational hygienists.

One of the key limitations of empirical modelling is the difficulty in making inferences outside of the range of available data. However, it is our contention that a relaxation of such restrictions, if explicitly stated, is still preferable to the "expert evaluation" approach in exposure modelling. This avoids the hidden assumptions that an individual assessor makes, which are either difficult or impossible to validate. On the other hand, empirical modelling of exposures for the epidemiological study permitted a fast and straight-forward evaluation of their internal and external validity (1).

Conclusion

It is possible to construct empirical models of exposure in occupational settings by applying advanced statistical tools to exposure databases. In constructing empirical models of exposure, the ultimate objective of modelling determines which determinants of exposure are considered. While modelling exposure for epidemiological studies we can derive important information on how to control exposures, if the studied exposure was found to confer a health risk. One may also consider it unethical to collect data without fully realising its potential. In such a multifaceted use of exposure data lies the future of empirical exposure modelling.

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Exposure modelling - The EASE approach

D.M. Llewellyn

Technology Division, Health and Safety Executive, Magdalen House, Stanley Precinct, Bootle, Merseyside L20 3QZ, United kingdom. E-mail: diane.llewellyn@hse.gsi.gov.uk

Background

Assessment of occupational exposure may be necessary for a variety of reasons e.g. to estimate potential health risks, to help in setting or changing statutory occupational exposure limits or for epidemiological purposes. In some cases there is little or no exposure data available for assessment purposes. Nevertheless, it is possible to predict exposures by analogy with exposures to other substances with similar physical properties. To cover the situations where little or no data are available, the British Health and Safety Executive (HSE) developed its Estimation and Assessment of Substance Exposure model (EASE).

This presentation will outline the conceptual basis for the EASE model, briefly review some of the studies examining the reliability of the model and give some thoughts on the future development of EASE.

The EASE model

The concept for the basis of exposure modelling in EASE is the systematic examination and codifying of the various factors which are likely to influence exposure. The factors fall into one of three categories, those describing the physical properties of the substance, those describing the pattern of use of the substance and those describing the pattern of control.

EASE is essentially a series of decision trees. For any substance the system asks a number of questions. For any one question (apart from those asking about physical properties), the EASE user selects from a number of representative options. Once all the questions have been answered, the exposure prediction, a range of estimated exposure, is determined by the choices made. The ranges were determined using HSE's National Exposure Database, and the collective experience and judgement of HSE's occupational hygiene inspectors.

The model is a knowledge-based electronic expert system. It was designed to be simple and to be applicable across a wide range of workplace scenarios. The model was not designed to replace either representative measured data or the professional judgement and experience of a properly qualified occupational hygienist. It was designed as a tool to generate predictions to support estimates of exposure where real data are inadequate or insufficient.

The EASE model was developed in the mid 1990s, and has now been in use for several years. During this time it has evolved considerably, becoming technically more complex, in software terms, and extending its scope to cover a wider range of workplace scenarios for exposure to hazardous chemicals. Inevitably, since its development several areas have been identified where the model is known to have technical shortcomings. A number of these have already been addressed and the EASE model is now in its third Windows version. However, the HSE's policy for the EASE model is to continuously improve it. Future plans include a fundamental review of the model aiming to capitalise on the increase in our knowledge and experience in the past decade and make the most of advances in expert system technology.

Exposure assessment strategies and validation for estimation of radon exposure among nuclear workers

Hornung R W[(1)] Pinney S M[(1)] Killough G G[(2)] and Lodwick J[(1)]

[(1)] *University of Cincinnati Medical Center, Cincinnati, OH, USA,*
e-mail: rick.hornung@uc.edu
[(2)] *Hendecagon Corp., Oak Ridge, TN, USA*

Introduction

We will describe the exposure assessment strategy used to estimate exposures to radon (Rn-222) decay products among workers at the Fernald Feed Materials Production Center, a uranium processing plant operated under contract to the U.S. Department of Energy. We used a stochastic mathematical model, specifically developed to estimate radon levels to residents in the area surrounding the plant, to estimate radon exposure to workers employed at the plant from 1952 to 1988. We also employed CR-39 alpha particle detectors throughout the plant to both augment and validate the estimates generated by the model.

Methods

In 1998 a dose reconstruction study of residents living near the Fernald plant was completed. This study used a stochastic model to estimate radon exposures to residents living within a 10 km radius of the plant (1). The sources of the radon were two silos located on-site containing large quantities of radium-226. Estimated exposures to radon were highest near the silos and downwind. Since the wind direction is westerly and the silos are located on the west side of the plant, exposures to workers are considerably higher than to residents. The primary buildings inhabited by workers were identified for the period 1952-88 and a set of longitude/latitude coordinates were generated for each building. The model produces annual radon decay product estimates for the period 1952 –88 based upon these geographic coordinates as a function of atmospheric conditions and known or estimated emission rates from the silos.

In addition we used 109 CR-39 plastic film detectors deployed throughout the plant to measure cumulative radon exposures. These detectors are mounted on window glass in buildings selected to cover the plant and which housed the majority of workers over the 1952-88 period. The CR-39 plastic records the polonium-210 alpha activity embedded in the glass using a method developed by researchers at the University of Bristol, England (2). These values are used for two objectives: to validate the estimates of the stochastic model and to supplement the model's predictions for areas of the plant known to generate secondary sources of alpha activity.

In addition, we used area measurements of radon taken at various points around the plant in the 1990's to validate the model's predictions for the late 1980's. Other than atmospheric conditions, there were no changes to the silos from the plant closing in 1988 to the time the measurements were made.

Results

As expected, the estimated radon levels (WL) varied over both space and time. Averaged over the period 1952-88, the ratio of the exposures closest to the silos compared to those with the lowest estimated levels was 2.23. However, the variation over time was much greater; the ratio of radon levels before the silos were capped in 1979 to levels in subsequent years was 15.6.

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Assessment of workstation design, working technique and work postures during computer work using an ergonomic checklist

Hansson Risberg E [(1)], Wigaeus Tornqvist E [(1)], Hagberg M [(2)], Hagman M [(1)], Toomingas A [(1)]

[1.] *Programme for Ergonomics, National Institute for Working Life, Stockholm, Sweden, e-mail: eva.hansson.risberg@niwl.se*
[2.] *Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg, Sweden.*

Introduction

In Sweden work with visual display units (VDUs) has increased with 30 % within a 10-year period, 1989-1999. In 1999 58 % of the female working population and 62 % of the men used VDUs at work (1).

Several studies have indicated evidence for the effect of non-neutral wrist, arm and neck postures as well as poor workstation design, which influence postures, on neck and upper extremity disorders among computer users (2). Working technique during computer work have also shown an impact on the occurrence of muscular strain (3). Female computer users appear to be associated with higher occurrences of neck and upper extremity disorders than men are (2).

As a part of the exposure assessments in an epidemiological cohort study among computer users an ergonomic checklist was elaborated. The objective of the ergonomic checklist was to enable structured assessments of workstation design, working technique and work postures.

The aim of this study was to compare workstation design, working technique and work postures between male and female computer users.

Methods

An ergonomic checklist with a key enclosed, explaining and defining all the exposure categories, was used in a prospective cohort study. The checklist was used on all subjects who did not report any musculoskeletal symptoms 3 days or more during the preceding month. At the baseline measurements 72% of the women and 51% of the men reported symptoms. Totally 471 women and 382 men were assessed according to the ergonomic checklist. The assessments were conducted by trained ergonomists at the subject's ordinary work places. The subjects were instructed to perform their "ordinary" computer work during the observation.

The checklist consisted of four different parts, background questions, workstation design, working technique and work postures. The protocol of the assessments of the first three parts of the checklist were filled in at the workplace while the work postures were video recorded and subsequently analysed in the laboratory.

The background questions included e.g. job title, year of examination of vision, use of special glasses for computer work and type of computer work when observed. Other important background factors such as sex and age were collected from another questionnaire used in the study.

Workstation design consisted of questions about the design and usability of the chair and the desk and the position, in relation to the operator, of the screen, the keyboard and the input devices. A tape measure was used for assessments of distance. The items regarding workstation design were classified into 2-5 categories.

Support of the arm, local pressure on wrist/lower arm, grip on input device and shrugged shoulders were some studied items regarding working technique. The working technique items were classified into 2-5 categories.

The work postures included the joint angles of the trunk, the neck, the shoulder and the wrist/forearm classified in 2-5 categories and the variation of postures during work in 3 categories (figure 1). The subjects were video recorded for approximately 30 minutes and each angle was recorded both during work with keyboard and non-keyboard input device for at least one minute each.

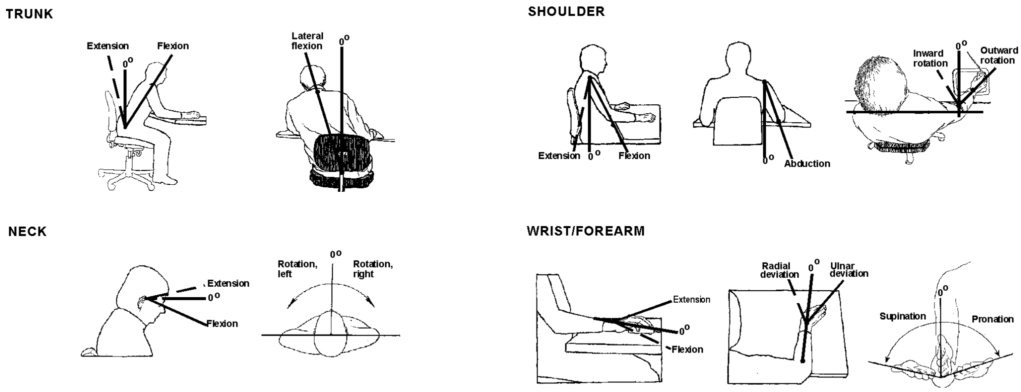

Figure 1. Description of assessments of joint angles.

According to known risk factors and the research groups believes about "harmful" exposure the items were combined into various "optimal" and "non-optimal" conditions (table 1).

Results

There were no major differences in the proportion of "non-optimal" conditions concerning workstation design between women and men with the possible exception of the chair (table 1). Women had a higher proportion of "non-optimal" working technique at the keyboard work than men. The working technique was estimated more optimal at work with non-keyboard input device compared with work with keyboard, both for women and men, mainly due to more frequent support of the arms. Men had higher prevalence of "non-optimal" work postures, apart from wrist/forearm in work with non-keyboard input device, compared with women. The proportion of "non-optimal" work posture in shoulder and wrist/forearm was higher in work with non-keyboard input device than in work with keyboard but the neck posture was more "non-optimal" in work with keyboard.

Table 1. The relative frequency (%) of "non-optimal" workstation design, working technique and work postures among women and men.

"Non-optimal" conditions	Women (%)	Men (%)
WORKSTATION DESIGN		
Chair	56	47
Desk	80	78
Position of screen	20	26
Position of keyboard	63	59
Position of non-keyboard input device	61	62
WORKING TECHNIQUE		
Keyboard	68	57
Non-keyboard input device	44	40
WORK POSTURES		
Neck		
work with keyboard	31	53
work with non-keyboard input device	18	28
Shoulder		
work with keyboard	34	51
work with non-keyboard input device	83	91
Wrist/forearm		
work with keyboard	33	44
work with non-keyboard input device	61	60

Discussion

A previous study has indicated that women had more adverse work postures during computer work, possibly because of smaller anthropometric dimensions, than men did (3). In this study the occurrence of "non-optimal" work postures was more prevalent among men compared with women.

