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On the Identification and Prevention of Ergonomic Risk Factors

With Special Regard to Reported Occupational Injuries of the Musculo-skeletal System

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To all who take personal
or professional interest
in ergonomics

Original papers

The thesis is based on the following papers, in the text referred to as Study or Paper and Roman numerals, I-VII:

I. Kemmlert K. A method assigned for the identification of ergonomic hazards - PLIBEL. *Appl Ergon* 1995; 26: 199-211. Best Paper Award 1995. Reprinted with kind permisson.

II. Waters TR, Kemmlert K, Baron SL. Measurement issues and reliability-tests of measurements for the revised NIOSH Lifting Equation. Submitted.

III. Kemmlert, K, Lundholm, L. Slips, trips and falls in different work groups with reference to age. Submitted.

IV. Kemmlert, K, Lundholm, L. Factors influencing ergonomic conditions and employment rate after an occupational musculo-skeletal injury. *J Occup Rehab* 1994; 4: 11-20. Reprinted with kind permission.

V. Kemmlert K. Preventive effects of workplace investigations in connection with musculo-skeletal occupational injuries. *Scand J Rehab Med* 1994; 26: 21-26. Reprinted with kind permission.

VI. Kemmlert K. Economic impact of ergonomic intervention - Four case studies. *J Occup Rehab* 1996; 6: 17-32. Reprinted with kind permission.

VII. Kemmlert K, Örelius-Dallner M, Kilbom Å, Gamberale F. A three-year follow-up of 195 reported occupational over-exertion injuries. *Scand J Rehab Med* 1993; 25: 16-24. Reprinted with kind permission.

Studies, IV-VII, were approved by the local Ethics Committee. Study II was performed in the USA.

Definitions and abbreviations

Definitions

active employment	being employed and not being on sick-leave, not pensioned or unemployed.
co-workers	workers performing the same tasks as the injured worker at the time of the injury.
Lifting Index	the ratio of the recommended weight limit to the actual weight of an object being lifted.
occupational factor	one factor at work sufficient to cause a disease.
occupational musculo-skeletal injuries	work related musculo-skeletal accidents and work related musculo-skeletal diseases.
occupational musculo-skeletal accident	musculo-skeletal injury with a sudden onset and with a distinct relation to a certain work task.
occupational musculo-skeletal disease	work related musculo-skeletal injury other than accident.
reduced physical work load	physical or organisational measures resulting in an elimination or considerable reduction of the harmful situation described in the injury report and at interviews.
prevention	Primary prevention; prevention of the occurrence of a disease. Secondary prevention; prevention of the development of a disease. Tertiary prevention; prevention of the progression of established disease or disability by appropriate treatment.
sick-leave with social cost, 1988	direct wages paid by the social insurance system and social costs, (47.9%) paid by the employer.
surveillance	systematic ongoing collection and analysis of work place information, performed for the purpose of prevention.

work related factor	a factor at work among several factors (although not necessarily a sufficient factor) that causes provokes or aggravates a latent disorder.

Abbreviations

ADL	activities of daily living
AET	Das Arbeitswissenschaftliche Erhebungsverfahren zur Tätigkeitsanalyse
CI	confidence interval
EPS	Ergonomic Protection Standard
IN	inspection notice
ISA	Swedish information system on occupational injury statistics
LE	lifting equation
LI	labour inspection
NBOSH	National Board of Occupational Safety and Health
NIOSH	National Institute for Occupational Safety and Health
NSIB	National Social Insurance Board
NYK	Nordic occupational classification scheme (Nordisk Yrkes Klassifiering)
OA	occupational accident
OD	occupational disease
OE	overexertion
OR	odds ratio
PLIBEL	Method for the identification of musculo-skeletal stress factors which may have injurious effects (Plan för identifiering av belastningsfaktorer som kan innebära skadlig inverkan)
RR STF	relative risks for STF accidents among older (≥ 45 years) people as compared to younger (< 45 years)
R STF	rates of STF accidents per 1 000 employed
RWL	recommended weight limit
STF	slip, trip and fall

Contents

Introduction

Background

Scope of the thesis

Work related musculo-skeletal injuries are a common health problem through out the world and a major cause of disability (11, 21, 13, 57, 43, 44). However, the full extent of the problem is not known. Conditions at work are difficult to assess and relate to the measure of disease. Diagnostic criteria differ and the definitions are not unanimous (49, 68, 44). These factors imply major problems in the design and interpretation of epidemiologic research.

Such research is essential to understand the associations between diseases and their determinants. Epidemiologic studies can also be of use in risk assessment and planning and evaluation of the efficacy of treatment and intervention (49).

In several countries there are national registers of workers' compensation records or data from surveys of specific groups regarding occupational health (12, 13, 123, 49). However, reporting customs and compensation rules differ between nations and also over time and estimations and comparisons must be performed with great caution. It can be assumed that the frequency of symptoms among employees is far more elevated than the figures in compensation statistics (13, 44, 58).

Due to the multifactorial origin of most musculo-skeletal disorders, where conditions at work can be one of several factors causing or aggravating symptoms, a use of the attribute '*work related*'[1] has been suggested (49, 68, 51, 44). As defined by Hagberg et al (44), the expression 'work related musculo-skeletal disorders' excludes musculo-skeletal accidents.

In the present thesis, which includes both accidents and diseases, the term '*occupational*' is used, while recognising the slightly improper use.

There is no clear, unequivocal line of demarcation between musculo-skeletal accidents and diseases. Specialist researchers in the area are of the view that musculo-skeletal injuries usually develop over a lengthy period of time and it can even be the case that repeated minor accidents, in the long term, lead to disease (49, 43) (Figure I). For this reason, the present thesis applies to both *occupational musculo-skeletal accidents* and *occupational musculo-skeletal diseases* under the joint term *occupational musculo-skeletal injuries*.

At the *Swedish occupational injury information system*, ISA, an injury with a sudden onset and with a distinct relation to a certain task is coded as an *occupational accident*, OA, whereas all other injuries are coded as *occupational diseases*, OD.

[1] For expressions, marked at first occurrence, see Definitions and Abbreviations.

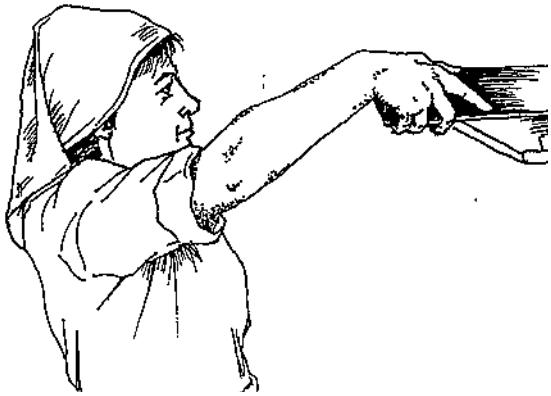
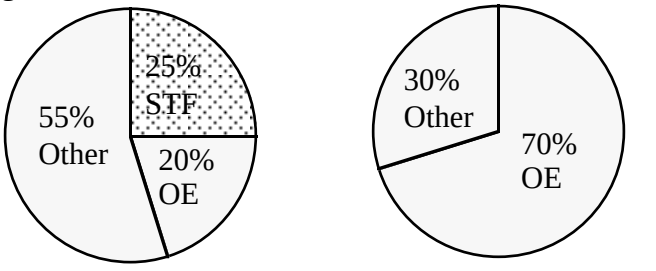


Figure I. Musculo-skeletal injuries usually develop over a lengthy period of time. Repeated minor overexertion can lead to diseases. Illustration K. Kemmlert/ B. Näsström.

According to ISA, the reported accidents and diseases have decreased since the Work Injury Insurance Act was tightened up from 1 January 1993 (13). In 1994 a total of 37 000 occupational accidents and 17 000 diseases were received and coded at ISA. Recent ISA statistics report that for 1994 the most frequently reported occupational injuries were attributed to ergonomic factors. They are called *overexertion*, OE, injuries. The most common occupational accidents were *slip, trip and fall*, STF, accidents (13) (Figure II).

STF accidents as a part of a broader ergonomics perspective. The interaction between STF and OE accidents is well known (9, 84). As an example it was established that every third OE accident had a slip or at trip as a contributing factor (9). Also the similarity in structures most commonly injured, i. e., the musculo-skeletal system is evident. Hence, STF accidents deserve to be included in the broader perspective of ergonomics.



a. Occupational accidents (n=38 994)

b. Occupational diseases (n=17 475)

Figure II. a. Reported occupational accidents 1994 due to *overexertion*, OE, *slip, trip and fall*, STF, and other factors (moving machinery or vehicles, handling of objects, human beings or animals, electrical/chemical exposure or explosion). Commuting accidents are not included. b. Reported occupational diseases 1994 due to overexertion and other factors (chemical substances or products, social or o rganisational factors, noise, vibration, physical factors or contagion) (13).

Occupational musculo-skeletal injuries have been internationally in focus for more than a decade and during that period several epidemiological studies have been presented where ergonomic hazards have been identified and described (13, 101, 124, 102, 41, 106, 68, 40, 117, 42, 120).

The contributing factors for STF accidents have, however, been very sparsely studied, which has been argued to make the direction of any *prevention* unclear (9, 78, 80, 81, 79).

Recently several articles on occupational accidents were published, where the age-related variation between accident types was recommended for research attention (82, 78, 80, 81, 79). To better understand the routes for a more efficient prevention of STF accidents the following question is essential:

* Which are the most critical contributing factors for STF accidents and which are the most urgent preventative measures to be taken at work places with reference to gender and age?

Economic aspects

Occupational musculo-skeletal injuries carry great costs to our society and its companies, as well as to the individuals themselves (10, 118, 3, 115, 39, 99, 48, 25, 15, 77).

The economic impact from occupational musculo-skeletal injuries can be obtained from Swedish statistics implying that such an injury on average induces thirty-three days of sick-leave for accidents and sixtio-five days for diseases. One out of two disability pensions is due to musculo-skeletal disorders (116, 13).

The enormous costs of STF accidents, measured in terms of individual pain and suffering and in losses to organisations, were recently highlighted in a paper by the major carrier of worker's compensation insurance in the the USA (84).

Internationally, investigations of costs and benefits have advocated an increased understanding of the efficiency of different rehabilitation strategies (36, 38).

In a previous study, preliminary calculations were reported of the company costs on reduction of physical workload after reported occupational injuries (60). From this experience a more detailed cost benefit analysis was regarded relevant to answer the following question:

* Is the reduction of physical workload after a reported occupational musculo-skeletal injury, cost effective from the company perspective?

Prevention

Due to the relative importance of OE and of STF among reported injuries, studies with a view to prevention seem reasonable. It has been stressed that prevention is unfeasible without knowledge of the causes of the health problems that should be prevented (49, 46, 33). By occupational epidemiology the relation between determinants and injuries can be studied (49).

During recent years syntheses of occupational factors, considered to cause or aggravate work related disorders and injuries have been published, of which a 421 pagelong book, carries the significant subtitle "A reference book for prevention" (67, 49, 68, 132, 117, 44). Silverstein, one of the authors of the mentioned book on

prevention, argues: "We have enough information to act now to reduce hazardous exposures" (111).

Reporting systems for work related injuries as sources of knowledge has already been exemplified by ISA. This form of descriptive epidemiology can provide "group diagnoses" of work places or occupational groups, identify work related health problems and monitor the effects of changes in work conditions (49).

Another example comes from the preparation for the US *Ergonomic Protection Standard*, EPS, where national data sources of workers compensation records were used to estimate the rate of work related musculo-skeletal disorders among US workers (122, 111).

Prevention through NBOSH and LI, the labour inspection. In Sweden several registers of different natures are in existence. Two of these databases are under the authority of the Swedish National Board of Occupational Safety and Health, NBOSH. They serve as sources of information for preventive activities.