The assessments of working technique in this checklist were more of a subjective character than the assessments of workplace design and work postures. However, a recent study using the same protocol for working technique indicated that subjects with a "good" working technique had lower muscular load on the trapezius and the forearm extensor muscles compared to the subjects with a "poor" working technique (personal communication with A. Lindegård, Göteborg).

Conclusions

No major differences in workstation design and working technique were observed between women and men. Men had generally less optimal work postures than women did. The results do not support that these factors explain the higher proportion of symptoms generally observed among women compared with men.

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Physiological effects of time pressure and verbal provocation when working with a computer mouse

Wahlström J [1,2], Hagberg M [1,2], Johnson PW [1,3], Rempel D [3], Svensson J [1]

[1]Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg, Sweden. e-mail: jens.wahlstrom@ymk.gu.se
[2]*Department of Occupational Medicine, Göteborg University, Sweden.*
[3]*Ergonomics Program, University of California, Berkeley and San Francisco, California, USA.*

Introduction

Musculoskeletal symptoms among VDU operators are believed to have a multi-factorial etiology. Non-neutral wrist, arm and neck postures, workstation ergonomics, duration of computer work, psychological and social factors, such as time pressure and high perceived work load, are believed to interact in the development of these symptoms (6).

The pathophysiological mechanisms behind symptoms in the neck/shoulder area is not clear, but may involve an imbalance in the nervous system, local ischemia of muscle and nociceptor sensitisation (1). The Cinderella hypothesis proposed by Hägg (2), suggests that myalgic pain is caused by an overuse of low threshold motor-units active throughout the contraction. Experimental studies have shown that low threshold motor-units are active not only in static, but also in different arm postures and during shoulder movements (3). There are also some preliminary findings suggesting that low threshold motor-units are recruited in voluntary as well as in stress induced muscular activation (4).

The aim of this study was to investigate the effect of time pressure and verbal provocation on physical and psychophysiological load when working with a computer mouse.

Methods

Subjects and experimental procedure

Thirty subjects, 15 men and 15 women, ranging in age between 18-60 years volunteered to participate in the study. All subjects were experienced mouse users with a mean experience of 51 months and used the mouse with their right hand. None of the subjects used medication for hypertension or any other cardiovascular disease and they were all free of upper extremity musculoskeletal disorders.

An adjustable VDU workstation was set up and the subjects adjusted the table and chair to fit their personal preferences. A Macintosh computer with a 13-inch colour display and a standard keyboard was used. Prior to the measurements, subjects practised at the experimental work-site to familiarise themselves with the equipment and task. The experiment consisted of subjects performing a text-editing task in a stress and control condition. First, subjects completed two pages of the text-editing task with no time constraints or verbal provocation (control condition). Then, approximately 10 minutes later, the same task was performed, except it was twice as long (4 pages), a 40 second per page time constraint was imposed and subjects were verbally provoked (e.g. “hurry up”, “come on, you can work faster”) every 15 seconds (stress condition). If the subjects could not complete a given page of text within the time limit, they were verbally prompted to use the “Page Down” key on the keyboard and continue with the text editing task on the next page.

Psychophysiological and physical load

Heart rate (HR) was measured with a Polar Vantage NV™ heart rate monitor and data were analysed using the Precision Performance version software 2.0 (Polar Electro Oy, Professorintie 5, 90440 Kempele, Finland). Systolic and diastolic blood pressure (SBP, DBP) was registered with an ambulatory blood pressure monitor, CardioTens (Medikolt International AB; Skärholmen, Sweden). SBP and DBP were registered once during the control condition mid-way through the task (approximately 2 minutes). During the stress condition SBP and DBP were measured approximately one minute after the start of the task. To describe mood during work, the stress/energy questionnaire was used. The means of the subjectively perceived stress (SPS) from the stress dimension was calculated.

The procedures and equipment used to measure physical load were identical to what previously have been described in detail by Wahlström et al. (8). Briefly, surface electromyographic (SEMG) recordings from four separate muscles; the right first interossei (FDI), the right extensor digitorum (ED), and the pars descendent of the right and left trapezius muscles was collected. The 50^{th} percentile of the EMG signal was calculated, and the results are presented as group means. To measure the forces applied to the sides and button of the mouse, a force sensing Apple ADBII mouse was used. The force-sensing mouse was fully operational, and similar in weight, feel and appearance to a regular Apple ADBII mouse. Mean and peak forces applied to the sides and button of the mouse was calculated.

Results

When the stress condition was compared to the control condition, both the psychophysiological load and the physical load increased (Figure 1).

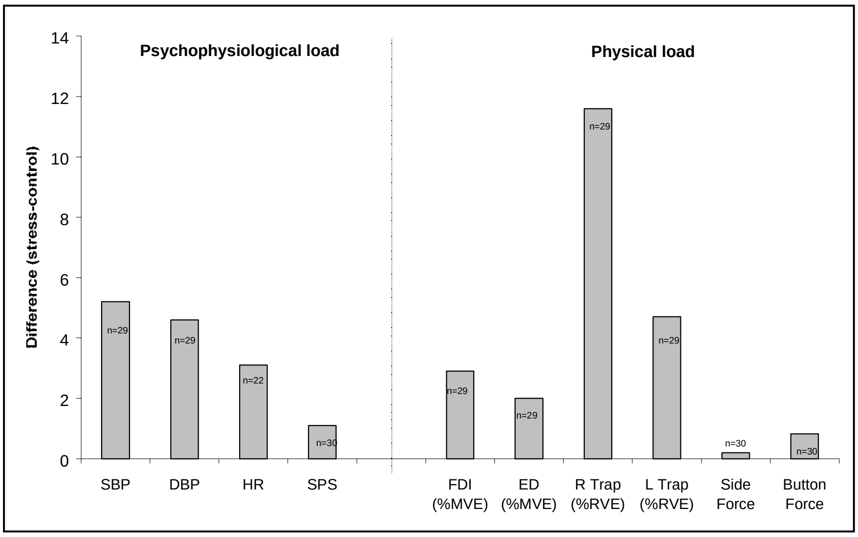

Figure 1. Mean difference in psychophysiological and physical load between the stress and control condition.

Discussion

When working under time pressure and verbal provocation, subjects reported to be more stressed as measured by the stress/energy questionnaire. The time pressure and verbal provocation also resulted in an increase in psychophysiological (SBP, DBP, HR) and physical load (EMG, mouse forces).

Muscle activity increased in all muscles measured. Part of the muscle activity increase in the FDI, ED and right trapezius muscles could be attributed to the fact that subjects worked faster, i.e. under time pressure, in the stress condition. Similar results have been presented by Laursen et al. (5), where the investigators reported higher shoulder muscle activity with increasing speed and precision demands. However, the muscular activity also increased in the left trapezius muscle which was not actively used in the experiment. This finding supports a hypothesis that some of the increase in muscle activity may be stress related. Increase in muscle activity due to stress has been reported in previous studies, but mainly with data from the trapezius muscle (6).

The forces applied to the computer mouse increased during the stress condition. However, with the present study design, it is uncertain whether this increase in the stress condition was due to the subjects working faster, the stress itself or a combination of the two factors. Whether these low forces are a risk factor for developing musculoskeletal disorders is unknown, but the cumulative effect of these forces and the patterns in which they occur could be a risk factor for developing work related musculoskeletal disorders, especially if working up to 8 hours a day at a VDU under time pressure or stress.

When possible, future stress-related studies should be designed so changes in productivity do not confound the interpretation of experimental outcome parameters.

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Computer mouse use in two different hand positions - exposure, comfort, perceived exertion and productivity

Gustafsson E [(1)], Hagberg M [(1)]

[1.] *Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg* University, Sweden, e-mail:*ewa.gustafsson@ymk.gu.se*

Introduction

Musculoskeletal symptoms from the upper extremity are common according to studies of computer mouse users (1, 2, 3). Most of the used computer mice are traditionally designed, i.e. they are held with a more or less pronated forearm. In recent years, however, computer mice which are gripped with a less pronated wrist have been developed. The aim of this study was to determine whether there are differences in exposure, comfort, exertion and productivity between a neutral and a pronated mouse hand position.

Methods

Two different types of mice were used: a traditionally designed mouse and a newly designed prototype of a mouse which is held with a neutral hand position (Figure 1).

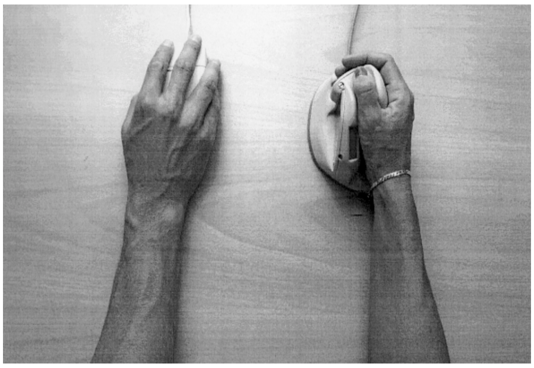

Figure 1. The two hand positions. The neutral hand position to the right with the newly designed prototype mouse and the pronated hand position to the left with the traditional mouse.

Twenty subjects, ten males and ten females, participated in the study. They were all experienced VDU workers and used computer mouse as input device in their ordinary work. The subjects performed a standardized text-editing task with each mouse hand position at their own VDU work station. Wrist positions/movements in the working arm were registered with an electrogoniometer and the 50^{th} percentile of the wrist angle distribution and the mean power frequency (MPF) for both flexion/extension and radial/ulnar deviation were calculated. The muscle activity was registered in the extensor digitorum (ED), the extensor carpi ulnaris (ECU), the first dorsal interossei (FDI) and the pars descendent of the trapezius muscle (Trap) by electromyography (EMG). The 10^{th} (static level) and the 50^{th} (median level) percentile of the EMG signal were calculated for each subjects. Perceived exertion was rated in neck, shoulders, arms, wrists and hands during work with each mouse hand position using Borg´s CR-10 scale. Perceived whole body comfort was rated on a scale, going from –4, very poor comfort, to +4, excellent comfort. Productivity was measured as the number of produced edited pages and the number of errors within the given time.

Results

Work with the neutral mouse hand position compared to the pronated showed a decreased muscle activity in the ED, the ECU and the FDI (table 1) and an affect indicating a decrease in the frequency of the deviation movements (table 2).

Table 1. Muscular activity in work with pronated and neutral mouse hand position (n=19). % MVE = maximal voluntary electrical activity, % RVE = reference voluntary electrical activity.

	Pronated	**Neutral**	**Difference** (Pronated – Neutral)		
	Median	Median	Median	95%CI	p-value
M.Extensor digitorum					
10e percentile (%MVE)	5,0	3,0	2	1;3	0,001
50e percentile (“)	8,0	5,0	3	2;5	0,001
M.Extensor carpi ulnaris					
10e percentile (%MVE)	5,0	3,0	2	2;4	0,001
50e percentile (”)	8,0	6,0	3	2;5	0,001
M.Interossei 1					
10e percentile (%MVE)	2,0	1,0	1	0;1	0,05
50e percentile (”)	6,5	2,0	5	3;7	0,01
M.Trapezius desc					
10e percentile (%RVE)	5,5	5,0	0	-2;1	>0,2
50e percentile (”)	12,0	11,0	0	-3;4	>0,2

Table 2. Wrist movements and MPF in work with a pronated and a neutral mouse hand position respectively (n=15). Positive value in wrist angles stands for extension and ulnar deviation. Negative value stands for flexion and radial deviation.

	Pronated	**Neutral**	**Difference** (Pronated-Neutral)		
Flexion/extension	Median	Median	Median	95%CI	p-value
50th percentile(°)	23,4	18,0	5,4	-1,8;16,2	>0,1
MPF (Hz)	0,60	0,63	-0,09	-0,19;0,14	>0,2
Deviation					
50th percentile(°)	5,4	-3,6	7,2	1,8;14,4	0,001
MPF (Hz)	0,51	0,44	0,07	-0,08;0,17	>0,2

The neutral mouse hand position were rated to give a lower whole body comfort than the pronated (Md -1 scale step, CI -2;-1, $p<0,05$). No difference in perceived exertion was shown. All subjects edited less number of pages (Md -2,5 pages, CI -3,25;-1,5, $p<0,05$) in work with the neutral mouse hand position compared with the pronated but only minor differences in produced number of errors.

Discussion

The decrease in muscular activity in the extensor muscles of the forearm during work with the neutral mouse hand position is in agreement with a norwegian study (4) and can probably be explained by the fact that this position is a more relaxing position for the muscles. High muscular load in the forearm muscles, as well as high frequency in wrist movements, is related to musculoskeletal disorders (5,6,7). It is likely that work with a neutral hand position can reduce the risk for musculoskeletal disorders in intensive computer mouse use. However, the study also showed that work with the neutral hand position in this experimental settings resulted in less productivity and less perceived whole body comfort. To minimize the musculoskelatal disorders due to computer mouse use it seems to be of importance to optimize the computer mouse design regarding both hand position, productivity and perceived comfort.

Conclusions

The neutral hand position in work with a computer mouse was shown to decrease the muscle activity in the forearm but also to decrease the productivity and the perceived comfort.

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Predicting exposure of the finger flexor muscle and tendon to dynamic loads during finger tapping

Dennerlein JT, Zhou Y, and Becker TE

Department of Environmental Health, Harvard School of Public Health, Boston,MA, USA, e-mail: jax@hsph.harvard.edu

Introduction

Exposure to different key switch designs within a computer keyboard has been associated with different levels of Carpal Tunnel Syndrome symptoms (3). However, knowledge of the associated forces within the tendons that transverse the carpal tunnel remains limited. Biomechanical models can predict the exposure of tendon to forces using posture and fingertip force data. Yet, these models often assume quasi-static equilibrium and neglect the dynamics of the finger mass (1). Our goal was therefore to use a lumped parameter dynamic model of the finger that predicted effective values for tendon forces during a dynamic activity of finger tapping and evaluated its effectiveness across different motor control conditions.

Methods

Ten healthy people (five female, five male, age range 25-36) participated in the study, which was approved by the Harvard School of Public Health Committee on Human Research Subjects. Participants tapped repeatedly on a flat plate with their right index finger while the fingertip contact force and movement were measured simultaneously. A single-camera motion analysis system tracked the vertical position of the fingertip by measuring the position of an infrared LED glued to the fingernail of subject's index finger (Resolution = 0.040 mm). A strain gauge based force sensor mounted beneath the flat plate measured the fingertip force (rms noise = 3mN). Data were recorded by a desktop personal computer using a 12-bit analog–to–digit converter at a 10,000 samples per second.

The finger was modeled as a linear second order mass-spring-dashpot system (2). The fingertip force and an effective muscle-tendon force acted directly upon the inertia. The parameters for the dynamic model were only calculated for the first 40 ms of fingertip contact and therefore the effective muscle force was assumed to be proportion to time after the initiation of the fingertip contact with an initial level of force. The force levels were small compared to Hajian et al. (2), therefore the stiffness of the finger was assumed to be small and was neglected. Simple least squares regression techniques estimated the parameters for the model for each tap. Digital differentiation of the fingertip position provided measures for fingertip velocity and acceleration during the tapping exercise.

Four different tapping conditions were evaluated to examine the differences between model parameters. The first was a relaxed position with all five digits extended and in a natural orientation. For the second condition, subjects curled digits three, four and five under the palm and squeezed with a moderate to high amount of effort. The subjects repeated these two conditions at two different speeds of down-stroke portion of the tap (normal and fast) with the same rate of tapping (1Hz). Normal speed simulated a 'comfortable' speed with which a subject would normally type. For the fast tapping, subjects were instructed to increase the downward speed of the fingertip. The subjects were also instructed for each tap to minimize the contact time with the force sensor. After a brief training and warm up session, each subject completed two trials for each condition. Data were collected for fifteen taps per trial. The order of the conditions was randomized for each subject. Parameters were averaged across the 15 taps and two trials for each subject and then averaged across the subjects within each condition.

Results and Discussion

Figure 1 illustrates the first 0.030 seconds of a typical tap. Most of the dynamic activity occurs within the first 10 milliseconds with the inertia (acceleration) and damping (velocity) forces quickly approaching zero. The effective muscle force contributes most of the force thereafter.

Table 1 lists the lumped parameter estimates for the four different conditions. The mass and damper parameters vary little over the four conditions tested and are consistent with Hajian et al. (2). The effective muscle force, however, does vary considerably over the four conditions. During the co-contraction of other hand muscles through the making of a partial fist, the rate of change in force increases significantly. The initial muscle force increases with the speed of the tap down-stroke suggesting extra muscle effort was used to accelerate the finger during the faster taps.

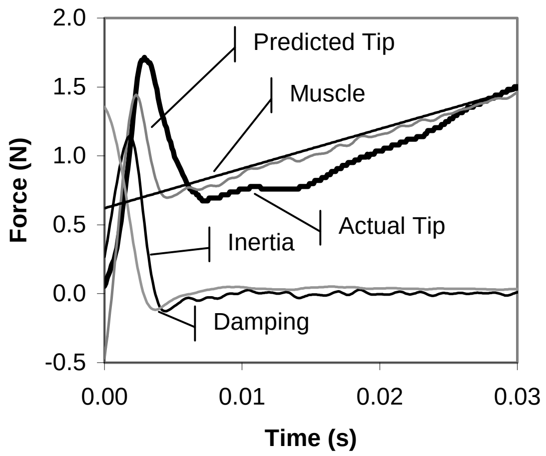

Fig. 1: Tip and model predicted force trajectories for a typical tap

The model has relatively small errors. Root mean square values average 0.3 Newton and the variance of the measured force accounted for (VAF) by the predicted value averaged 93%. A large portion of the error occurs during the impact phase of the force trajectory. The inertia force diminishes before the impact force begins to decrease. This was observed across subjects and conditions. Recall we measured the movement of the fingertip. The finger has other joints that might be still moving while the fingertip has stopped. Hence the inertia force to stop those portions of the finger is spread out over a longer period of time. The negative force rate of change values can also be attributed to this difference in the later portion of the impact because the dynamics are close to zero, the muscle force accommodates for this error. Measuring the interphalangeal joint angles during a keystroke would elicit such a mechanism.

Typing forces are relatively small and therefore understanding the nuances between different keyboard and key switch designs can help explain the differences observed in Rempel et al. (1999). Knowing these tendon forces allows us to understand the dynamic differences in the exposure to the different keyboards and therefore provides better understanding of the etiology of musculoskeletal disorders and improved engineering design interventions.

Table 1 Lumped parameter model estimates -- mean values and (standard deviation).

Parameter	Relaxed	Relaxed fast	Fist	Fist fast
Mass (g)	6.0 (0.6)	5.2 (0.4)	5.5 (0.7)	5.2 (0.6)
Damper (N/m/s)	1.9 (0.1)	2.3 (0.2)	2.0 (0.2)	2.4 (0.3)
Initial Force (N)	0.9 (0.2)	1.6 (0.3)	0.9 (0.3)	1.5 (0.3)
Force Rate (N/s)	-0.9 (6.3)	-10.8 (8.2)	34.7 (13.9)	47.9 (20.7)
RMSE (N)	0.3 (0.1)	0.4 (0.1)	0.2 (0.1)	0.4 (0.1)
VAF (%)	91 (1)	92 (2)	94 (1)	93 (2)

Acknowledgements: Whitaker Bioengineering Foundation

Conclusions and Future Work

The results suggest that the lumped parameter model can be used to examine differences of effective muscle loads between different key switch designs. The limitations of the model require future work investigating the specific interphalangeal kinematics during the impact phase of the key strike.

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Is it the peak that matters or is it the cumulative exposure?

Richard Wells[(1)] and Gisela Sjøgaard[(2)]

(1) Department of Kinesiology, Faculty of Applied Health Sciences, University of Waterloo, Waterloo, Canada, *wells@healthy.uwaterloo,ca*, and
(2) National Institute of Occupational Health, Copenhagen, Denmark *gs@ami.dk*.

Introduction

Musculoskeletal disorders (MSDs), including low back pain, carpal tunnel syndrome, tenosynovitis and certain myalgias are considered to have strong work-related components. Many measures of "ergonomic exposure" in the workplace have been used in determining their work-relatedness. There are many possible injury mechanisms that could be responsible for the development of these disorders at work. Some are clearly due to a high peak load, rupture of the interspinous ligament (due perhaps to a fall) or end plate failure in a lumbar motion unit while some are the result of longer term processes such as the development of myalgia in the trapezius. Inspection of some recent reviews shows that exposure measures used in epidemiological studies of musculoskeletal disorders fall into groups such as force, posture, repetition, static load, and vibration (1, 2). It should be noted that this discussion of the importance of peak and average exposures is also present in environmental and occupational health sciences where the most common metric of exposure is the Time-Weighted Average (TWA).

This paper addresses the findings from physiological and epidemiological sources as to the importance of peak and cumulative exposure on the development of musculoskeletal disorders and makes some suggestions on exposures to include in the study of MSDs.

Acute and chronic injury mechanisms

A starting point for the discussion is the injury mechanism for MSDs, also called cumulative trauma disorders. Table 1 shows examples of postulated mechanisms.

Acute and chronic exposure measures

Table 1 would suggest that exposure measurement strategies be matched to injury mechanisms and include both cumulative and acute measures (3). The exposure descriptors least well developed are those describing the time variation pattern of the exposure. It is from this time variation pattern that the highest value (peak) or some measure of average or cumulative exposure originates. The average value can often be taken as a surrogate of cumulative exposure; the average value times the length of shift or employment is cumulative exposure. If the basic exposure variable is force then peak exposures have units of N, as do average exposures, however cumulative exposures have units of N.s. In the case of posture peak exposures have units of degree as do average exposures, however cumulative exposures have units of degree.s or using a cumulative probability approach, the % of time with exposure greater than 45 degrees. Table 2 shows examples of common exposure measures

Table 1: Examples of Disorders Caused by Peak and Cumulative Exposure (Putative mechanism in brackets)

Tissue	**Injury Caused by Single Peak Force**	**Injury Caused by Repeated Force**
Muscle	Z line disruption/muscle tear (Single eccentric contraction)	Muscle pain with ragged red and moth eaten fibres (Cinderella Hypothesis)
Joint	-	Osteoarthroses
Lumbar Motion Unit	-Interspinous ligament rupture (Fall on buttocks) -End plate fracture (Single high compressive load)	Disc herniation (Continuous or repeated load in flexed posture)
Nerve	-	Sensory and motor loss, (Entrapment/elevated compartment pressure)

Table 2: Examples of Peak and Cumulative Ergonomic Exposure Measures

Basic Exposure Category	Peak Variable	Average/Cumulative Variable
Force	Maximum load lifted	Average load or cumulative load per shift/employment
Posture Joint angle Velocity Acceleration	 Peak limb flexion Max angular velocity Max angular acceleration	(%) time limb flexed greater than 45º Average angular velocity Average angular acceleration

Epidemiological evidence

Although not explicitly denoted by peak or cumulative, many studies use both types of exposure measures. Both peak and cumulative exposures have been shown to be related to the development of MSDs, (1). Unfortunately, there are few studies where both have been measured and where a comparison of their relationships to musculoskeletal health outcomes can be compared. Norman and colleagues did measure both peak and cumulative exposures to the low back simultaneously and showed that both were related independently to risk of reporting low back pain (4) and the same may hold true for upper limb disorders (5).