A special use of register data is applied at the regional Labour Inspectorates, where Labour Inspectors are connected to ISA by personal computers, from where they can retrieve data on reported injuries distributed by company or branch, focusing on certain injuries, accident types or machinery involved in the injury (30).

Moreover, in the three-year plan of NBOSH activities, 1997-99, several of the goals were supported by recent statistics (123). The ergonomic goals concern a decrease in monotonous, repetitive work, cumbersome work postures, manual handling of objects, negative stress and the use of ladders (100). A complementary letter, referring to the underlying statistics documentation (123), explained why these issues were prioritised. The possibility to measure the results of the NBOSH activities by future periodic surveys, planned for 1997 and 1999, was also ensured.

Surveillance is the systematic ongoing collection and analysis of work place information performed for the purpose of prevention. Surveillance tells us what the problems are, how big they are and where improvements are needed (46). The term can be applied to the employers responsibility to perform work site analyses for the identification and control of ergonomic and other hazards as expressed in the Swedish work environment legislation (121).

The demands on a Swedish employer are firm. He must investigate work activities in a systematic way, examine the risks, and when necessary take the measures prompted (121). However, neither in law nor in the ordinance regarding ergonomics, are methods suitable for the purpose recommended (121, 133).

Methods for the identification of musculo-skeltal hazards

In Sweden ergonomics is a prioritised field for research and surveillance activities (69, 134). The problems of occupational musculo-skeletal disorders have gradually been acknowledged all over the world (43). Consequently several detailed and informative reviews on methods and instruments for structured ergonomic job analyses have been published (67, 131, 44).

Available methods have different purposes e. g., research, epidemiologic studies, work place surveillance, priority setting in ergonomic work or evaluation of effects of

preventive activities. Hence, the methods differ in design and accuracy ranging from diaries, questionnaires and interviews to systematic observations, direct measurement and computerised EMG-assisted biomechanical models (67, 131, 92, 44).

It is rational that methods are combined e. g., checklists are used as initial screening instruments to assess whether a risk factor is present, for the purpose of further specification of levels by means of direct measurements (67, 62, 18, 74, 92).

With reference to the evident need for instruments to be used at assessment of ergonomic conditions, by both employers and others, the following question challenged an answer:

* Can a method for the identification of musculo-skeletal stress factors which may have injurious effects be developed?

In the USA, the proposed EPS, checklists were recommended to be used by management and occupational safety officials for the evaluation of ergonomic risk factors and manual handling tasks (122, 111).

For a more exact determination of how much a worker should be asked to lift, the use of the revised *National Institute for Occupational Safety and Health, lifting equation*, NIOSH LE, was recommended (122, 128, 111).

The first version of the NIOSH LE was developed in 1981 to assist safety and health practitioners to evaluate lifting demands in the sagittal plane. By the LE a *recommended weight limit*, RWL, can be calculated and factors that contribute significantly to the difficulty of a manual handling task determined (128, 127).

In 1991 the revised version of the NIOSH LE, applicable for asymmetrical lifting, was described and the Lifting Index presented. This value is the ratio of the RWL to the actual weight of the object being lifted (Figure III). The index gives a relative estimate of the level of physical stress associated with a particular lifting task (128, 127).

Lifting Index = Weight of load lifted / Recommended Weight Limit (RWL)

Figure III. The calculation of a Lifting Index.

In 1994 NIOSH initiated a project where RWLs should be calculated at a multitude of manual handling jobs (Draft 6/13/94). Hence, for the data collection well-trained analysts were needed. The possible precision in the measurements (49) was crucial and the following question was posed:

* Can reliable measures for calculations of RWLs be collected by a group of well-trained analysts?

Supervision

In Sweden the employer has the main responsibility for the conditions at work and the employee shall take part in the implementation of measures needed (121). To further ensure a good working environment there are several possible collaborators, safety

stewards, personnel from the occupational health service, consultants etc. However, only the LI has the legal right to enforce ergonomic and other improvements by supervision at work places. With respect to this unique possibility it was of interest to establish:

* Are preventive measures at work places undertaken more often after investigations by the LI than at work places that have not been subject to such investigations?

Evaluation of preventive activities

By intervention oriented epidemiology, the efficacy of health care programmes can be studied (49). However, controlled intervention studies are seldom performed and reported in a systematic way (112, 66, 49, 44). Several outcome measures for such evaluation have been suggested. Reduction in disorders, sick-leave or turn-over has been proposed as well as changes in productivity, and last but not least the view of management and employees concerning performed ergonomic improvements (112, 26, 39, 1, 66, 25)**.**

Halperin describes interventive activities as natural events in the continuum of prevention (46). However, even if a modification of ergonomic factors in the work-place is considered an important approach to prevention and rehabilitation of work related musculo-skeletal injuries (105, 126, 41, 57, 117, 43, 120) only a few studies have used work place conditions as intermediate outcome measures (1, 34). Hence, it has been argued that in the evaluation of prevention and rehabilitation programmes, work place conditions should be more regularly involved (67, 36, 66, 49, 34, 46, 33).

Therefore, it was of interest to focus on possible ergonomic improvements of work place conditions as an intermediate outcome measure for the prospect of a better understanding of the prevention process:

* Which factors influence ergonomic conditions in cases of occupational musculo-skeletal injury?

Return to work has been suggested as a final outcome measure for occupational rehabilitation (36, 38). It can be surmised that prevention, manifested as an improvement of the work place conditions, would be of significant importance for an active employment. There could, however, also be other influential factors. Hence, a second question ought to be added to the above mentioned:

* Which factors influence the employment rate after an occupational musculo-skeletal injury?

Long time effects of work related musculo-skeletal injuries

Longitudinal studies on occupational groups are rare. They have inherent difficulties in tracing the members of the study population and unpredictable social changes occur that distort the results (66, 49). Nevertheless it was considered valuable to make an effort to answer the following questions:

* What is the state of musculo-skeletal health, psychological well-being and functional capacity in a group of injured people that three years earlier reported a work related musculo-skeletal injury?

* What are the economic consequences encountered by the injured?

* Which factors are associated with the state of musculo-skeletal health, psychological well-being and functional capacity in the group three years after the report?

* What is the influence from preventive measures on musculo-skeletal health, psychological well-being and functional capacity in the group?

Aims of studies I-VII

The central aim of the present study was to analyse how intervention after occupational musculo-skeletal injuries could be made more effective and to describe the costs and benefits from work place assessments in monetary terms. Therefore, it was found to be important to develop and evaluate a feasible screening instrument for ergonomic work place assessments and also to examine the potential for an instrumental, quantitative estimation of work load. Another related aspect was to identify the predictors for ergonomic work place improvement and active employment. Moreover, it was found important, with a widened view to prevention, to establish the prevailing contributing factors for STF accidents. Finally, it was of interest to establish the state of health and well being in a group of injured employees a few years after the time of the injury reports. Therefore, the aims of the present study were:

- develop and evaluate a simple instrument for rapid screening of ergonomic risks at work places.

- describe the training procedure and the reliability of participant performance in the calculation of work load by the revised NIOSH LE.

- describe the contributing factors for STF accidents in relation to gender, age and occupation for the purpose of a more efficient accident prevention at work places.

- identify which individual and work related factors were associated with reduced physical work load and active employment after reported work related musculo-skeletal injuries.

- analyse whether investigations performed by the LI would induce an increase in preventive ergonomic measures at work places in cases of reported work related musculo-skeletal injury.

- from a company perspective, provide examples of financial accounts for ergonomic improvements performed at work places, where occupational musculo-skeletal injuries had been reported.

- perform a follow-up of the state of musculo-skeletal health, psychological well-being and functional capacity three years after reported occupational musculo-skeletal injuries.

Materials and Methods

Study design and Material

Paper I
To meet above mentioned needs for a feasible screening instrument for the identification of risks to the musculo-skeletal system, a checklist, PLIBEL, (*Method for the identification of musculo-skeletal stress factors which may have injurious effects, Plan för identifiering av belastningsfaktorer som kan innebära skadlig inverkan*), was developed.

Current scientific literature, regarding exposure at work and its relation to occupational accidents and diseases, was studied and arranged for the PLIBEL check–list.

The validity test of the method, was performed by two observers in altogether twenty-five simultaneous work place assessments, where one observer used PLIBEL and the other a reference method, AET (107).

At the inter-observer reliability test, four job situations, documented by video, were assessed by twenty-four ergonomists using the PLIBEL method.

Paper II
An inter-observer reliability test was performed in co-operation with researchers at NIOSH, USA Thirty four experienced and knowledgeable NIOSH officials, who had attended a training course in measuring techniques for the application of the revised NIOSH LE, were asked to measure the necessary components for a calculation of a RWL (128, 127). None of the trainees had any prior training in making the measurements for a calculation by the revised NIOSH LE.

Paper III
A register study of reported STF accidents was performed together with ISA officials and researchers from the University of Manchester, UK. Results from this co-operation have been reported earlier (95). In study III, ISA statistics on 18 000 male and 9 000 female reported STF accidents from 1990-91 and data from the latest Census in 1990 were used to establish occupational groups to be included in a continued study on contributing factors for STF accidents with a reference to age. In this part of the study 1 600 full textual descriptions on STF accidents, reported in 1994, were analysed and categorised by age and gender for further analyses by occupation.

Paper IV
This study was performed to identify which individual and work related factors that were associated with a successful occupational rehabilitation after reported occupational musculo-skeletal injuries. Individual and work related data was

compiled from occupational injury reports, from work place visits eighteen months after the reports and from questionnaires distributed three years after the injury reports (Papers V and VII). *'Reduced physical work load'* and *'active employment'* were the two outcome measures studied.

Paper V, VII (Study design)
Reports on musculo-skeletal occupational injuries from men and women, independently of age, were collected consecutively at three LI offices during a few weeks in 1985. Both accidents and diseases in different body regions, causing over seven days of sick-leave, were included.

In study V the retrieved injury reports (n=195) were randomly subdivided into two groups: ninety-two work places in the first group were to be investigated by Labour Inspectors and the reports in the other group were gathered for control (Figure IV).

However, six work places remained uninvestigated. After studying four of the reports, the inspectors decided that individual visits were not required and two other reports were put aside in connection with staff changes at one of the inspectorates.

Approximately one and a half years after the date of the reports all 195 work places were visited by one of three ergonomists, who did not know at which work places the inspectors had been. Individual assessments of current ergonomic conditions could only be performed at ninety-three work places, since many of the injured had left their employment or had been on prolonged sick leave. In a few cases the information on the background of the injuries was not sufficient for assessments.

At 172 of the work sites, on average twenty people were performing the same tasks as the injured worker. To assess the extent of primary prevention, these work places, similar to those of the injured, were assessed (60).

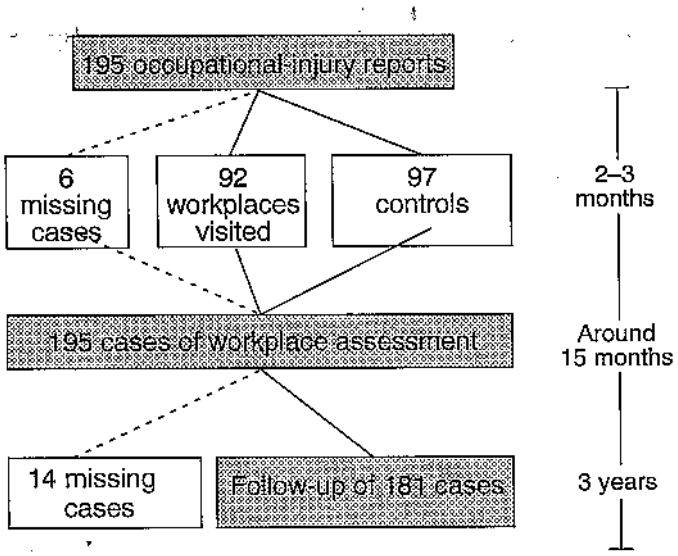


Figure IV. Flowchart of work place visits, work place assessments and three-year follow-up following 195 occupational injury reports.

In study VII, performed three years after the time for the injury report, 181 of the injured people (93%) took part in a postal follow-up of physical and psychological health, functional capacity and well-being. Eight people in the group, previously studied, could not be reached and six did not want to participate in this part of the study. The design of studies V and VII is summarised in Figure IV.

Paper V, VII (Study material)

The studied injury reports derived from 104 men and 91 women. The women were eighteen to sixtio-three years of age (median 42) and the men ninteen to sixtio-three years of age (median 38). The distribution by sex, age and occupation in the group was in accordance with national ISA data on occupational musculo-skeletal injuries from the same year. The distribution on accidents and diseases was in accordance with regional data, but compared with statistics from the country as a whole, diseases were over represented in the studied group (Table 1).

Background factors like education, branch, occupation, injured body region and duration of sick-leave among the injured visited by the inspectors and in the control group were investigated and no particular differences between the groups were found.

Table 1. The inspected group and the control group, distribution by sex and type of injury (n=195).

		Diseases	Accidents	Total
Inspected group	Men	33	17	50
	Women	40	8	48
Control group	Men	34	20	54
	Women	33	10	43
		140	55	195

Paper VI

During the same period four of the companies, where preventive measures had been undertaken, were subsequently visited for interviews regarding costs and benefits related to the reported injuries. Interviews were performed with the aim of investigating situations, where the employers had performed improvements. As representative for these visits, cases from various sectors of working life and with different injuries were chosen (Table 2).

Table 2. Studied cases distributed by gender, age and diagnosis of the injured worker (n=4).

	I.	II.	III.	IV.
Work place	Radiator industry	Administration	Metal industry	Nursing home
Gender	Male	Female	Male	Female
Age	45 years	34 years	25 years	52 years
Diagnosis	Lumbago. sciatica dx	Elbow tendinitis	Low back pain	Shoulder tendinitis

Methods and procedures

Paper I. Development and evaluation of a method for the identification of ergonomic risk factors

After studies of scientific literature regarding exposure at work and its relation to occupational musculo-skeletal accidents and diseases, the PLIBEL method was designed to serve as a rapid screening tool of major ergonomic risks which may have injurious effects on the musculo-skeletal system.

On a register-chart five body regions were mapped and questions on musculo-skeletal stress factors listed. After a pilot study and minor modifications, an instruction for the user was developed (unpublished material).

PLIBEL can be used for a general assessment of the ergonomic conditions at a work site, but is usually applied for an assessment of risk to a specific body region. In the validity- and reliability-tests in Paper I, the latter application was in focus.

The validity of PLIBEL was analysed through simultaneous work place assessments in the field and performed with the method under study and AET (*Das Arbeitswissenschaftliche Erhebungsverfahren zur Tätigkeitsanalyse)* (107). The AET method was chosen as being the observation method most equivalent to PLIBEL. The response levels of the two methods are however, not synonymous, which was compensated for in the analysis.

The inter-observer reliability test was performed by assessment of different work situations at video recordings.

Finally, scientific reports published through 1993, documenting a use of PLIBEL, were accounted for.

Paper II. The possibility to perform uniform quantitative registrations of work load

To meet up with the aims of having a well trained group of analysts at NIOSH, a one day course on the theoretical background for the revised NIOSH LE and practical training in measuring techniques was provided. All trainees were asked to be prepared to participate in a test of their measuring capacity after about two months and the majority did participate. This inter-observer reliability test consisted of one simple, standardised lifting task in a laboratory setting, where measures were to be taken following the instructions given during the course.

Paper III. Contributing factors for STF accidents in relation to gender, age and occupation

ISA statistics for reported occupational accidents 1990-1991 and data from the latest Census 1990 were combined with NYK data (*Nordic Occupational Classification scheme, Nordisk Yrkes Klassifiering*) to give STF rates by gender, age and occupational group. To identify the contributing factors for STF accidents and to understand the route to more efficient preventive activities in work places, full-text descriptions from STF accident reports in occupational groups with elevated rates were studied regarding injury incidence, place and activity at the time of the injury.

The information on contributing factors was distributed by gender and age and divided into subgroups with respect to urgency of prevention according to the Swedish work environment legislation (121).

Paper IV. Influence on the outcome variables; reduced physical work load and active employment

Individual and work related data were compiled from material in studies V and VII. The association between independent data i. e., gender, age, injured body region, length of sick-leave, occupation, quality of injury report etc. and the outcome variables, reduced physical work load eighteen months after the time for the injury reports and active employment after three years was analysed.

Paper V. Do investigations performed by the Labour Inspectorate induce an increase in preventive ergonomic measures at work places in cases of work related musculo-skeletal injury?

Work place assessments by Labour Inspectors
Fifteen inspectors (twelve men and three women) from three LI districts volunteered to make official visits to assess about eight work places each within two to three months after the time for the reports. In total 92 workplaces were visited. The inspectors were recommended to issue *inspection notices*, INs, to the employers following customary principles (53).

The inspectors evaluated the ergonomic conditions at the work places where occupational musculo-skeletal injuries had been reported, using the PLIBEL method. Initially they had been given two days of class room training in the theory and operation of the method.

Work place assessments by ergonomists
Three ergonomists performed work place assessments eighteen months after the injury reports at all 195 workplaces. These assessments were supplemented with interviews with employees, safety representatives, occupational health staff and employers concerning the work situation at the time of the report. Investigations were also undertaken regarding possible improvements, performed at the work-place since the time of the injury.

Reduced physical work load was considered to have been achieved where physical or organisational measures had been performed in such a manner that the harmful situation described in the injury report and at the interview no longer existed.

The assessments of the working conditions of the injured were complemented with equivalent studies of work place changes among *co-workers* (60). This enabled the ergonomists to assess work places similar to those which were vacant due to sick-leave, or turn-over.

By evaluating the ergonomic situation for co-workers the extent of primary prevention, in connection with the occupational injury report, could be established.

Paper VI. Economic impact of performed ergonomic improvements

Three years after the injury reports, two economics students made work place visits after introductory letters to four companies. Interviews were conducted with managing directors, personnel managers, foremen, safety guards, occupational health personnel and with the injured workers and their co-workers.

The employer and the personnel manager were asked about the expenses associated with the control of the ergonomic problem e. g., costs for consultations, purchase of new equipment or material and attributed education of the employees. Moreover, the respondents were asked to estimate financial effects associated with the improvements during the first year after the injury report. Figure V gives an overview of the categories in question.

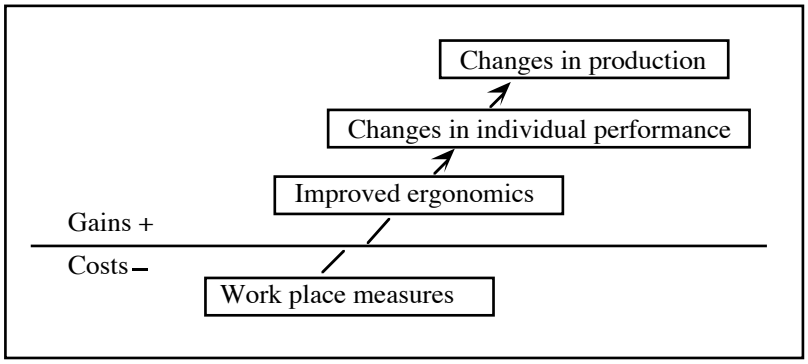


Figure V. A model of the costs and gains of a successful rehabilitation. After Aronsson and Malmquist (15).

Following areas, as mentioned in the literature on human factors in budgetary work (118, 26, 39, 99, 88) were focused on:

Changes in performance
- *sick-leave with social cost*
- replacements, overtime and over-employment
- turn-over, recruitment costs, introduction and education costs
- good will and motivation

Changes in production
- quality
- quantity

At the interviews, data on expenses were compiled from account books, while specifications of gains mostly relied on estimated values. Data was analysed and calculations performed according to scientific articles and text books (see above).

Paper VII. Follow-up of the state of musculo-skeletal health, psychological well-being, employment, and functional capacity

A postal questionnaire was constructed to investigate psychological and somatic symptoms, social support, functional capacity and employment status three years after

the injury reports. To enable comparisons of the answers with results from reference studies, the questions were partly identical to questions used earlier (6, 85, 52). For questions about musculo-skeletal symptoms the Nordic Questionnaire was used (76). In the analyses complementary data from study V was used i. e., information from the occupational injury reports and from the work place visits.

Statistics and calculations

Paper I
In the validity test 'overall proportion of agreement' and kappa statistics were calculated for individual items (37). In the reliability test the consensus between observers was estimated (47). Furthermore, weighted averages of kappa were calculated (37).

Paper II
Descriptive statistics, range, mean and standard deviation, were computed for each of the numerical measurements performed by the participants in the reliability test. A student's t value was computed for each variable of interest to test the hypothesis that the differences between the participants mean values and the reference values were zero (110).

The values from each participant in the test were entered for calculations of RWL values by the revised NIOSH LE computer programme (109, 127). For the computations of Lifting Indices, the duration of the task was set to < 1 hour and the frequency to one lift every five minutes. To evaluate the influence of measurement variability across different object weights, three hypothetical weight levels were applied.

Paper III
Register data was analysed to provide *rates of STF accidents* per 1 000 employed, R STF. From these values *relative risks for STF accidents*, RR STF, among older (≥ 45 years) men and women as compared to younger (< 45 years) were calculated. R STF and RR STF values were calculated in occupational groups and the data was arranged with reference to age. The association between age and different contributing factors was tested by homogeneity tests (110).

Moreover, age specific proportions were calculated for each contributing factor, in each occupational group and in subsets of groups. Finally, ratios of the two proportions were calculated as estimates of the association with age (75, 73, 49, 108). To demonstrate the precision of ratio estimates the values were supplemented with test based 95% *confidence intervals,* CI (2).

Paper IV, V, VII
Differences between groups were tested by χ^2 calculations. Significance was accepted at $p<0.05$ (Paper V and VII). *Odds ratios*, OR, were calculated as estimates of the likelihood of work place improvements for different groups (Paper V).

Logistic regression methodology was used to analyse the association between independent data and the outcome variables, reduced physical work load and active employment, and OR estimates were calculated (Paper IV). To demonstrate the

precision of OR estimates the values were supplemented with 95% CIs (Paper IV and V) (2)

Paper VI
For each case in the study a pay-back period (39, 99) was calculated based on data from the interviews (Figure VI).

$$\text{Pay-back period (months)} = \frac{\text{costs for improvements}}{\text{monthly gain}}$$

Figure VI. Model for the calculation of the pay-back period.

The amount of hours at work each year was set to 1760 hours (7.75 hours/day ∗ 227 days). Week ends, national holidays and a holiday of five weeks were excluded. Sick-leave was expressed as percent of yearly hours at work.

Loss in production time due to sick-leave (118, 99) was not included in the present study. Nor were 'overhead costs' e. g., costs for localities, administration etc. (48).

Results

Summary of Paper I

The construct validity (20) of PLIBEL was ascertained by accounting for the scientific publications supporting for the items in the checklist.

For the test of criterion validity (20), eighteen of the forty-two PLIBEL items could be matched with similar AET items. The agreement between these items was analysed in twenty-five work place assessments. Paired comparisons between PLIBEL and AET registrations were made. At nine work places there was full agreement; no ergonomic risks were found. At ten of the remaining sixteen observations PLIBEL was in concordance with AET, but there were also additional PLIBEL registrations. At six other observations, risks were registered only with PLIBEL. In general the discordant registrations concerned peak loads, where the duration was not sufficient for AET coding. In one case the explanation for the additional registrations was the individual performance of work tasks.