Summary and conclusions

Both peak and cumulative exposures appear to be important and independently related to WMSDs. Investigators studying work-relatedness of MSDs and evaluating hazards in workplaces should ensure that their exposure strategy includes both peak and cumulative/average measures appropriate to the disorders studied/expected.

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The dose concept – reflections on definitions and applications

Hägg G M[(1)(2)], Bergqvist U[(1)(3)]

(1) Expert Group for Ergonomics Documentation, National Institute for Working Life, Stockholm, Sweden, e-mail: Goran.Hagg@niwl.se
(2) Programme for Ergonomics, National Institute for Working Life
(3) Industrial Ergonomics, University of Linköping, Linköping, Sweden

Introduction

The present paper originates from informal discussions within the Swedish Expert Group for Ergonomics Documentation. However, the authors are solely responsible for the present discussion and conclusions.

In almost any kind of scientific work aiming at identifying possible relationships between an external physical/chemical quantity and an effect on a biological system, the dose concept is used. In e.g. radiofrequency electromagnetic radiation, the "absorbed dose" has been described as "the image of exposure under a transformation which accounts for the absorption, scattering and geometric properties of an irradiation condition." (8). This absorbed dose may also be modified "to obtain quantities more representative of biological effects, such as dose equivalent and effective dose" (3). To describe such transformations is fundamental when developing dose concepts in any field of exposure assessment.

The definition of dose concepts vary but most often they are applied with at least some of the following implicit aims:

- To facilitate the formulation of relationships between the external exposure situation and the biological impact. This may, as in the citations given above, be done in a two-step process: the transformation of the external exposure to an internal one, and the modification of that internal exposure in terms of biological efficacy.
- To incorporate the duration of exposure and other exposure conditions in the measure.
- As a specific construct in some recommendations or regulations.

It can be argued that any attempt to harmonise the dose concept across different disciplines must be done at a fairly high level of abstraction. In its practical formulation, it must also be recognised that there are divergent traditions and professional interests, and that practical consideration of different measurement techniques and different biological mechanisms must be observed.

General aspects on the dose concept

This varying definition of dose – or sometimes lack of a definition - may, however, lead to confusion. One prominent example is the frequently used definition that "dose equals exposure x time", often refined as meaning the integral of exposure over various time elements. As will be discussed below, this definition is probably meaningful under a number of different assumptions only, some of which may – in most cases - not be fulfilled.

Most physical exposures will manifest its biological impact through a force (which can be mechanical or electromagnetic). At a given point in time, exposure to e.g. a mechanical (external) factor results in an internal mechanical force at some point(s) in the body. Cessation of the external exposure leads to the cessation of its internal counterpart.

How should then a more complex variation in time be handled, e. g. such as in figure 1? One possibility is that the system will react only when a certain threshold is exceeded, e.g. at the upper dashed line in figure 1 (threshold 1). In such a case, the exposure could be described in statistical terms – the likelihood that exposure will exceed this threshold. Important parameters should then be variation and time. The opposite extreme possibility is that all exposure will cause an effect – in figure 1 this would correspond to the threshold being reduced to exposure = 0 (x axis). In such a situation, time and the average exposure may be important parameters for the dose. In more realistic situations, there may be a lower level of exposure that is required in order to elicit an effect.

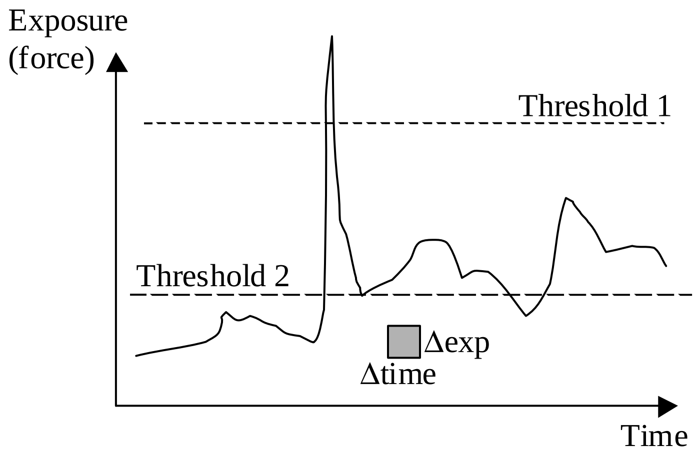

Figure 1. Variation of exposure over time, and possibilities of various thresholds.

In order for an effect to appear at a time t_1, influenced by the exposure at another (previous) time t_0, the system must somehow have stored information about this earlier exposure. For certain chemical exposures, this can be achieved by the storage (accumulation) of the chemical substance or a metabolite in some organ or tissue, but a physical force can in principle not be stored in such a way. The possibility of exposure information storage rests with some biological effect(s) of the instantaneous exposure. This suggests that the question of accumulation of exposure is not a strict question of dosimetry, but a question of accumulated biological consequences of the instantaneous exposure, and as such probably specific to each type of such consequence (initial biological effect).

The suggestion that dose should equal the integration of exposure over time (“reciprocity”) can now be examined. In such a model, each “surface element” in figure 1 (Δexp x Δtime) should then contribute equally to the accumulated effect. This presuppose:

- that the threshold = 0, i.e. that even an infinitive small exposure causes an effect,
- that the effect is linear, i.e. the same for each increment of exposure, regardless of the level, and
- that the storage (“memory”) is perfect under the time frame considered, i.e. that exposure occurring in the past means the same as exposure closer in time.

It is difficult to conceive of a situation fulfilling all these conditions, and thus it does not appear reasonable to base a conceptual definition of dose on the idea that dose = exposure x time. However it may of course be fruitful to consider situations where reciprocity can be a reasonable approximation of dose.

Since the dose concept in this context always is linked to a specific biological effect it can not be defined independently of this effect and at least a plausible notion about an interaction mechanism. Hence, the same external exposure situation can in principle be transformed into different internal ”doses”, depending on the effect that is considered. One example of this is given below. It can be argued that this complication, if realised, may actually be an asset for a more precise design of research efforts and also in the formulation of various recommendations or regulations.

Dose and musculoskeletal disorders

In the literature regarding mechanical exposure and musculoskeletal disorders mainly three alternative definitions of dose and related measures have been suggested.

In the conceptual model suggested by (1), "exposure" refers to external factors in working life. The "internal dose" is the forces and torques acting on tissues and organs. Unfortunately, the time relations are not clearly stated.

Winkel and Mathiassen (7) make the distinction between "external exposure" which concerns the work load constituted by work station design and work organisation, and "internal exposure" which refers to loads on tissues and organs. The "dose" is here defined as the time integral of the internal exposure.

Hagberg et al. (5) use the traditional occupational epidemiological definitions given by Checkoway et al. (2). The instant load on tissues and organs is referred to as burden. The dose is "the amount of the (exposure) factor that remains in the worker's target organ for some time interval". Cumulative exposure is also introduced and defined as the time integral of exposure.

The application of traditional occupational epidemiology concepts (2) in the field of musculoskeletal disorders is associated with several problems. These concepts have been developed and adapted to exposure situations where a chemical agent is taken up and partly stored in specific tissues and organs. A chemical substance normally remains for some time in an organ which, as pointed out above, cannot be the case for a force or a torque. The mechanical exposure on a tissue of course may imply tissue damage which may increase with extended or added exposure duration but we are then not discussing exposure or dose but the transformation into a biological effect.

A major complicating factor when evaluating exposure risks and developing dose concepts for musculoskeletal disorders, at least for some disorder types, is that the timing properties of the exposure (repetitivity, duty cycle etc.) are likely to be crucial for the risk level. This implies that a one-dimensional dose quantity is not sufficient. This have been emphasised in the model by Winkel and Mathiassen (7) by introducing repetitivity as a fundamental aspect to consider in exposure assessment. However, in spite of several suggested methods to quantify repetitivity, little is known about the validity of these methods.

Musculoskeletal disorders are often discussed as an entity despite the fact that different organs like a tendon, muscle or nerve may be the primary disorder origin with disorder mechanisms of totally different nature. For instance does the discussed increase of carpal tunnel pressure due to wrist posture and grip force in the wrist (6) imply totally different transformation mechanisms compared to the over-loading of "Cinderella fibres" in the trapezius muscle (5). Considering the discussion above regarding the close relationship between dose definition and disorder mechanism, an obvious conclusion is that relevant dose definitions for these two types of disorders should be different. These dose definitions should also most likely comprise different quantifications of repetitivity.

Conclusions

- It is important to have a general, common understanding of the dose concept in order to avoid confusion, facilitate research and improve the structure of regulation and recommendation.
- The dose concept needs to handle the duration of exposure and for MSD also address repetitivity.
- The practical definition of dose will vary depending on the nature of the exposure agent.
- The definition of dose will also vary depending on the biological effect and biological

interaction mechanism in question. Thus, a single exposure situation may actually be connected to more than one dose definition, depending on the effect.

- A consensus regarding exposure terminology within the MSD field considering these aspects is desirable for the advancement of research compatibility and quality

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Assessment of microbiological exposure in paper plant using recycled paper

Sigsgaard, T.

Institute of Occupational and Environmental Medicine, Aarhus University, Denmark, e-mail: Sigsgaard@dadlnet.dk

Introduction

The study of health effects in occupations with potential exposure to microorganisms has gained a lot from the basic works performed in the cotton industry during the eighties and nineties, where new methods for the assessment of the total microbiological exposure were introduced i.e. LPS-exposure. When negative health effects first were associated with the working conditions in paper recycling (3)we studied the exposure to LPS viable as well as total microorganisms, since others studies had pointed towards these exposures.(1,2). The production had been rearranged in order to minimise the production of waste water, and during that process the workers at the plant had increasing problems with respiratory and general symptoms during or after work. This was especially so after cleaning of the plant with production-water from the pipings containing a mixture of organic material (paper-pulp) and micro organisms (3). This study was carried out after a refurbishing of the plant with new ventilation systems, better encapsulation of the machinery and installation of special piping for the water used for cleaning of the plant.