The conditions at the work places visited did not imply many ergonomic risks. Hence, the registrations were sparse, which made the estimates of agreement uncertain. The 'overall proportion of agreement' on the occurrence of the eighteen studied items was eighty-nine percent. Due to the distribution of registrations kappa analyses (37) could only be calculated for nine matched pairs. The agreement for three items was 'poor to slight', for three 'fair to moderate', for two 'substantial' and for one 'almost perfect' (83).

Reliability tests were performed using video recordings at class room settings. At two out of four work situations there was consensus in ratings (47) for at least fifty

Table 3. Consensus in registrations and weighted averages of kappa for 24 observations. Distribution on four work situations/body regions.

	Machine work Neck/shoulders, upper part of back	Bookbindery work Elbows, fore-arms, hands	Garbage collection Hips, knees, feet	Laundry work Low back
Consensus	35%	45%	50%	62%
Weighted average of kappa	0.24	0.38	0.41	0.44

percent of the actual items. Expressed in weighted averages of kappa (37), the inter observer agreement was fair to moderate (83) (Table 3).

PLIBEL was designed to meet the needs for a standardised practical method for the assessment of ergonomic conditions at work places. Therefore, the applicability of the method was illustrated through references to various studies, where PLIBEL has been used. Studies from different branches have reported a use of PLIBEL e. g., to provide a base for recommended improvements in cases of occupational musculo-skeletal injury, for discussions of ergonomic problems and for ergonomic work site education. Moreover, PLIBEL has been used for ergonomics training both in industry and in the Swedish school system (14, 54, 60, 97, 32, 23, 125).

Summary of Paper II

There was little variability for six of the eight measurements obtained at the assessments of the standardised lifting task. The measurements for the most important task factor (i. e., the horizontal distance) were consistent between the observers.

Variability occurred in the determination of the coupling quality and the symmetry measurements. However, by computer calculations with the revised NIOSH LE programme (109) it was established that this inter-observer variability had little impact on the Lifting Indices obtained from the measurements.

Hence, it was concluded that individuals can be trained to make accurate measurements for the revised NIOSH LE and consistent lifting indices can be expected for simple tasks, but improvements are needed in the assessment of coupling and asymmetry factors.

Summary of Paper III

Analyses of register data on occupational STF accidents revealed that there was an increased incidence of such accidents in the group aged forty-five years or more. Older women reported STF accidents twice as often as their younger colleagues.

For three of the studied male occupations, an age difference was evident with regard to STF accidents related to snow and ice. Older men reported such falls more often than younger. For the other factors involved in the STF accidents no noticeable age differences were found.

One in three of the male STF accidents had occurred when climbing on a ladder. Such accidents were common in metal machine work, electrical work and building and construction work. More than one in two of these climbing accidents were due to

sliding or breakage of ladder, lack of step at the ladder or tilt of support. The association between age and the frequency of sliding accidents did not demonstrate any significant age differences.

In the studied female occupational groups slippages on floors or missing of step and material/oil/grease/water on the floor together explained almost two thirds, and snow and ice almost one third of the reported STF accidents. Snow and ice was an influential contributing factor especially for women employed in social work. As an example, home helpers had snow and ice as the explanation for half of the studied STF accidents.

In the group occupied with lodging and catering service, on the other hand, almost half of the studied STF accidents were due to material/oil/grease/water on the floor. A more detailed analysis revealed that for waiters sixtio-four percent of the STF accidents were of this kind.

In the female group there were no particular age differences as regards accidents due to the most common factors, missing of step or slippage on floor or material/oil/grease/ water on the floor neither in the occupational groups nor in the separate subsets of occupational groups. The same was valid for falling on snow and ice.

The reason to the finding that both older male and female workers reported STF accident more often than their younger colleagues could be both because older people fall more than younger and also because accidents have a more evident impact in older ages and that at least a sick-leave of some weeks is needed after such an accident.

To conclude; the same preventive measures should be implemented for both younger and older people, employed in the same occupation, but as older workers proved to have longer sick leaves in connection to STF accidents, the preventive measures are even more urgent to perform where the work force is comprised of workers aged forty-five years or more.

Summary of Papers IV and V

Effects of LI investigations

The Labour Inspectors delivered detailed work place reports to the ergonomists in charge of the project. At ninety-three percent of the work places they identified great or very great risks for injuries to the musculo-skeletal system (97) .

The ergonomists established that ninety-one percent of the reported situations included tasks which might have an injurious effect to the musculo-skeletal system. Furthermore, they assessed that a reduction of workload had been achieved for forty-seven of the injured, while forty-five injured were working in unchanged conditions (Table 4).

Table 4. Reduction of work load among injured at 92 work places 18 months after reported musculo-skeletal occupational injuries.

	Inspection group (n=44)		Control group (n=42)
	inspection notice		
	yes	no	
Reduced work load	6	15	26
Unchanged conditions	5	18	22
	11	33	48

After twenty of the work place visits, INs were issued by six of the inspectors. The majority of the INs came from the same LI office. Nine male inspectors did not issue any INs.

Eleven of the INs were issued on behalf of the injured persons. When compared with the control group neither the visits from the LI nor the INs were associated with reduced physical work load among the injured (Table 4).

Fourteen of the INs that were issued had demands on behalf of co-workers. For co-workers there was a significant reduction of work load where INs had been issued as compared to the control group χ^2; 9. 42, OR; 5. 64 (CI; 1. 87-17. 16) (Table 5). Thus, the effect exercised by the inspectors was in primary prevention.

Table 5. Reduction of work load among co-workers at 160 work places 18 months after reported musculo-skeletal occupational injuries.

	Inspection group (n=76)		Control group (n=84)
	inspection notice		
	yes	no	
Reduced work load	8	15	16
Unchanged conditions	6	47	68
	14	62	84

Factors associated with reduction of physical work load

Of all 195 injury reports only twenty-two had information on the origin of the injury regarded as being sufficient for determination of preventive activities at a work-place (60). Eleven of the reports from those ninety-two injured, that could be assessed at their work places, had such descriptions. Ten of these injured achieved reduction of work load. Thus, the odds for reduced work load were increased when the injury descriptions were informative, but the wide CI indicate that the magnitude of the estimate is uncertain. There was a weak tendency that reduction of physical work load was negatively associated with male sex, age below forty-five years, OAs and with injuries in several body region (Table 6).

Table 6. Logistic regression of the chances for reduction of work load. For each independent variable the OR value is given and complemented with the 95% CI for the estimate (n=93).

	OR	CI
Description of the origin of the injury (informative versus insufficient)	7.45	0.85–64.92
Type of injury (occupational accidents versus occupational diseases)	0.36	0.12–1.06
Age (≥45 versus <45 years)	1.30	0.50–3.37
Sex (men versus women)	0.62	0.24–1.62
Extent of injury (≥ two body regions versus one region)	2.47	0.54– 11.23

Table 7. Logistic regression of the chances for being in employment. For each indepen dent variable the OR value is given and complemented with the 95% CI for the estimate (n=181).

	OR	CI
Sex (men versus women)	3.40	1.28–9.07
Education (>elementary school versus elementary school)	3.67	1.49–9.03
Sick-leave (1-6 months versus < 1 month)	0.96	0.33–2.80
Sick-leave (6-12 months versus < 1 month)	0.06	0.02–0.18
Type of injury (occupational accidents versus occupational diseases)	0.41	0.14–1.16
Age (≥45 versus <45 years)	0.62	0.26–1.52
Extent of injury (≥ two body regions versus one region)	1.14	0.38–3.40

Factors associated with active employment

At the logistic regression analysis, three variables had CIs indicating reliable point estimates; sex, education and sick-leave six to twelwe months. Men were considerably more often than women in active employment three years after reported injuries. People with higher education than elementary school were also more often in employment, while long lasting sick-leaves had an extremely negative association with employment (Table 7).

There was no evidence that age or type and extent of injury were associated with employment.

To conclude; Where INs were issued, primary preventive ergonomic measures were undertaken, whereas secondary preventive measures i. e., physical or organisational measures, were implemented where the occupational injury reports had informative descriptions of the origin of the injury. Hence, injury investigation and documentation were influential factors for prevention.

To increase the extent of employment after occupational musculo-skeletal injuries, it seems reasonable to suggest an avoidance of long-lasting sick-leaves and also an initiation of more effective rehabilitation measures for women and for people with lower levels of education.

Summary of Paper VI

The positive economic consequences of ergonomic prevention became evident by using simple calculations in four case studies.

The interviews with management representatives at the studied workplaces, established that the ergonomic problems were well known and had also been associated with health problems. They had caused repeated periods of sick-leave over the years, but none of the visited companies recognised any evident changes in productivity associated with the sick-leave periods in the studied groups. It was not until the injuries were reported that preventive measures were initiated. After sick-leave periods of on average six months in connection to the reports, the injured employees were transferred to lighter duties, while the co-workers were provided with improved ergonomic conditions.

The improvements that had been carried out, were based on different recommendations implying that heavy and awkward tasks were re-engineered after consultations with machine constructors and the occupational health service or after suggestions from the employees and proposals from the local labour inspector.

In three of the cases, specific ergonomics training was provided as part of the improvements. Work techniques, which emphasised administrative efficiency, training of new tasks to facilitate job-rotation, and lifting techniques were introduced.

In three of the cases no costs were identified besides the investment costs, whereas a loss in income was recognised at a nursing home where a reduction of patients was necessary to give required space for proper nursing. However, this cost could not be determined. As the nursing home was financed by the county, the staff was not aware of the real figures. In the other three cases a gain in productivity was noted, but it could not be defined by any of the respondents.

When costs for improvements were compared to estimated gains, the investments turned out to be clearly profitable with short pay-back periods (Table 8).

Table 8. Investment costs, estimated monthly gain and pay-back period in connection with four reported occupational musculo-skeletal injuries, in US dollar ($).

	I. Radiator industry	II. Administration	III. Metal industry	IV. Nursing home
Investment costs	$21.368	$19.316	$5.043	$4.992
Estimated monthly gain	$4.828	$6.411	$1.684	$4.934
Pay-off time (months)	4	3	3	1

Summary of Paper VII

Three years after the injury reports the occurrence of long-lasting symptoms and functional disturbances among the 181 respondents was high. A majority of the injured reported symptoms corresponding to what had been diagnosed at the medical investigations at the time of the injury report. The studied group reported more physical (Figure VII) and psychological symptoms (Figure VIII) than reference groups and more than fifty percent of the injured reported difficulties in *activities of daily living,* ADL. More than a quarter of the respondents mentioned that life had

become complicated and expensive, to them and their families, due to effects of the occupational injury.

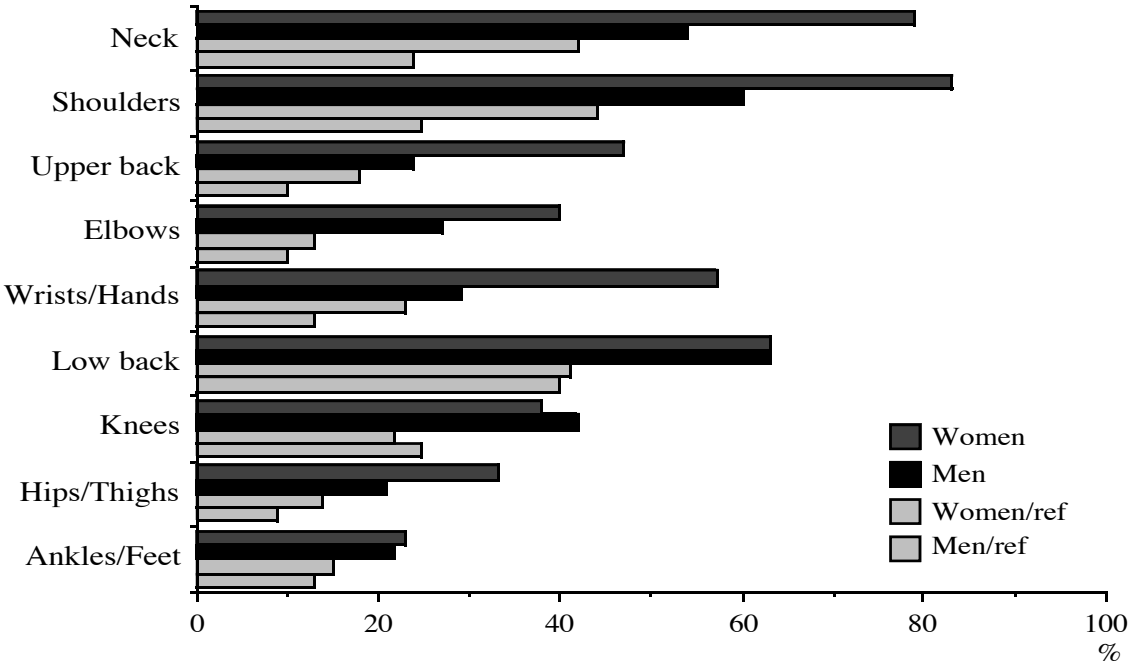


Figure VII. Reported symptoms in different body regions during the previous 12 months. Percentages of answers from the studied group (95 men and 86 women) and reference data (17 443 men and 17 701 women) (6).

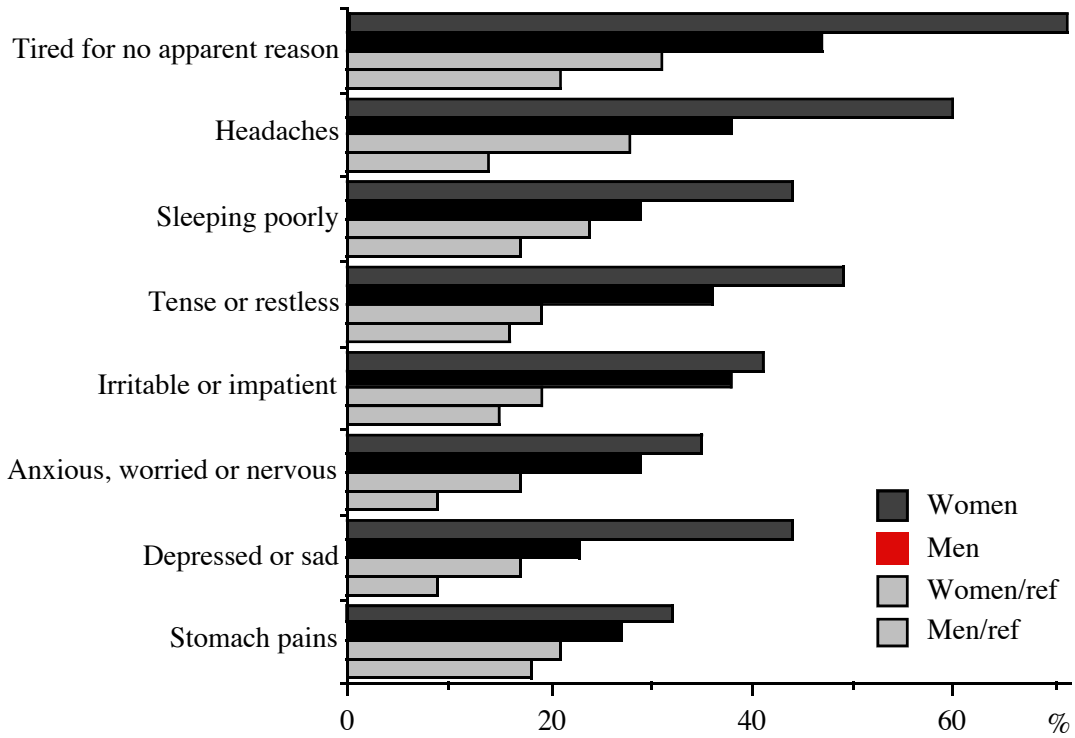


Figure VIII. Reported psychological symptoms. Percentages of answers from the study group (95 men and 86 women) and reference data (17 443 men and 17 701 women)(6).

Longer sick-leaves (≥ 6 months) in the year following the injury report were associated with remaining pain and low rate of employment. Perceived access to social support was positively associated with health and psychological well-being. The group with shorter sick-leaves (<6 months) had lower prevalences of musculo-skeletal symptoms, a more positive opinion of their general health and present life-situation. The difference between groups was statistically significant ($p<0.05$).

A special analysis was performed of some of the questionnaire answers from the subgroup that had been in employment at the assessment at the work-places eighteen months after the injury report. Those whose work loads had been reduced after the injury, did not report less musculo-skeletal disorders than others, but they experienced less anxiety and irritability than those who worked in unchanged conditions (Table 9). There was no association between reduction of physical work load and active employment.

Three years after the time of the injury report 109 (60%) of the injured workers, who responded to the follow-up, were in employment, while seventy-two injured were not. Most of these injured had not been working at all since the time of the report. Almost one third of those who were in employment, had changed occupations and had now more varied tasks than at the time of the report.

Table 9. Percentages of answers concerning occurrence of symptoms, employment and opinion on received help with the occupational injury problem. The results are distributed according to those who had obtained reduced work load (n=47) and those who were working in unchanged conditions (n=44) eighteen months after the reported injury.

	work load reduced	work load not reduced	p<
	%	%	
Tired for no apparent reason	47	46	
Headaches	55	42	
Sleeping poorly	20	30	
Tense or restless	28	37	
Irritable or impatient	21	40	0.01
Anxious, worried or nervous	12	29	0.01
Depressed or sad	18	26	
Stomach pains	24	26	
Remaining musculoskeletal symptoms	50	66	
Not in employment	30	23	
Dissatisfied with the assistance regarding the occupational injury problem	32	48	0.05

General discussion

Study design and methological considerations

Aims of the study

Occupational musculo-skeletal injuries and slip, trip and fall accidents cause considerable costs to society, the companies and the injured themselves. They are also manifest by long-lasting sick-leaves and numerous disability pensions. The aim of the

present thesis is to contribute to the increasing understanding of the routes to prevention of the mentioned injuries.

Papers I-VII cover a wide range of methodological approaches i. e., literature and register studies, field and laboratory studies and finally direct and postal interviews. In some papers a combined use of the mentioned approaches, has been applied.

Register studies

Register studies are considered useful as starting points in occupational epidemiology (49, 91). The readiness to report occupational injuries may differ between branches. However, the possible bias from such influence on present results, can not be estimated. Rather, the results are representative for occupational injuries that in fact have been reported to ISA.

Register data can also be used for comparisons between study results. As was demonstrated in study VII, data from national surveys on living conditions (85), from studies based on 35 000 answers to the Nordic Questionnaire (6, 76) and from Finnish surveys (52) were used as reference data.

As mentioned earlier, ISA is one of two registers on occupational and work environment data, under the authority of the Swedish NBOSH (13, 123). The injury reports to be studied (Paper V), were randomly retrieved from this register as well as the textual descriptions (Paper III). This kind of data have only been available for a few years and has since been used in current information material. Study III is the first published example of a use of this material. The results indicate that this data comprise valuable information.

In Sweden all economically active citizens are insured for occupational injuries (116). ISA has been responsible for the collection of injury statistics since January 1979. An illness, work related or not, is most often reported by telephone to the local office of the *National Social Insurance Board,* NSIB, after which the sick-listed person receives a form, where one of the questions concerns the illness and its possible work relation. If the answer to this question is affirmative, the employer in his turn receives an enquiry, in which he has a responsability to describe the background of the injury and also planned control measures (116, 98).

For information, a copy of every occupational injury report is distributed from NSIB to the local LI office and to ISA for registration and coding. Hence, in Sweden information on work related health problems is carefully retrieved and promptly distributed. Thus, there are several challenging sources of information, only waiting to be used!

In the present thesis the use of registerdata compiled from the entire country (Paper III) and from three geografical regions (Papers IV-VII) vouches for more representative results, than could have been achieved with other methods.

Field studies

Studies V, VI and the validity test in study I, were performed as field studies. In study V, Labour Inspectors made official visits to work places and three ergonomists performed follow-up assessments about one and a half years later. Both visits were announced in advance and appointments made with employers, safety stewards and the person who had reported the occupational injury.

This study design gave a large amount of organisational work, which was compensated for by the fact that the majority of the injured group (77%) came to the visits. Hence, even if many were at sick-leave or had changed position etc., there were good opportunities to gather the data required, which in turn should vouch for reliable results.

The value of getting information at the work site from the employer, safety stewards and the worker himself can not be overestimated (33). Field studies are labour intensive, but most likely provide more comprehensive and applicable information than other study designs e. g., register, questionnaire and experimental studies.

The companies to visit for economic interviews (Paper VI) were selected as examples of work places where improvements of the working conditions had been performed after the injury reports. The selection strategy aimed at finding representatives from different occupational groups and of both sexes, which resulted in a very small sample. To collect another, larger and more representative sample, however, would have taken great resources as work place measures after a reported occupational injury are of rare occurrence. The case studies that were accomplished can be regarded as pilot studies denoting a calculation technique to be used for larger samples in the future.

The validity test (Paper I) was performed as work place observations of twentyfive professionals, which was fundamentally to test the checklist.

Interviews

Direct interviews were performed in the field after introductory letters to the companies (Paper VI). The respondents , employers and personnel managers, were co-operative in accounting for costs and estimating gains. However, the interviewers brought up several issues where documentation was not available or estimations could not be obtained, e. g., change in productivity and possible loss in competence at change of position.

On the whole, it can be surmised that the responses were more reliable at these direct interviews than they would have been if given to a postal enquiry.

Postal interviews were chosen for practical reasons for the three-year follow-up (Paper VII). It would naturally have been preferable if data on functional capacity and ADL status had been compiled objectively for each individual (87, 66), but that was not possible.

It is probable that the high (93%) response rate to the postal questionnaires was due to the personal contacts that had been established at the workplace visits (Paper V). If so, the extensive preparations for the field studies gave effects also for the follow-up. The high response rate vouches for a representative picture of the conditions in the group.

As the results in study VII depend on subjective responses they might, to some extent, be influenced by expectations and attitudes concerning occupational injuries among the injured subjects. In a previous study of the same material, however, it was shown that there were no differences in physical and psycho social well-being between the group where injuries were approved, and the group where they were not

(59). These results, especially the lack of differences in psycho social conditions, suggest that the effects of expectancies appear to be insignificant.

Moreover, as mentioned in a review by Wallace and Buckle, studies of personal conditions, such as pain, must always rely on self report (126).

Mock-up study at a laboratory

For the inter-observer reliability test a simple lifting task with a cardboard box, was set up at a laboratory, where the participants were asked to measure the necessary components for a calculation of a RWL. They were neither required to determine the frequency or duration of the lifting activity, nor to determine the weight of the box. No time limits were set for the data collection.

Hence, the conditions for the test lift were extremely simple and in fact very different from real work site conditions. The design of the lift was such that an application of the revised NIOSH LE was appropriate e. g., the lift was performed with two hands, no carrying, pushing or pulling occurred and the work space was not restricted (128).

It can be assumed that the reliability of the test-results might have been lower if the testing had taken place in more realistic environments e. g., at work sites with more complex tasks, where the revised NIOSH LE might have been only partly applicable. If so, difficult decisions regarding the appropriateness of a use of the revised NIOSH LE would have been needed.

Studied groups and material

The main study group consisted of 195 men and women of different ages in different occupations with injuries classified as accidents and diseases, engaging different body regions (Paper IV, V, VI and VII). Hence, no restriction in inclusion criteria e.g., with regard to certain body regions, types of injuries, occupations or branches of industry, was applied.