Methods

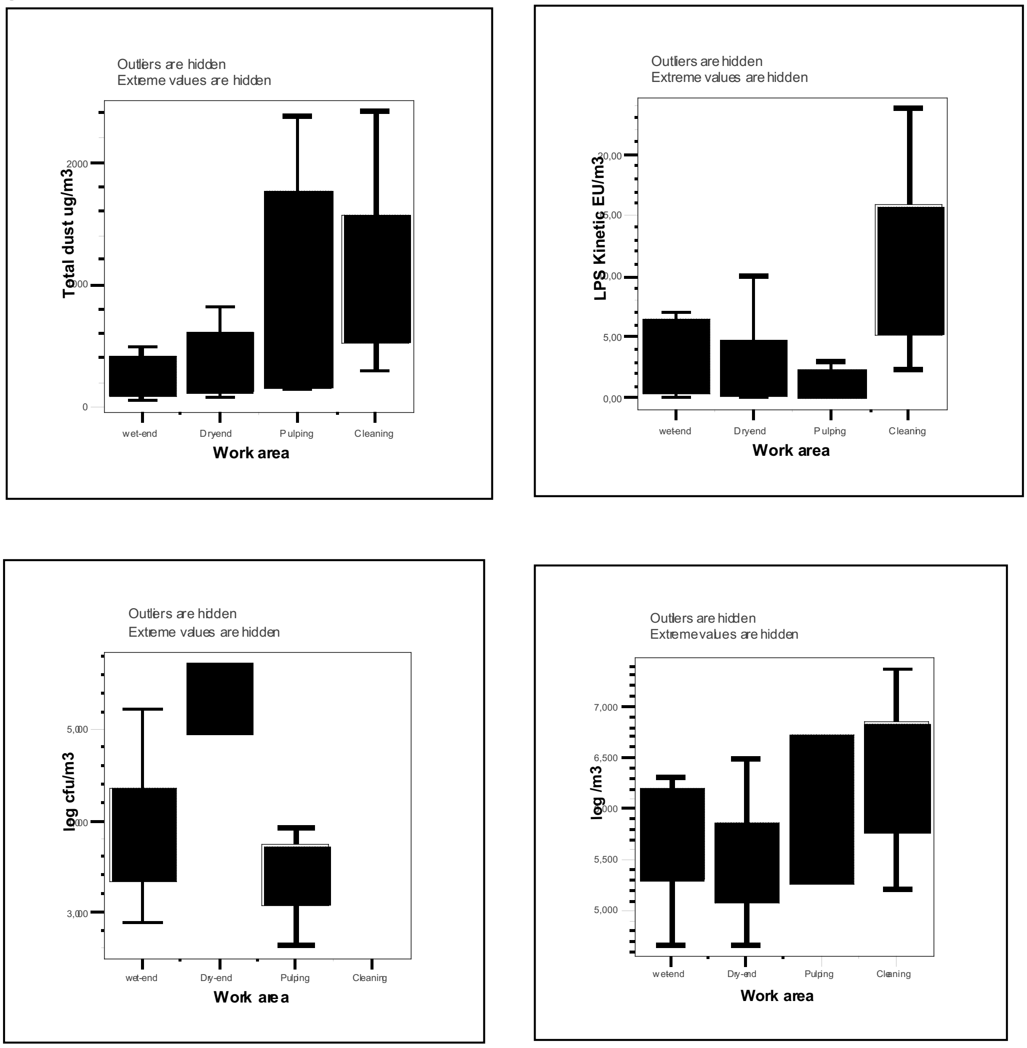
In order to describe the occupational exposure in the plant we measured personal exposures to total dust, LPS and total microorganisms. The bulk of measurements covered personal samples of total dust. Samples were taken of: total dust, endotoxin, microorganisms on a Millipore filter, and microorganisms on a gelatine filter. The air velocity in the sampling area was $1.25 ms^{-1}$ for dust and CAMNEA samples and $0.33 ms^{-1}$ for C-GEL (SARTORIUS). After dilution the microorganisms were incubated on Nutrient Agar for bacteria and Malt Agar for moulds in dilutions of 10. The plates were incubated at 20 °C. The colonies were counted after 3 and 10 days and reported as colony forming units (cfu.) per m^3. The same dilutions were used for microscopic counting of the total number of microorganisms CAMNEA. The gelatine filters were diluted in peptone and incubated on a modified C-GEL. One ml of the dilution was incubated for 30 s with acridin orange 20ppm filtered and counted in an epiflouroscens microscope at a magnification of 1,250. The dust filters were used for endotoxin analysis. The filters were shaken for 30 minutes in 10 ml of pyrogen free water and centrifuged 10 min at 1000 rpm. The endotoxin level were determined by the kinetic LAL method and the concentrations are given in ng/m3 the EU units are ng/m3 * 12 and the standard used were E. Coli 0111B:4.

Results

We found the highest dust concentrations in the pulping and the cleaning processes, mean (sd) in the two areas were 0.96(1.05) mg/m^3 and 1.15(1.11) in the two areas respectively. This was significantly higher than the concentrations found for workers attending the paper machines in the wet and the dry end, where the levels were .32(.30) and .36(.30), fig 1a.

For LPS the highest concentrations found were in the cleaning processes with a concentration of 11.3(11.1) EU/m^3 compared to 4.3(6.2), 2.6(3.5) and 1.3(1.4) EU/m3 in the wet end, dry end and pulping area, respectively, fig 1b. For viable counts we found no clear trend, however the dry end was almost one log higher than the wet end and pulping, fig 1c. The mean of the log of the total microorganisms were all between 5.6 and 6.3, see fig 1c.

Fig 1a-d The dust LPS and microorganisms stratified by location



§; p < 0,10 §§; p < 0.05, onevay.

Discussion

We found a higher concentration of dust in the pulping area and during cleaning. Compared to measurements from 1989 the total dust concentrations are in the same order of magnitude however there has been a change in the order between the different working areas, since in 1989 the highest concentrations were found in the wet and dry end of the paper machines 0,94(0,94) and 0,56(0,13) mg/m^3, respectively. Furthermore the lowest concentrations at that time were in the pulping area 0,18(0,03) mg/m^3 (Sigsgaard *et al*, 1994).

We have no personal samples of LPS from 1989. However, stationary samples from that period show a markedly higher concentration in the air, range 30-425 EU/m^3. The decrease was from 24 fold in the pulping area to 99 fold in the wet end.

Conclusions

By means of encapsulation of machinery and improved ventilation systems it has been possible to reduce the exposure to LPS substantially in a paper mill making cardboard of recycled paper.

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Seasonal variations in exposure to microbial components among waste collectors

Thorn J, Rylander R

Department of Environmental Medicine, Göteborg University, Sweden, email: jorgen.thorn@envmed.gu.se

Introduction

Collection, separation, and composting of household waste generate organic dusts that may contain the inflammagenic agent endotoxin and (1→3)-ß-D-glucan, a cell wall component of fungi, plants and certain bacteria. In previous studies, waste collectors have reported a greater number of or more severe symptoms in the summer. To elucidate influence of seasonal variation on the exposure, a study was performed to assess exposures to airborne (1→3)-ß-D-glucan and endotoxin during different seasons among household waste collectors handling compostable waste.

Methods

The study group comprised two household waste collectors handling compostable waste in Gothenburg, Sweden. The compostable household waste was sorted separately in paper bags placed in well ventilated metal bins and was collected once a week. Personal sampler were carried every second week (on Fridays) from September 1998 to January 2000. Determinations of the amounts of airborne (1→3)-ß-D-glucan were performed every second week and of endotoxin every fourth week.

Results

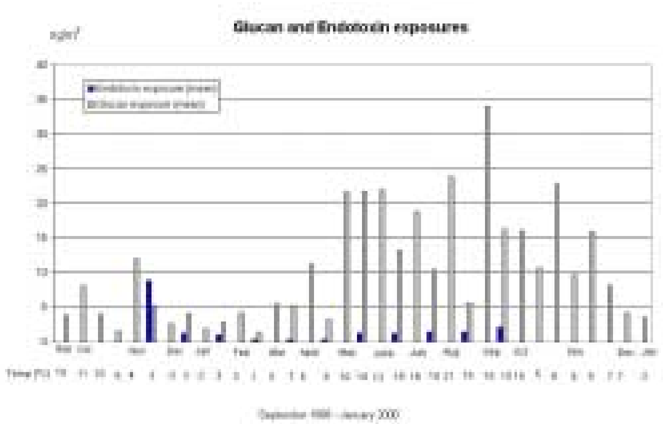

Figure 1. Amounts of airborne (1→3)-ß-D-glucan and endotoxin (mean values) among household waste collectors handling compostable waste, from September 1998 to January 2000 for (1→3)-ß-D-glucan and from November 1998 to September 1999 for endotoxin.

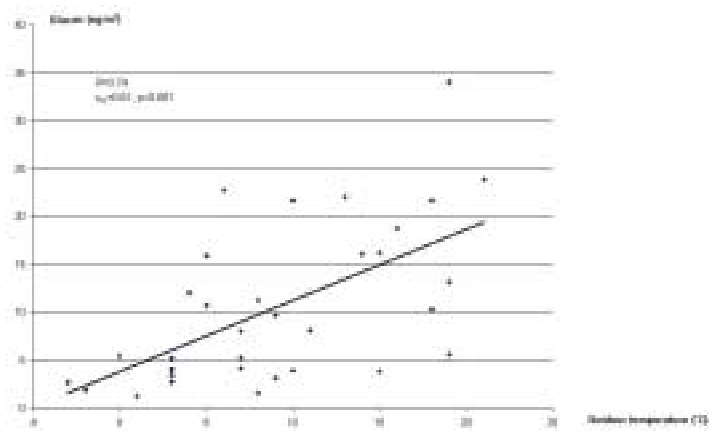

Figure 2. Relation between (1→3)-ß-D-glucan exposure and outdoor temperature (r_{xy}=correlation coefficient and R=regression coefficient).

The amounts of airborne endotoxin were low during the study period. The amount of airborne (1→3)-ß-D-glucan was higher during the warm season, and there was a relationship between exposure levels of (1→3)-ß-D-glucan and outdoor temperature.

Discussion

The measurements focused on airborne (1→3)-ß-D-glucan and endotoxin as indicators of microbial biomass exposure. The values observed must be considered rough estimates, as exposure values depend on many factors, such as the environment, weather conditions, work practices, sampling techniques and methods for assessing exposure. Furthermore, variations in the personal exposure situations, the amounts of compostable waste collected and aerosolization of dust are other factors that may influence the exposure. Wind speed can also affect the sampling procedure.

In a previous study among waste collectors, the exposure to fungi was low in winter [1]. The highest concentrations of fungi were found in the summer. In the present study, the levels of airborne (1→3)-ß-D-glucan were higher in the warm season. These results suggest a seasonal variation in fungal/(1→3)-ß-D-glucan exposure among workers collecting compostable waste. A seasonal variation in microbial exposure has also been found in sewage treatment plants.

Conclusions

The results suggest that ecological factors may influence the exposure among persons exposed to microbial components in organic dusts. Apart from the temperature, as evaluated in this study, humidity and wind could also be important in relation to exposure. It is important to take these factors into account when assessing exposure to organic dusts.

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Work related acute and chronic respiratory symptoms among sewage workers

A. Bener [(1)], M. Dogan [(2)], G. G. Lestringant [(3)], M. A. H. Pasha [(4)],

[(1)] *Dept. of Community Medicine,*
[(2)] *Dept. of Chemistry, Faculty of Science, Yildiz Technical University, Istanbul,*
[(3)] *Dept. of Medicine, Consultant Dermatologist,*
[(4)] *Dept. of Preventive Medicine, Faculty of Medicine and Health Sciences, UAE University, PO Box 17666, Al-Ain, United Arab Emirates*

Background

The United Arab Emirates (UAE), similar to other developing countries, has witnessed a rapid development in many aspects of life in the last two decades, [1]. There is subsequent increase in discharged liquid wastes and chemical wastes in the municipal sewers. Exposure to toxic gas and occupational respiratory illness are very well known hazard for sewer workers employed at the sewage system [2,3]. Recently studies reported that sanitation workers may develop acute and chronic respiratory symptoms and some defects in lung function [4,5]. However, there has been no clear strategy to prevent occupational illnesses due to potential risk factors in the work environment in the UAE community.