Instead, the injury reports were randomly retrieved, as randomisation has been pointed out to be the most effective method of controlling confounding inferences (49). Moreover, by the inclusion of a fairly large number of consecutive reports no misclassification would have occurred due to biased selection (49). The main purpose of studies IV, V, VI and VII was to establish what could be influential for an effective prevention. Therefore, restrictions would have reduced the possiblities to draw conclusions valid for the entire range of reported musculo-skeletal injuries (49).

Nevertheless, there was one restriction; the total number should be manageable with respect to the regional workplace visits that were planned. The limited size of the study group naturally reduces the conclusions that can be drawn from the statistical analyses. With a larger study group factors which influence the prevention could have been analysed in more detail and with less uncertainty.

In the study V, Labour Inspectors visited half the group, and all work places were later systematically assessed by ergonomists. Due to sick-leaves and turn-over, the ergonomists' assessments had to be performed for a reduced group, which limits the possibility of conclusive analyses.

However, sick-leaves of considerable duration occur frequently in cases of musculo-skeletal injury (29, 16) and change of position, in connection with

deficiencies at work-places, is a frequent action that has been focused on earlier (103, 102, 35, 25, 119, 33). Hence, the results from the study can not be rejected due to the reduction of the studied group. It rather mirrors what occurs at work places, and also provides useful information on the prevention for the subgroup that remained at work.

Study participants

For the validity test (Paper I), a colleague experienced from doing hundreds of assessments with the reference method AET (107), performed simultaneous assessments with the author, who used the method under study, PLIBEL. There was no communication between the two observers during the assessments.

In the inter-observer reliability tests, NIOSH officials and researchers from the Swedish Institute of Occupational Health participated (Paper I and II). They were registered physiotherapists, M. Ds or Ph. Ds in occupational health. They were experienced in collecting field data and motivated is doing the tests.

Nevertheless, during the assessments in study II, it could be observed that it was no easy task for the participants to take the measures. Similar findings have been reported earlier (65).

At the design of study V, it was assumed that the Labour Inspectors would be acting unanimously at their work place investigations, but individual and local conditions seem to have influenced their performance. For the purpose of this study, it would have been preferable to let only a few Labour Inspectors take part in the study, performing many more inspections per person. However, the inspections had to be undertaken by inspectors already in charge of the studied work places. Hence, they had the mandate to issue INs. The compromise reached illustrates that it is not possible to undertake interventions at work places wholly controlling all factors.

The inspectors reported that the studied work places entailed ergonomic hazards, but they seldom issued INs. The INs predominantly come from one LI district.

In fact these results agree with another study (89), which demonstrated that confident analyses of LI activity were difficult to achieve due to large variations in actions undertaken by the Labour Inspectors.

If consistent results, in terms of issued INs, can not be obtained from a group of officials that have general ergonomics training for more than eight weeks (134), who are experienced as specialised ergonomics officers and who have been provided with a specific checklist, including training for the application and finally been instructed to issue INs following NBOSH regulations (Paper V), from whom would such results then be obtained?

The prospect of comparisons between different ergonomics studies lies in consistent assessments (throughout the world!) (68). With this intention and as mentioned earlier, a range of original articles have been published that either account for different ergonomic risk factors, demonstrate different methods for assessment or combine the two aspects. Also in review articles and text books extensive syntheses over ergonomics hazards and assessment methods have been published.

The present results only give a slight hope for a more homogenous approach to ergonomic matters. Specialists and Labour Inspectors, alike, had problems to use the tools and possibilities provided. It was not uncomplicated to collect data for

ergonomic assessments (Paper II) and decisions after work place assessments were of a local or individual character (Paper V).

Some hope has been linked to the use of technical measurements (EMG, registration of body postures etc.) as a substitute for checklists and simple workplace evaluations. This will be discussed below.

The identification of ergonomic hazards

The purpose of studies of ergonomic hazards differ. The detailed measuring of exposure as applied in an etiologic epidemiologic study (56, 55, 113, 61, 44) is not the object of the present thesis, where the prevention and control of musculo-skeletal stress factors is the focus.

To identify ergonomic problems in the field, with a view to prevention, a checklist screening was recommended (104). PLIBEL was designed to serve as a simple screening tool at work place investigations. The use of a checklist, as a reminder to ascertain that all major ergonomic risks are evaluated, has been advocated earlier (63, 62, 18, 74, 66, 31).

The development of a method for the identification of musculo-skeletal stress factors

Literature studies. When designing the PLIBEL method, scientific literature on risk factors for occupational musculo-skeletal injury was studied and items of relevance for a work place assessment listed and put together as a checklist. Original papers and also review papers and text books, were used as references.

It is self evident that the final selection of what should be included in the checklist depended on the attitude and knowledge of the designer. However, available scientific reports on the association between work related risk factors and many musculo-skeletal disorders is uncontroversial, and for most basic items there is a solid agreement among researchers (68).

Validity- and reliability-tests. A trustworthy observation method should preferably be tested for both validity and reliability with acceptable results. However, such testing is problematic. The "truth" in the shape of observations performed with another method is usually not available (20).

For the validity test several methods were considered but found to be too limited, due to their either focusing only on postures, on a part of the body or being mainly applicable to stationary tasks (64, 63, 56, 55, 4, 113, 94). Finally AET, which allows for a detailed investigation of work-load and work-content, was chosen (107). No other method, so well documented and with such a broad approach was found.

The inter-observer reliability was tested by an analysis of PLIBEL forms that had been filled in by twenty-four observers at observations of video recordings. Strictly speaking, such forms are only work sheets where items of varying importance have been ticked. At the true use of PLIBEL, the aggregated evaluation of collected data would have been used to formulate a conclusion regarding the ergonomic situation.

Moreover, both what is filled in at the forms and the concluding report to a great extent relies on the education and attitude of the observer. The concluding report is regarded as the final product at the use of the instrument under study. Therefore, it could be discussed *what* in reality is tested by an analysis of individual items at filled-

in forms. Results from reliability tests, where the superior role is played by the qualifications of the user, must be taken with caution.

However, there seem to be no other possibility to test an instrument of this kind. The natural expectation that, when analysts follow a checklist at assessments, fewer items would be let out has been expressed earlier (63), but can not be tested.

Applicability. The use of PLIBEL enabled systematic registrations of ergonomic risks at the work places and made comparisons of ergonomic conditions at different points of time possible (Paper V).

It must be noted, that the list of reports using PLIBEL as presented in Paper I, gives an underestimation of its use. The everyday use is most often not published. Moreover, only reports published in English through 1993 are recorded in the list. Nevertheless, it is known that PLIBEL is in constant use in many different branches and occupations over the world.

Physical and work organisational stress factors included in PLIBEL

The aim of an ergonomic screening is to identify deviations from what would be called acceptable ergonomics. This is also the approach of PLIBEL, where only specific work characteristics defined and documented as ergonomic hazards are listed. Even if the questions are extremely basic a solid ergonomic knowledge and extended experience from observations of people at work is required for a PLIBEL assessment.

In the ergonomic knowledge lies a recognition of the multifactorial nature of the concept, implying that different components e. g., organisation of work, temperature, noise and vibration, can have modifying influences on the composite ergonomic situation (49, 68). Hence, as a comprehensive approach is needed at ergonomic assessments, which is why such factors are listed at the PLIBEL chart.

Already in the title of PLIBEL; 'Method for the identification of musculo-skeletal stress factors which *may* have injurious effects' an uncertainty is expressed, which implies that the observer must interpret and integrate findings for a final decision on the ergonomic hazard. In the concluding report individual, environmental and organisational aspects should be taken into consideration and the issues be arranged by importance.

PLIBEL registers on a dichotomous level, which is different from the detailed quantitative recordings of postures and work loads that have been applied in etiologic epidemiologic studies. It is important to make clear distinctions between methods designed for such different purposes (67, 71, 74, 70). However, checklist data may well be complemented with quantitative measures (67, 62, 18, 74, 92).

Direct quantification of musculo-skeletal stress

The troublesome lack of quantitative methods for the establishment of load at work has been brought to notice among experts (67, 131, 18, 104, 49, 129, 92).

The requirements for technical expertise, for data reduction and interpretation with instrumental approaches are, however, so large that they are unlikely ever to be common tools for ergonomic workplace investigations (67). The potential for technical measurements would rather lie in accurate and detailed answers to very specific questions.

Moreover, it has been stressed that research has not yet progressed to a stage where guidelines are given for different task demands to be compared to operator capabilities (93, 104). As an only exemption the revised NIOSH LE was mentioned for comparisons of demands at lifting tasks to operator capabilities(104).

Direct quantification by the revised NIOSH LE. By the use of a computer software package both the RWL estimate and the Lifting Index, can be presented with a one decimal precision (109). In the presentation of the method it is stressed that the revised NIOSH LE is only *one* tool in a comprehensive effort to prevent low back pain and disability and that lifting, in turn, is only *one* of many possible causes of work-related pain and disability. Moreover, the authors state that the application of the revised NIOSH LE is limited to those conditions for which it was designed and list where the NIOSH LE does not apply (128).

Hereby it could be assumed that independently of the use of checklists or more sophisticated measurements, a knowledgeable ergonomist would be needed to assess the complete ergonomic situation.

Prevention

The continuum of prevention

As mentioned in the introduction this thesis, prevention can be seen as a continuum, where different preventive techniques are applied at different stages. In Papers I-VII a wide range of elements in primary, secondary and tertiary prevention were focused i. e., identification of risk factors for occupational musculo-skeletal OAs and ODs, contributing factors for accidents and influential conditions at different stages of prevention. Moreover, the studies focused on LI intervention, costs and gains at prevention and finally health, well-being and functional capacity three years after reported occupational injuries.

It has been stressed that prevention is not feasible without an understanding of the causes of health problems. Thus, the first step in the continuum of prevention is to monitor the presence of a hazard (49, 46, 33). These views were supported by the results in studies III, IV and V.

It was suggested that by surveillance, feed back can be gained regarding different stages in the continuum and preventive measures be instituted, if needed (46). Halperin differentiates between rate based and case based surveillance. At rate based surveillance, the rate of occurrence of an outcome is compared with an expected rate (46).

A rate based study. Register data was used and rates were calculated for occupational groups to understand what factors that contribute to STF accidents (Paper III).

The study highlighted the excess rates of reported STF accidents among older workers and also several urgent objectives for primary prevention. As an example it became evident that a big part of the studied male STF accidents were associated with sliding ladders. In some occupational groups this was extremely common. This finding could be of use at LI supervision. The work environment legislation

emphasises the employer's responsibility to provide adequate equipment for work that shall be performed (121).

The reported study of 1 600 reports of STF accidents could be taken as a beginning to a future understanding of the factors behind STF accidents in *all* occupational groups. To agree with Hernberg and Halperin, when discussing register data, the use of the data registered by ISA could serve as fruitful starting points for the purpose of prevention (49, 46).

Case based studies were mentioned above as another concept of surveillance. According to Halperin the occurrence of a case is a signal of a failure of prevention. He further stresses that investigation of cases leads to recognition of prevention failures and their amelioration (46). Findings in the present thesis are in accordance with these views. The main findings in Papers IV, V and VI support the idea that individual injury reports can trigger both primary and secondary prevention.

Secondary prevention

Where injury investigations had been performed and the ergonomic problem defined and described, work place improvements were more often undertaken than where no such descriptions had been produced (Paper IV). Hence, the results are in agreement with the statement from Halperin (46) and with previous studies where the need for work place investigations has been stressed (36, 62, 130, 66, 34, 68, 38, 45, 7, 33).

A strategy corresponding to that mentioned above is applied at several of the LIs in Sweden, where companies that have reported occupational injuries without adequate information, receive so called "shuttle letters". This means that, by support from the work environment legislation, incomplete injury reports are returned to the employers with a request for an injury investigation, providing complementary data (121, 86).