Objectives

To determine the prevalence of acute and chronic respiratory symptoms and lung function changes among sewage and manual workers in the UAE.

Design

This is a cross-sectional study matched for the age, sex, nationality, duration of employment and socio-economic status.

Subjects

The present study was based on 148 sewage and 144 manual workers (who are not engaged in sewage works). The choice of subjects was based on screening of all available sewage workers employed at the Al-Ain City Municipality, Sewage Department in the UAE. The manual worker group consisted of employees among non-sewage workers who were employed in the machine shops, assembly operations in machinery plants, or were manual laborers in different occupations other than sewage work.

Methods and respiratory symptoms

Chronic respiratory symptoms were recorded by using the British Medical Research Council [6] and other validated questionnaire on respiratory symptom [1] and a fairly comprehensive range of symptoms were included in the questionnaire.

Ventilatory Capacity

Spirometer testing was performed using a standard spirometer (Vitalograph-PFTII plus, Vitalograph Ltd., Buckingham, UK. At least three acceptable forced spirograms were recorded from each subject. Smokers were asked to refrain from smoking for at least one hour before measurement. Spirometric tests and data collections were performed according to the American Thoracic Society [7], and Cotes [8].

Statistical analysis

The significance of difference between two continuous variables was performed by t-test. The Mantel-Haenszel procedure was used to calculate the Relative Risk (RR) and their 95% confidence intervals (CI). The level $p<0.05$ was considered to be the cut-off value for significance.

Results

The mean age of 144 sewage workers was 34.4±7.6 years with their mean height and weight of 168.7±6.1 cm and 71.0±12.7 kg, respectively and the mean duration of their employment was 7.1± 5.2 years. The mean age of manual workers was 34.5±7.8 years with their mean height and weight of 170.1±5.9 cm and 72.1±10.7 kg, respectively and mean duration of employment was 7.4±6.1 years. The sewage workers had a slightly higher proportion (31.3%) of smokers than manual workers (30.3%). The data on chronic respiratory symptoms (Table 1) shows that sewage workers had a higher prevalence of symptoms than manual workers. These findings are consistent with other reported studies [1,4,5]. Furthermore, all forced spirometric tests in the exposed sewage workers tended to be lower than in manual workers (Table 2). These findings are consistent with other reported studies [1,3-5]. In the present study, most of the sewage workers complained of chronic and acute symptoms.

Conclusion

Long-term working in sewage treatment plants may be associated with the development of chronic respiratory symptoms and lung function impairment that may have adverse health consequences for sewage workers.

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Table 1. Prevalence of chronic respiratory and acute symptoms during work in sewage and manual Workers

Symptoms	Sewage Workers N= 144 (%)	Manual Workers N= 149 (%)	Relative Risk (RR) 95 % Confidence Interval (CI)	p-value
Chronic cough	27.8	22.8	1.38 (1.09 - 1.76)	P<0.02
Chronic phlegm	20.1	14.1	1.23 (0.93 – 1.61)	P<0.03
Chest tightness	24.3	9.4	1.60 (1.28 – 2.00)	p<0.002
Chronic bronchitis	27.1	15.4	1.38 (1.09 - 1.78)	p<0.02
Doctor diagnosis asthma	29.2	13.4	1.53 (1.23 - 1.92)	p<0.002
Allergic rhinitis	39.6	16.8	1.68 (1.35 – 2.09)	p<0.0001
Breathlessness	16.0	12.1	1.16 (0.86 - 1.57)	NS
Pneumonia	26.4	19.5	1.21 (0.94 - 1.55)	NS
Dyspneoa	29.2	12.8	1.57 (1.25 - 1.96)	p<0.001
Nasal catarrh	25.7	12.8	1.46 (1.15 - 1.84)	p<0.005
Sinusitis	17.4	11.4	1.23 (0.95 - 1.66)	NS
Throat irritation	16.0	13.4	1.10(0.81 – 1.50)	NS
Nose irritation	26.6	10.7	1.59 (1.27 - 1.98)	p<0.001
Eye irritation	29.2	20.8	1.24 (0.97 - 1.58)	NS
Skin pruritus	24.3	8.1	1.68 (1.35 -.2.09)	p<0.003
Tinea	25.7	14.1	1.80 (1.43 – 2.27)	p<0.004
Contact dermatitis	33.3	20.8	1.80 (1.46 – 2.22)	p<0.001

Table 2. Lung Function Test Measured Values in Sewage Workers and Manual Workers

Lung Function Tests	Sewage workers n=144		Manual workers n=149		t-test value	p-value
	Mean	SD	Mean	SD		
FVC	3.73	0.52	3.86	0.33	-2.67	p<0.009
FEV_1	3.30	0.79	3.52	0.52	-3.14	p<0.003
FEV_1 / FVC	84.5	1.07	85.9	0.46	-14.54	p<0.0001
FEF_{25-75}	4.01	1.51	4.37	1.34	-6.98	p<0.04
PEFR	548	30.3	564	20.1	-5.56	p<0.0001

Respiratory effects in waste handlers exposed to organic dust

Heldal KK [(1)], Eduard W [(1)], Straumfors A [(1)], Wouters I [(2)], Djupesland PG [(3)]

[1].*National Institute of Occupational Health, Oslo, e-mail: kari.heldal@stami.no.*
[2].*Institute of Risk Assessment Sciences, Division Environmental & Occupational Health, University of Utrecht,NL*
[3].*Department of Otorhinolaryngology, Ullevål Univeristy Hospital, Oslo*

Introduction

It has been reported that exposure to airborne organic dust in several working populations can cause respiratory health problems. So far, the health risk from exposure to bioaerosols in the waste industry is less is known, although ODTS, airway irritation and occupational asthma have been reported to occur in workers involved in household waste and compost handling (1-4). Different methods have been used to measure health effects and exposure in these relatively small studies, which make comparisons between studies difficult, and more information on exposure-response associations is needed. The objectives of this work are to examine irritation effects in the airways by use of nasal lavage, induced sputum, spirometry and acoustic rhinometry and to correlate these findings with exposure to different components of organic dust. Here we present the changes in lung function and nose congestion among waste collectors and compost workers.

Material and methods

The survey took place in summer periods of two consecutive years. In total 31 workers participated in the survey (participation rate 66%), 19 the first summer and 12 the second summer. Six worked at a compost facility for organic waste, 25 collected different fractions of household waste. The arithmetic mean age of the workers was 34 years (sd=11) and years of employment was 2 years (sd=2). 87% of the workers were current smokers, with an average consumption of 15 pack-years (sd=16).

The health study was performed at the local hospital. Each worker underwent lung function tests and acoustic rhinometry before work start on Monday morning and on the following Thursday morning. The forced vital capacity (FVC) and the forced expiratory volume in one second (FEV_1) were measured using a pneumotachograph (Vitalograph©,Birmingham, UK). Measurements of nasal airway dimensions were performed by acoustic rhinometry (Rhin2100, Rhino Metrics AS, Denmark). The total minimum cross-sectional area between 20 and 50 mm (TMCA) from the nostrils and total volume between 20-50 mm were measured ($TVOL_{2\text{-}5mm}$). Mucosal swelling was estimated from the decongestive effect after application of a nasal decongestant (oxymetazoline hydrochloride) (5). The decongestion factor was calculated as the ratio of $TVOL_{2\text{-}5mm}$ before and after application, and $TVOL_{2\text{-}5mm}$ before.

Personal exposure was monitored during work on Monday, Tuesday and Wednesday. Inhalable aerosols were collected with two PAS-6 cassettes (sampling flow rate 2.0 l/min), one monitor loaded with a glass fibre filter for determination of endotoxins and glucans, and the other with a polycarbonate filter for determination of microorganisms and mass. Sampling time was full shift, ranging from 4 to six hours. Each day after work, the participants completed a self-administered questionnaire on work related symptoms of that day. Number of rod-shaped and spherical bacteria were determined by acridine orange staining and subsequent fluorescence microscopy (FM) (6) and fungal and bacterial spores (actinomycetes) were counted with a scanning electron microscope (SEM)(7). Biologically active endotoxins were analysed by the quantitative kinetic chromogenic LAL assay (8) and β(1→3)-glucans by inhibition enzyme-immunoassay (EIA)(9).

Results

Preliminary data are presented here. The exposure levels to microbial agents are shown in the table.

Exposure level of microbial components (n=88)

	median	range	aritmetic mean
bacteria ($10^6/m^3$)	0.95	0-7.3	1.5
rod-shaped ($10^6/m^3$)	0.01	0-0.2	0.02
spherical ($10^6/m^3$)	0.61	0-6.2	1.1
actinomycetes ($10^6/m^3$)	0	0-5.2	0.2
fungal spores ($10^6/m^3$)	0.17	0-8.1	0.5
dust	0.41	0.1-12.2	0.7
endotoxins (EU/ m^3)	12.1	<1.3*-140	20
β(1-3)-glucan (μg/ m^3)	<3.0*	<3.0-10.5	-

*Below detection limit for airborne endotoxin (1.3 EU/m^3) and β(1-3)-glucan (3.0 μg/ m^3)

The symptoms headache and unusual tiredness (26 and 29%), cough with and without phlegm (19%), breathlessness (19%) and nose irritation (16%) were reported among the workers. Prevalence of any respiratory or work related symptoms were 48% and 61% respectively. The results of the lung function tests showed a significant decline in FEV_1 from Monday to Thursday of 0.11 L (range –0.65; +0.15) or 2.4 % of FEV_1 predicted ($p<0.01$) (Gulsvik, 1979). The volume in the nose ($TVOL_{2-5mm}$) decreased significantly from Monday to Thursday (n=12, median -1.0 cm^3 , range –2.9; +1.2, $p<0.05$). The cross sectional area decreased from Monday to Thursday (median –0.12 cm^2, range –0.49; +0.13), but the change was not significant. The median decongestion factor was 65% (range 33-153%).

Discussion

The exposure levels of bacteria, dust and endotoxins during collection and composting found in this study are moderate, and do not differ from earlier studies (10, 4, 2). Only 7% of the samples exceeded the proposed threshold level for endotoxin of 50 EU/m^3. Higher exposure levels of endotoxins have been found during composting (75-500 EU/m3) (3). A decrease in lung function of 2,4% (FEV_1 % of predicted) from Monday to Thursday was also found in this study. This is in agreement with Sigsgaard (1994) who found a cross-shift decrease of 1.2% among waste collectors, which was associated with relatively low inhalable dust and endotoxin exposure to (0.8 mg/ m^3 , 25 EU/m^3). The prevalences of breathlessness, nose irritation and cough in Sigsgaard's study was at the same level as in the present study.

Significant nose congestion from Monday to Thursday was observed in this study, and the decongestion factor of 65% was found. A mean decongestion factor of 20% is reported in normal subjects (5). A mucosal swelling among tunnel workers, and a decongestion factor of 69% was found among tunnel workers, highly exposed to dust and NOx gases (11). This is contrary to findings in a study, where five garbage workers with occupational airway symptoms were intranasally challenged with endotoxin, glucans (curdlan), *A. fumigatus* and compost (12).