Primary prevention

A higher occurrence of primary preventive measures was noted where the employers had received INs from the Labour Inspectors than where no INs had been issued (Paper V). Many of the workers, who had reported the injuries were on prolonged sick-leaves or had left their positions, and were not available for secondary preventive measures. With regard to this finding, three aspects have to be emphasised.

Firstly, the results of the study defines the area of influence for LI intervention, namely primary prevention. From the study results it seems that it is already too late for secondary prevention when an occupational injury is reported. However, at most of the visited work places so called co-workers performed the same tasks as the injured man or woman had done at the time of their injury. The groups of co-workers were usually of a considerable size (Figure IX).

Where INs had been issued to the employer, there was a significant reduction of work load among co-workers. It could be assumed that by the elimination of risk factors for these healthy individuals their risk of developing occupational musculo-skeletal disorders would be reduced.

Thus, the preventive impact the inspectors may have is not to be neglected. To investigate and understand the origin of reported injuries for the purpose of primary prevention seems to be most efficient.

At future evaluations of LI activities this finding must be taken into consideration. An extended knowledge among inspectors concerning causes of work related musculo-skeletal disorders and of the LI potential regarding primary prevention, would probably strengthen their activities at work-places.

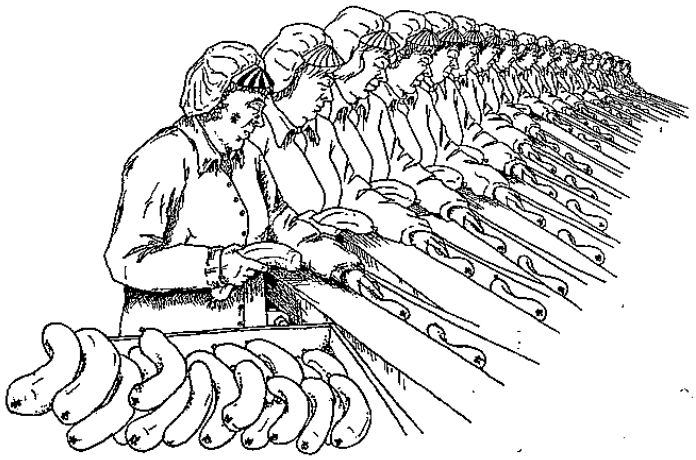


Figure IX. Due to high numbers of co-workers the preventive effects that could be achieved were often considerable. Illustration K. Kemmlert/B. Näsström.

The second aspect could be expressed in few words; It is worth issuing INs! This is a statement that links up with encouraging results recently reported. The NBOSH ergonomics programme, conducted with the purpose of raising the level of competence for ergonomic supervision, has given a positive change in supervisory activities. The number of INs, making stipulations of an ergonomic nature, have increased (90, 134).

The third aspect regards the case studies (Paper VI). It must be emphasized, that although unsatisfactory ergonomic conditions were previously known, only the reporting of an occupational injury initiated improvements. However, none of the injured workers could profit from these improvements. Their capacity was probably apprehended to be so decreased that only lighter duties could be of question. Instead the ergonomic situation of co-workers was improved by the investments. A more attentive attitude towards ergonomic matters and prevention is needed.

Predictors for a successful occupational rehabilitation

To study what the predictors are for a successful occupational rehabilitation the effect measures, reduced physical work load eighteen months after the reported injury and active employment three years after the same incidence were chosen as two relevant and well defined stages in the occupational rehabilitation process (Paper IV). As mentioned in the introduction of the thesis, these two stages have also been mentioned as important by other researchers (36, 66, 38, 33).

Reduced physical work load

For this intermediate measure an informative description of the background to the injury, was the strongest predictor (Paper IV). Hence, the results are in accordance with suggestions in above mentioned articles expressing the value of work place assessments for the identification of ergonomic hazards. By the understanding and description of an ergonomic problem the first step on the route to prevention is taken.

ODs, as compared to OAs, had a positive association with reduction of work load. This is in agreement with another study, where it was stressed that attitudes towards disease-related risks differ from those towards accident risks (7).

No other factors e. g., branch or occupation were positively or negatively associated with reduced work load. Despite the uncertainty in these results due to low numbers in certain occupations and branches, the results give a new, valuable, piece of information. Further and larger studies without restriction to branch and occupation would be valuable.

Active employment

Gender was influential for active employment (Paper IV). Men had three times increased odds for being in employment as compared to women, as has also been found by Ekberg (34). Education was another influential factor.

Many (74%) among those who had left their former positions had a higher level of education and were employed at the follow-up (Paper VII). It can be assumed that most of them had actively been searching for more suitable work (101, 35, 25, 119, 33). Punnett and Stetson both found that one third of the occupational groups they studied had changed job because of problems with hands (119) or low-back (101).

It is reasonable to surmise that a good education might be a factor that facilitates the application for an alternative employment. Hence, the results indicate that special attention as regards rehabilitation measures seems to be needed both for women and for people with lower levels of education.

There was a significant negative association between long-lasting sick-leave and active employment (Paper IV). The chronic character of musculo-skeletal occupational injuries (29, 28, 16) can of course be the explanation of the low employment rate three years after the reported injuries. But it might also be, that some among those who got long lasting sick-leaves, could through adequate rehabilitation, have been helped back to work again (27). The bad prospects of a return to work after a sick-leave of more than 6 months has been stressed by several researchers (36, 34, 38, 96).

At the design of study IV the effect measures reduced physical work load and active employment were chosen with an assumption about their interrelation.

Reduced work load was believed to be a necessary prerequisite for active employment. However, the study could not establish any positive association between these measures. Only one quarter of the original group had achieved reduced work load, instead many had left their positions and applied for new tasks. Hence, analyses could only be performed with regard to a limited group and thus, the results were not conclusive. To further establish the cause-effect relationship as regards reduction of physical work load and employment, additional studies of a prospective nature are needed.

The evaluation of preventive activities

The evaluation of prevention is important, e. g., assessments have to be performed to follow changes in individual working conditions (62, 5, 112, 34, 33) and also to gather knowledge on the effects of alternative prevention programmes (66, 68, 46). However, such evaluation is seldom performed and reported in a systematic way (112). It is suggested that controlled intervention studies are probably among the most complex that can be undertaken (66, 49).

For evaluation of prevention, the goals for the preventive activities have to be defined. Reduction in sick-leave and turn-over have been mentioned, as have positive changes in productivity (112, 39, 66, 25, 33). However, the difficulties in a use of productivity estimates became evident in Paper VI. Losses in income and gains due to changes in productivity could not be determined.

Moreover, the adequacy of using changes in morbidity as a dependant variable at the evaluation of ergonomic intervention could be questioned. Through the results of Paper VII, and other studies (29, 28, 16) the chronicity of musculo-skeletal disorders has become evident. Hence, once a musculo-skeletal disorder has developed, it may not necessarily be cured when risk factors have been eliminated. Rather, it seems reasonable to suggest the use of an intermediate effect measure like reduction of work load or improved ergonomics, for the evaluation of prevention at a work place (36, 66, 34, 38, 32, 46, 33).

The request for direct quantifying measurements that has been argued for is also certainly valid for the evaluation of preventive activities. However, methods for such quantification are not yet feasible or available. If available, findings would still have to be compared to defined risk levels to be integrated in a final composite ergonomics evaluation. It has been argued that at ergonomic evaluations the interpretation of data is more valuable than the data themselves (31).

The unsophisticated PLIBEL checklist was designed to facilitate systematic assessments of ergonomic hazards at work places and, hence, was found useful for subsequent follow-ups of possible improvements of the ergonomic situation. As advocated for surveillance systems, PLIBEL was tailored with regard to the specific type of injury, that is to be prevented (46). The implementation of PLIBEL for the surveillance of prevention is supported by Corlett who, when describing the method, states that "After changes have been introduced at a work place it is clear that the same method can be used to demonstrate any improvements which have been achieved" (23).

Economic impact of ergonomic improvements

Occupational injuries cause great costs not only to the society due to sick-leave and pension benefits but also to the injured employee and the company (10, 19, 4, 38).

In a cost/benefit study Gervais and co-workers studied compensation costs at low back pain (38). Based on positive cost/benefit analyses, they advocate an early detection of workers at risk and like other authors, suggest work place conditions and economic aspects as illustrative variables in the evaluation of intervention (118, 114, 115, 99, 66, 68, 38).

More than half a century ago, it was demonstrated how work environment activities could be evaluated including an economic aspect (48). The economy of prevention

was calculated in individual cases and the "hidden costs" to the company were demonstrated. Recently several reports have described models to visualise human factors in budgetary work, and the value of their application has been stressed (118, 115, 26, 39, 99, 15, 77, 88).

In Paper VI economic evaluations of prevention were performed. Cost and gains were made evident in monetary terms with unequivocal results; the ergonomic improvements were really worth doing. Hence, it seems to be of great importance to perform financial calculations for the purpose of stimulating more frequent and earlier preventive activities.

Well-being and functional capacity three years after a reported occupational injury

Through the three-year follow-up (Paper VII) it became evident that the rate of long lasting symptoms and functional disturbances was high among the injured. The chronicity of symptoms, demonstrated in this study, emphasises the poor prospects of recovery in cases of musculo-skeletal injuries.

Most answers from the studied group were significantly more negative than from the reference groups. Hence, in the studied group the general health was impaired. According to recent research in rehabilitation it can be assumed that shorter sick-leaves could have resulted in reduced symptoms (27). However, study VII can not answer this assumption. The results from studies IV and VII can only emphasise that long lasting sick-leaves are warning signals. The present results agree with the criticism of such sick-leaves, which have been shown to create inactivity and to limit social contacts (27). Hence, early and effective preventive measures seem essential.

There was a significantly lower occurrence of musculo-skeletal and psychological symptoms, a more positive belief in future working capacity and a greater satisfaction with present life situation in the group that experienced strong social support, than in the group with weak social support, which is in agreement with the findings in other studies (17). In study VII, it became evident that those who had received a reduced work load did not report a decrease in symptoms, but they experienced less anxiety and irritability than those who worked in unchanged conditions. The possibilities for coping had probably improved, despite remaining musculo-skeletal symptoms (22, 50).

It could be that even if a reduction in work load does not appear to lead to freedom from symptoms, it will probably prevent further impairment. As suggested by Wallace and Buckle, preventive activities may provide opportunities to continue an employment despite symptoms i.e., exert a tertiary rehabilitation effect (126).

Change of position - an alternative to prevention?

The need for earlier prevention was already discussed with regard to the four case studies, where the injured workers were transferred to lighter duties (Paper VI).

However, the transfer to another post, as a rehabilitation action, is to be questioned. In study VII it was reported that those who perceived strong social support at work, experienced less physical and psychological problems. This indicates that symptoms can be handled with a more positive attitude when a supportive social network is available, such as can be at work. However, there are evident risks that this social network could be deranged at transfers.

Nearly one third of those in employment had changed professions since the notification of the injury, mostly to less monotonous tasks (Paper VII). That a change of work can be positive from an exposure point of view was also verified in other studies (72, 33).

In Paper IV it was described that many men and women with higher level of education had left their former positions. It can be assumed that most of them did so for the purpose of finding more suitable work (101, 35, 25, 119, 33). In a long-term follow up of neck and shoulder disorders it was found that sick-leave was less frequent among injured who had changed work (32).

In a time of unemployment, it might be seen as a socially acceptable action to let employees with disorders search for another position and replace them by younger and healthier people. However, injury statistics have shown that young employees are subject to work accidents more often than experienced (8). Thus, a shift from older, injured employees to younger is no guarantee against problems (25). Apart from the lack of competence, young employees are more prone to leave an employment when experiencing unsatisfactory working conditions (118, 35).