The total nose volume, measured from 0 to 50 mm from the nostril, increased with a maximum 4-6 hours after the exposure.

Further association between respiratory effects and exposure will be studied and presented at the conference.

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Exposure to radiofrequency fields and mobile telephony

Bergqvist U

University of Linköping, IKP/IAV, SE-581 83 Linköping, Sweden, e-mail: ulber@ikp.liu.se

Aim of the presentation

The topic of this presentation is the evaluation of measurement strategies and exposure to radiofrequency fields due to mobile telephone technology. The usefulness of such data for different purposes such as evaluating compliance with exposure limits and provide data for epidemiological research, will be commented on. Both occupational and general public exposure situations are considered.

Background description

The radiofrequency part of the electromagnetic spectrum

The radiofrequency part of the electromagnetic spectrum has traditionally included fields with frequencies from a few hundred Hz to 300 GHz. The presentation here will be somewhat more limited, covering the frequency range from about 30 MHz to a few GHz. Within this frequency range, a large number of different technical applications are used, that may intentionally or unintentionally cause emissions of electromagnetic fields. Such emissions are strictly controlled, and will, in most cases, require a license. Within this range, a large part is devoted to radio and TV broadcasts and other wireless communication systems, including different mobile telephony operations. Some bands within this range are, however, free in the sense that no license is needed, and here, various industrial, scientific and medical applications are used (the so-called ISM bands). Overall, there are tendencies for use of more broadband sources as well as increased use of frequencies in the GHz frequency range.

Measurements have been performed showing the total general public exposure from all sources within this (or parts of this) frequency range. Other measurements have also been performed that describe the spectral distribution of this exposure, enabling the contribution of various sources to be identified. The GSM systems operate at about 900 MHz (GSM900) or about 1800 MHz (GSM1800). As expected, mobile telephony sources do contribute – together with a number of other sources – to the overall exposure (see further below).

The decision to employ broadband or the more time-consuming spectral distribution measurements should be determined by the actual circumstances. In locations where one source with a single narrow frequency band dominates the exposure to the extent that other sources and the background can be neglected, then the more simple approach can be used. This may sometimes occur in occupational settings, e.g. in the close vicinity of plastic heaters or broadcast antennas, where the frequency may be obtained from equipment specifications etc. Apart from such special circumstances, it would normally be preferable to obtain frequency-specific information, since this would be required for source identification, is required for compliance evaluation of thermal effects (see next section), and may be valuable for research into non-thermal effects as well.

Exposure limits

Several organisations have issued recommendations on the limitation of electromagnetic field exposure to humans, prominent among them the International Commission on Non-Ionizing Radiation Protection (ICNIRP). In the radiofrequency range, current recommendations are intended to protect against thermal influences of the exposure, as health effects due to non-thermal loads have at present not been verified. For this purpose, ICNIRP (and others) have formulated basic restrictions expressed in dosimetric quantities. Based on general considerations, different limits are recommended for occupational and general public exposure (1).

Between 100 kHz and 10 GHz, the basic restrictions are expressed in specific absorption rate (SAR), and are 0.4 W/kg for occupational and 0.08 W/kg for general public exposure. In addition, restrictions have also been issued for localised exposure, important in case of non-homogenous exposure (e.g. for a source located very close to the body). The limits for head exposure are 10 W/kg and 2 W/kg for occupational and general public exposure, respectively, a condition that should be met at every 10 g mass (1).

Reference levels that ensure compliance with basic restrictions under worst case conditions have also been issued. For 0.9 GHz (a common GSM frequency) the reference levels are 22 and 4.5 W/m^2, respectively for occupational and general public exposure. For higher frequencies, limits are somewhat higher (a factor of 2 higher for 1800 MHz). It should be noted, however, that if reference levels are exceeded, it is not obvious that the basic restrictions are exceeded, this must be ascertained by a situation-specific evaluation (1).

According to ICNIRP (1), contributions to exposure at different frequencies between 100 kHz and 300 GHz should be weighted according to their biological potency and added, according to the formula:

$$\Sigma_i \exp(f_i)/\text{limit}(f_i) \leq 1 \quad \text{(equation 1)}$$

where $\exp(f_i)$ is the exposure at a given frequency, and $\text{limit}(f_i)$ is the corresponding exposure limit at that frequency. Accordingly, it is in principle not correct to use the exposure limits to derive corresponding emission limits, as this may result in exposure exceeding the limits if two or more sources are placed in the same environment. In occupational environment, this could be handled by providing information on the actual emission level to the person responsible for the work environment, who could then add the different contributions at worker's locations according to equation 1. In the general environment, there is, however, no such direct responsibility. On the other hand, the number of situations where several radiofrequency sources would combine to exceed the exposure limits is probably very limited. (One example could be the use of a mobile phone with bad connection in the immediate vicinity of a major radio or TV broadcast station.)

Mobile telephone systems

A mobile telephony system consists of a large number of cells, where each cell is covered by a base station, with which mobile phones within the cell can be in contact. Emissions are mainly due to the base station link to the phone (downlink) and the phone link to the base station (uplink). The base station antenna and the phone should be considered separately, as the emission characteristics, distances involved etc. are quite different. (The description here is limited to digital GSM phone systems, as these are dominating in most countries.)

There is also a microwave link from the base station to other parts of the telephone system operating at some tens of GHz. Compared to the downlink emission, this emission is negligible for two reasons; a/ the need for line of sight path in order not to disturb the transmission suggests that this link is not positioned where humans could interfere (block the signal) and b/ the very low power due to the line of sight and very narrow beam used.

The signal from the phone to the base station is sent in pulses, with a maximum peak of e.g. 2 W (for GSM 900 systems). The average power across pulses will be 1/8 of this, i.e. 0.25 W. For GSM 1800 systems, the figures are 1 W and 0.125 W, respectively. This maximum power is, however, often reduced due to either downregulation of the power or to DTX. The former is a reduction in transmission power to that required for adequate contact with the base station, while the latter is a reduction in transmission that occurs when the phone user is listening and not talking. Both are at least partly motivated to save battery power. When no call is going on, the phone transmits a signal only infrequently to inform the system about its localisation. No signal is sent when the phone is off.

Measurements performed by Swedish Telia Mobile in Stockholm during a 24 hour period indicate that the effect from GSM phones vary due to downregulation between 0.05% and 100% of the maximum, with a median effect of all registrations of 5%, and a mean effect of 35% of the maximum (2). (A measure of the median of all individual user's mean effect could not be obtained from these data, but should fall between the median and mean value given above.)

In contrast, one channel of the base station is in principle always active, i.e. it transmits all the time, and is sending continuously, not in pulses. This channel is also not downregulated, since the phones require this constant signal in order to determine receiving conditions. If more than one channel is used, then the other traffic channels have a varied transmission power depending on traffic. Accordingly, the effect emitted from a three-channel antenna could vary from e.g. 10 W to 30 W. Statistically, such maximum transmission occurs only infrequently, data from Telia Mobile suggest that this occurs typically 20 – 40 seconds/day, since full use of the system would impact on availability of service (2).

In urban areas, base stations may occur within a few hundred meters or less, and are often of sector type, i.e. they transmit only in a given sector (in the horizontal plane) of e.g. 120^o. In less populated areas, with base stations being some kilometres apart, they are more often omnidirectional, meaning that they transmit in all directions (horizontally). The antennas normally have a rather narrow vertical radiation pattern, such that the beam width (to half power) could be some $6\text{-}10^o$, and with a slight downward tilt of perhaps 2^o.

Some measurement strategies

Considerations of the distance to the source

The physical characteristics of the radiofrequency radiation are very different in the near vicinity of the source and at further distances, which will have a major influence on the methods to be used for exposure assessment.

At a sufficiently large distance from the source, in the so-called far-field region, the electric and magnetic field components are closely related, and it is sufficient to evaluate only one of them. This region can be expected at a distance larger than $2D^2/\lambda$, where D is the largest dimension of the antenna, and λ is the wavelength. Accordingly, such a situation would be found more than about 10 cm from a mobile phone, more than about 1 m from a small base station antenna (e.g. of size D=0.4 m), and more than some 20-40 m from a large base station antenna (e.g. of size D=1.8 m).

As this situation can be described as radiating, it is frequently found useful to characterise the exposure in terms of the incident power density in W/m^2. Since the electric and magnetic fields have a simple relationship, then the power density can be calculated based only on measurements of the electric field, according to the following formulae:

$$H = E/377, \quad P = E \cdot H, \quad \Rightarrow \; P = E^2/377 \quad \text{(equation 2)}$$

where H is the magnetic field in A/m, E is the electric field in V/m and P is the power density in W/m^2. The constant 377 has the dimension Ω.

In this far field region, the source can often be approximated as a point, suggesting that the power density will decrease as $1/r^2$. A complication for using a simple $1/r^2$ relation is that the emission from the base station antenna is not isotropic; i.e. it is stronger in some directions than others (as described above). At ground level around a base station antenna placed at some height (e.g. 15 m), the maximum exposure would occur at a distance of e.g. 100-200 m where the main beam reaches the ground. At ground levels, the $1/r^2$ relation would thus be valid only at such distances.

In practice, the $1/r^2$ relation is also not valid at large distances where objects such as houses, trees or hills will interfere with the line of sight. A decrease of power density with distance as $1/r^{3.5}$ has been found to be useful for e.g. base station power calculation (3).

Closer to the source, in the so-called near field, the relationships between the electric and the magnetic fields are much more complex, and separate evaluation of them must be performed. At distances larger than $\lambda/2\pi$ (6 cm at 900 MHz, 3 cm at 1800 MHz), the fields are still considered to be radiating, and external field levels would be relevant to determine exposure. Calculations by the NRPB has indicated that using the far-field approximation at e.g. 1 m from a large base station antenna would overestimate the exposure by some 10-20 times (4).

Very close to the source, there is a dynamic energy interaction between the source and the human body. As a consequence, the external field strengths are not good indicators of the actual exposure, and other methods of evaluations must be used. For mobile telephony situations at 900 MHz or 1800 MHz, such close distances occur below some 6 or 3 cm, respectively.

This would lead to the following strategy:

- When a mobile phone is held at or close to the head (< 10 cm), the exposure is best characterised by the localised specific absorption rate in W/kg. This can be derived from either computations based on Maxwell's equations or measurements with a so-called phantom (a shell containing a liquid with electrical properties similar to that of the human head, where internal electric fields can be measured and converted to SAR). Currently, compliance is mainly tested by phantom measurements. The results are directly usable for evaluation of compliance with the basic restrictions. Such methods could also be used to evaluate compliance with basic restrictions in cases where the reference levels are found to be exceeded, as may be the case very close to a base station antenna in the direction of the main beam.
- At short distances from a base station antenna (exceeding some 10 cm but < 1 m from a small antenna, and < 10 m from a large antenna), the electric and the magnetic fields should – in principle – both be measured. (In practise, the electric field often appears to be the more crucial parameter for compliance.)
- For all situations where the distance to a mobile phone exceeds some 10 cm, or where the distance to a small base station antenna exceeds about 1 m, or where the distance to a large base station antenna exceeds about 10 m, it is sufficient to measure the electric field, and use that to compute the power density.

In practise, this last condition is usually appropriate for determining the exposure to the general public (except where a person is holding a mobile phone to the ear). Evaluating the variation of ground level exposure over distance by using the $1/r^2$ relation appears, however, to be of limited use, it may in many situations result in fairly large overestimation of exposure.

Different causes of variations in exposure

Measurements of the fields from mobile telephony components are subject to several sources of variation, which together make detailed comparisons between measurements, compliance testing and usefulness for epidemiology uncertain. These variations may be due to

- measurement uncertainties depending on the measurement system,
- spatial variation of exposure, both on a small scale (precise position of phone at the

head), median (within a meter) and a large scale (10-100 m or more), and

- temporal variation of exposure, both in short (ms – seconds), in intermediate (hrs – days) as well as long terms (years).

While the first may limit the ability to accurately describe the exposure at a specific location and time, the latter two would limit the representativeness of the data, and thus the generalisation of site/time-specific data.

Measurement uncertainty can be substantial. In the NRPB evaluation (4), it was estimated that a measurement in the 300 – 1000 MHz region could be off by a factor of 3 in either direction, with slightly better performance at higher frequencies. A detailed description of the measurement methods, and their ability to accurately represent the actual SAR or field levels at a point in time and space is beyond the scope of this presentation. The reader's are referred to other texts for this purpose, such as the forth-coming CENELEC standards to be issued on mobile telephone and base station measurements. Here, other sources of variations will be discussed in some details.

For the situation with a person holding a mobile phone close to one ear, a number of different sources of variation have been identified (5). The largest sources of variation are a/ power level and effect of downregulation (reduction up to 1000 times for e.g. GSM1800 depending on location), b/ user positioning of the phone at the face (variation of about a factor of 10), and c/ the phone model (variation of about a factor of 20). Minor influences may also occur due to antenna extension/retraction (a factor of 5) and anatomical variation (a factor of 2).

There is also a large variation in the anatomical location of the exposure inside the head, depending e.g. on which side of the head the phone is held. For a phone held horizontally at the left ear, calculations on a 900 MHz phone have indicated the following relative distribution of SAR values (normalised to 1000 at the left ear, maximum level found at each site) (6): Left parotid 171, left tear duct 25, left submaxillary 31, meninges 257, brain 123, pineal 4, right parotid 6, right tear duct 5, right submaxillary 2, right ear 7. For 1800 MHz, the decrease from left to right side were generally larger, reflecting the reduced penetration of the higher frequency.

In addition to these variations affecting the exposure or dose at a given point in time, there are obvious temporal variations. In the short time perspective, changes in downregulation may occur during a call, with parts of the call made at maximum level, while the substantial part will (if transmission conditions are good) occur at a much lower level. The number of calls and the duration of calls are obvious parameters for intermediate range variations (hrs, days), while changes in phone models, technology and overall usage makes it difficult to ascertain exposure over long time periods.

For exposure due to base station emissions, there are, again, both spatial and temporal sources of variation. Occupational exposure for service personnel should be evaluated in terms of distance to the antenna in the main beam, antenna power and gain etc. For general public exposure, there are two different reasons for measurements, which may affect the site selection; that of measurements in the vicinity of a base station, and measurements at random locations in a geographical area. Other parameters of site selection that appear to be important for the recorded level are outdoor vs. indoor locations, ground level vs. roof/terrace level, and urban/rural environment.

Short/median temporal variations are largely due to traffic volumes. Measurements performed around a base station in Gothenburg (7) during a 24 h period suggested that while the first traffic channel was always on, the 2nd channel transmitted at more than half its nominal power of 10 W for about 10 hours, mainly between 14^{00} and 23^{00}. Given that one channel would always transmit, this results in a rather modest variation in power (and emission) levels (range 10-20 W, median 14 W).

The long time variation is more difficult to ascertain, as this would depend on trends in power output, localisation, number of cells, number of channels and operators etc. It can be safely assumed that this has increased over the years, but there appear to be no common understanding to what extent the total exposure to radiofrequency fields at these or adjoining frequencies have been influenced by the development of mobile telephony. Measurements made in Gothenburg and other locations in Sweden suggest that currently (1999), about half of the public's total exposure in the 30 MHz to 2 GHz range would be due to GSM900 base station emission, the other dominant source being TV broadcasts (7).

Exposure levels and evaluation

Exposure from mobile phones at close vicinity

As already indicated, data on exposure to mobile phone emissions during use (at the ear) are obtained by SAR measurements in laboratories. Such measurements are performed under worst case conditions consistent with normal usage, thus neglecting the impact of downregulations etc. By design, 2nd generation phones (GSM) cause SAR levels below 2 W/kg when averaged over 10 g tissue, but with a considerable variation between phone models. The worst case SAR measured for different GSM models appears to lie between 0.1 and 2 W/kg (5). For older analog phones such as NMT900, a more narrow range has been found to be between 1 and 2 W/kg. With the standardisation of measurement methods, SAR levels for specific phones are to be made public.

The maximum SAR in a small volume (1 cm^3) has been computed as 8.7 W/kg for each W emitted (6). Thus, a GSM900 phone with 0.25 W mean power would cause a SAR in such small local volume of 2.2 W/kg at the ear closest to the phone. The corresponding maximum levels at the meninges would be 0.6 W/kg, at the brain 0.3 W/kg and at the parotid gland 0.4 W/kg, with lower exposure levels in other organs and sites. This exposure has been calculated as causing a temperature increase of less than 0.1 ^{o}C.

Using the data obtained by Telia Mobile (2) on actual levels of downregulation and assuming DTX operation, the mean exposure caused by a worst telephone would be between 0.035 and 0.35 W/kg at the worst anatomical location, and less at other locations. To exemplify the influences of various factors on the maximum brain exposure: A nominal 2 W/kg phone (worst phone) would cause an exposure to the brain (at worst location) of 0.05 W/kg (mean, range 0.0003 to 0.3 W/kg), taking into account the effect of anatomical localisation, downregulation and use of DTX. A phone of nominal 0.2 W/kg phone would cause a brain localisation of a tenth of those numbers. Exposure to other parts of the brain region than the highest exposed point would be less, the mean value of 0.05 W/kg would e.g. be reduced to about 0.002 W/kg in the centrally placed pineal gland.

Exposure from mobile telephony components at a distance

A series of measurements were performed in city, small town and rural locations in Sweden in 1999, where the total exposure to radiofrequency fields in the range 30 MHz to 2 GHz was evaluated, and spectral analysis did also permit the identification of various specific sources (7). Sites were generally chosen at random at places were the general public had access. If outdoors, these sites were at ground levels. The results are summarised in table 1.

Table 1. Measured exposure levels in different environment (data from 7).

Location	No of mea-surements	Maximum level mW/m^2	Median level mW/m^2	Contribution from GSM900
City area [1)]	n=8	3.0	0.5	61%
Town area [1)]	n=3	0.05	0.03	54%
Rural area [1)]	n=5	0.006	0.0006	39%
Indoor, residen-tial premises	n=4	0.012	0.005	41%

[1)] Outdoor, ground levels.

Data from NRPB on outdoor and indoor measured levels at 73 locations in the vicinity of 18 base stations have also been presented (4). These locations were chosen by request, and do thus probably represent areas in the vicinity of a particular base station. The geometric mean of all radiofrequency signals between 30 MHz and 2.9 GHz were 0.24 (0.05-1.7) mW/m^2 for outdoor location, and 0.08 (0.002-1.0) mW/m^2 for indoor locations. Due to the large variation in emitted levels from both base station and other sources, it was not possible to discern any statistically significant difference in exposure between areas near and areas not near base stations (4).

For occupational exposure, NRPB (and others) have calculated the variation in exposure at different distances from a typical base station (4), using both simple $1/r^2$ assumptions and more sophisticated calculations adopted to near-field radiative conditions. For a GSM900 sector antenna of 20W and 17 dB gain, the exposure in the main lobe was found to be 0.6 W/m^2 at 10 m distance, increasing to 3.5 W/m^2 at 1 m distance and 6.5 W/m^2 at 0.5 m distance. For a 60W GSM1800 base station, the levels were 2.7 W/m^2 at 10 m distance, 36 W/m^2 at 1 m distance and 53 W/m^2 at 0.5 m distance. For a base station antenna with lower power, the levels will be reduced accordingly. In the NRPB study, the power of the GSM900 base station antennas varied between 1 and 19 W, while GSM1800 base station antennas varied between 0.9 and 63 W. In cases of both GSM900 and GSM1800 from the same base station antenna, the exposures should be added, leading to higher levels.

Usefulness of these data for compliance testing

Test of compliance should be made in a worst case situation, and with a current situation. Because of this, most problems due to both spatial and temporal variations that have been described above are – in principle – eliminated. A few general points should be mentioned, though:

- The worst case situation must be identified. One current discussion is whether children could have increased SAR levels in a specific situation due to anatomical differences with adults, or due to a higher conductivity of brain tissues. The upcoming CENELEC standards should have taken this into account.
- The problem of how to handle multiple sources is not yet resolved. One possibility is to reduce product (emission) standards, another to solve this by administrative ways, requiring judgements in each particular situation.
- Finally, it is not clear how to handle measurement uncertainty.

Despite these caveats, it appears that the data now available, and the standards being developed, should be adequate to handle compliance issues due to mobile telephony systems.

For mobile phones, it is a general assumption that no distinction is made between occupational and general public use, and that the lower general public basic restriction of 2 W/kg (or 1.6 W/kg according to IEEE) should be applied. The forthcoming CENELEC measurement standard is expected to enable tests ensuring that mobile phones in worst case are below the basic restrictions. As suggested above, the actual exposure will in many cases be substantially less.

For occupational exposure to base station antenna emissions, knowledge about antenna characteristics enables compliance testing in terms of closest distance ("exclusion zones"). In the NRPB calculations, the ICNIRP occupational reference levels were exceeded for an 80 W base station (worst case) at about 60 cm (900 MHz) and 1 m (1800 MHz). A short paper reported at the BEMS conference in June 2000 by Cooper et al suggested that the basic restriction might be exceeded only at some 6 cm (for a 40 W antenna).

For sites further away where the general public has access, compliance of base station antenna does not appear to be an issue. Levels found by various investigations have generally found levels to be below 1% of the ICNIRP reference levels. In the Swedish data presented here (7), the highest exposure from all sources combined was some 0.07% of the ICNIRP general public reference level.

Usefulness of these data for epidemiological research

Using mobile telephony exposure data for epidemiological research appears much more complicated. This is partly due to the large variations encountered, both spatially and temporally, and partly due to the fact that the dose is not defined for non-thermal issues (which presumably are the object of such research). As an important example, it is unclear if and how exposure can be accumulated, or whether the relevant measure should be the possibility of high exposure peaks.

Evaluations made for the international case-control cancer study presently conducted under the auspices of IARC suggest that while analysis of mobile phone use and cancer risk is feasible, it is unclear whether analysis could specifically address the radiofrequency field exposure from phones (8). Nevertheless, efforts are under way to develop a "dosimeter phone" (5). For other issues with a shorter latency time, the current development of dosimeter phones may also be valuable, and some of the problems of obtaining historical data may be less crucial.

Epidemiological studies on base station related exposure appear even more problematic. The NRPB finding given above that vicinity to a base station is not a good predictor of exposure is understandable due both to the presence of other sources (radio and TV broadcasts) and to the absence of clear relationships between distance and exposure at the ground level. In addition, the continuous proliferation of base station antenna does suggest that there may be little exposure contrast to be found in many areas.

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