Consequently, the need for healthy working conditions remains. It has been stressed that at replacement the probability still exists that the new employee will be affected by the work in the same way as his or her predecessor unless preventive action is taken (25).

Conclusions

The present study demonstrated a high occurrence of long lasting symptoms and functional disturbances among the injured three years after reported occupational musculo-skeletal injuries. Thus, prevention at all levels seems to be highly justified.

Studies of STF accidents could establish a higher rate of injury reports from older workers, but a similarity between age groups as regards contributing factors. Several areas for urgent primary preventive approaches were identified.

It was established that INs issued by Labour Inspectors could entail a significant influence in primary preventive measures, whereas, the identification of ergonomic problems, as expressed in an informative description of the origin of an injury, was important for secondary preventive measures. Hence, the identification and investigation of ergonomic hazards had an evident influence on prevention.

It was established that an identification of ergonomic hazards can be supported by the use of a checklist and that reliable quantitative estimates of the difficulty of a manual handling task can be obtained from measures taken by well trained specialists.

Improved ergonomic conditions were gained by one fourth of the studied group. Cost benefit analyses demonstrated positive economic consequences of such improvements.

The aims of the study are answered as follows:

* The simple checklist that was developed was found useful.
* Consistent RWL values could be obtained from well educated analysts after a one day training in measurement technique.

* STF accidents in studied occupational groups were more often reported from workers aged 45 years or more then from younger workers. As regards factors contributing to the studied STF accidents, there were no systematic age differences between older and younger workers.

* Reduced physical work load was achieved where injury reports had an informative description of the background to the injury. Male sex and higher education were positively associated with active employment three years after the injury report.

* The influence from LI intervention was evident in primary preventive measures.

* When costs and gains, associated with ergonomic improvements, were identified, it became evident that investment costs were paid back in a short period of time.

* Many of the injured had not recovered since the time of the injury report. They had more physical and psychological problems than reference populations. Only half the studied group was in active employment after three years.

Suggestions for a more efficient prevention of occupational musculo-skeletal injuries

With respect to the results in this study it seems reasonable to suggest:

- A continued development and implementation of simple screening methods for the identification of ergonomic risks at work places.

- A continued evaluation of direct measurement techniques for the establishment of ergonomic risks at work places, including training in real settings.

- A more widespread use of registered occupational injury data and occupational environment data for the estimation of injury rates and an identification and exploration of cases.

- An active approach at LIs in cases of occupational musculo-skeletal disorders.

- A prompt implementation of secondary preventive measures for the avoidance of long-lasting sick-leaves.

- A more observant attitude to musculo-skeletal accidents.

- Intensified prevention against STF accidents with special emphasis on groups that comprise workers aged 45 years or more.

- Initiation of more effective rehabilitation measures for women and for people with lower levels of education.

- The application of financial calculations for the purpose of stimulating more frequent and earlier preventive activities.

Summary

Kristina Kemmlert. On the Identification and Prevention of Ergonomic Risk factors. With Special Regard to Reported Occupational Injuries of the Musculo-skeletal system. *Arbete och Hälsa* 1997;2: 1-49.

A checklist for the screening of ergonomic risks was designed, evaluated and applied at work place assessments. Training for measurements for the NIOSH lifting equation was described and the inter-observer reliability discussed. With a view to prevention and with an age perspective, 1 600 textual descriptions of slip trip and fall accidents were studied. Older people reported accidents of this kind more often than younger, but as regards contributing factors for the accidents there were no age differences in the studied material.

Reports (n=195) on occupational musculo-skeletal injury (accidents and diseases) from men and women with different occupations were collected consecutively. The purpose was to investigate the effect on ergonomic conditions by Labour Inspectorate intervention at work places and to follow health and employment among occupationally injured. Fifteen Labour Inspectors volunteered to investigate half of the reports by work place visits within three months. The other half was kept for control. The inspectors were trained in ergonomics and also received complementary training in ergonomic work place assessment by means of the mentioned checklist.

Eighteen months after the reports, all work places were visited by ergonomists to evaluate possible improvements in ergonomic conditions. Due to turn-over and prolonged sick-leaves, evaluations were performed for only 92 of the injured. At 160 work places there were co-workers, who at the time of the injury report had performed similar tasks as the injured. Evaluations were performed also for these groups.

As regards preventive measures, there were no differences between the injured in the study and control groups. The inspectors had delivered eleven inspection notices to the employers demanding improvements for the injured people and fourteen notices regarding the conditions of co-workers. For this latter group there was a significant association between delivered notices and improved ergonomic conditions.

The cost benefit of the ergonomic improvements was investigated in case studies from four companies. Poor workplace ergonomics and related musculo-skeletal problems had been known previous to the injury reports. The ergonomic situation had caused repeated sick-leave periods, but only the report triggered the preventive measures. Expenses associated with the preventive measures were accounted for and financial effects estimated, based on interviews with representatives at the companies. When costs were compared to gains, the improvements appeared to be highly profitable.

Three years after the time of the reports a postal questionnaire on health, psychological well-being and employment was distributed to the injured. The response rate was high. There was a significantly higher prevalence of musculo-skeletal and psychological symptoms in the study group, compared to data from other populations. Activities in daily life were more restricted in the study group. After three years 109 people were in active employment.

The association between reduced physical work load and active employment, and both individual and work related characteristics was analysed. The odds for improved ergonomic conditions were increased where the employer had given an informative

injury description in the injury report, probably indicating that an understanding of the mechanisms of injury is a prerequisite for effective prevention. Sick-leaves for more than six months during the year following the report had a significant negative association with active employment, whereas male sex and higher education than elementary school had a positive association. Identification of ergonomic risk factors seemed to have a positive influence on the process of prevention.

Key words: Cost benefit analysis, ergonomics, labour inspection, occupational musculo-skeletal injury, prevention, rehabilitation, work place assessment.

Sammanfattning (summary in Swedish)

Kristina Kemmlert. On the Identification and Prevention of Ergonomic Risk factors. With Special Regard to Reported Occupational Injuries of the Musculo-skeletal system. *Arbete och Hälsa* 1997;2: 1-49.
Föreliggande forskningsarbete har utförts vid Enheten för Ergonomi och Psykologi, Arbetslivsinstitutet, Solna, Enheten för Rehabilitering och Fysikalisk Medicin, Institutionen för Kirurgi, Karolinska Institutet, Solna, Institutionen för Arbetsvetenskap, Luleå Tekniska Universitet och vid Avdelningen förMedicinska och Sociala frågor, Arbetarskyddsstyrelsen, Solna.

Syftet med studien var att undersöka hur förbättrad prevention kan uppnås beträffande belastningsskador och fall olyckor, samt att identifiera vilka individ- och arbetsknutna faktorer som har betydelse för uppkomst och prevention av sådana skador.

Som underlag för de arbetsplatsbedömningar som utfördes i projektet utformades en checklista, Plan för identifiering av belastningsfaktorer som kan innebära skadlig inverkan, PLIBEL. De förberedande litteraturstudierna rörande samband mellan belastning i arbete och skador i rörelseorganen samt validitets- och reliabilitets-test av metoden beskrivs och diskuteras.

Vidare beskrivs och diskuteras träning i datainsamling för kvantitativa beräkningar med NIOSH lyft-ekvation samt ett test av inter-bedömar reliabiliteten med denna metod.

Ur ett vidgat ergonomiskt perspektiv, och med sikte på prevention, har beskrivningar från 1 600 arbetsskadenmälningar rörande fall olyckor studerats. Uppgifterna ordnades med hänsyn till påverkande faktorer, ålder, kön och yrke. Äldre arbetstagare rapporterade fall olyckor oftare än yngre personer, men beträffande orsakerna till olyckorna var det ingen skillnad mellan äldre och yngre i det studerade materialet.

För att undersöka om arbetsplatsutredningar utförda av yrkesinspektörer medför en förbättrad prevention på arbetsplatser efter anmäld arbetsskada insamlades 195 konsekutiva arbetsskadeanmälningar av belastningskaraktär (55 arbetsolyckor och 140 arbetssjukdomar) från män och kvinnor i olika åldrar och sysselsatta inom olika yrken och branscher.

Arbetsskadorna hade samtliga föranlett minst åtta dagars sjukskrivning. Könsfördelning, åldersfördelning samt fördelning över yrken och näringsgrenar

överensstämnde i stort med statistik uppgifter rörande belastningsskador för riket samma år, medan materialets fördelningen mellan olyckor och sjukdomar endast överensstämde regionalt, dvs. i förhållande till hela riket var sjukdomarna överrepresenterade.

Femton ergonomiskt kunniga yrkesinspektörer engagerades för projektet och utbildades under två dagar i användandet av checklistan, varvid ergonomiska grundprinciper gicks igenom och tillsynsmetodik diskuterades för att nå ett enhetligt tillvägagångssätt.

Sedan hälften av anmälningarna från distriktskontoren hade lagts till sidan som kontroll material ombads yrkesinspektörerna att inom några veckor besöka övriga arbetsskadeanmälda på deras arbetsplatser. Belastningssituationen skulle bedömas och förändringar anbefallas i ett inspektionsmeddelande såsom brukligt.

Vid dessa besök skrevs tjugo inspektionsmeddelanden. Den arbetsskade-anmäldes arbetsförhållanden berördes i elva av dessa medan fjorton tog upp förhållandena för arbetskamrater med liknande arbetsuppgifter som den anmälde. Arton månader efter det att anmälningarna lämnats in besökte tre ergonomer samtliga arbetsplatser utan vetskap om huruvida de tillhörde kontrollgruppen eller inte. Information inhämtades om ergonomiska förhållanden vid anmälan och belastningsbedömning gjordes liksom en bedömning av eventuella genomförda förbättringar. På 172 arbetsplatser hade arbetskamrater vid anmälningstillfället utfört likadana arbetsuppgifter som den arbetsskadeanmälde. Bedömningar, enligt ovan, gjordes även på dessa arbetsplatser. Skillnader beträffande genomförda arbetsplatsförbättringar mellan yrkesinspektörs gruppen och kontroll gruppen prövades med x^2-test, varvid en signifikans nivå på $p<0.05$ accepterades.

En signifikant skillnad beträffande genomförda arbetsplatsförbättringar kunde observeras för arbetskamrater i de fall inspektionsmeddelande lämnats till arbetsgivarna. Däremot kunde ingen effekt av yrkesinspektörernas besök konstateras hos arbetsskadefallen. Den inverkan yrkesinspektörerna hade låg således inom primärpreventionen.

För att bedöma kostnader och vinster i samband med arbetsplatsförbättringar genomfördes fyra fall-studier. Två ekonomistuderande kopplades till projektet och utförde intervjuer angående åtgärder vidtagna av arbetsgivare vid fyra företag. Intervjuer på arbetsplatserna visade att de dåliga ergonomiska förhållandena varit kända sedan länge och även förorsakat upprepade sjukskrivningar. Men det var först när arbetsskadan hade anmälts, som åtgärder vidtogs. Vid de fyra arbetsplatser, som ingick i denna begränsade studie, var de arbetsskadeanmälda kvar i arbete, men utförde inte längre samma arbete som vid anmälningstillfället. De hade fått skonsammare uppgifter. De förbättringar som arbetgivaren vidtagit vid den ursprungliga arbetsplatsen kom således endast arbetskamrater till del.

Uppgifterna om kostnader och intäkter i samband med de preventiva åtgärderna togs fram av företagets representanter via räkenskapsböcker och personalstatistik. Där ej dokumentation fanns tillgänglig gjordes skattningar. Genom analyser av sjukskrivning, överanställning, vikarier etc. kunde många dolda utgifter och vinster tydliggöras. Efter pay-back beräkningar av det insamlade materialet visade det sig att utgifterna för de ergonomiska förbättringarna mycket snart var betalda.

Omfattningen av muskulo-skelettala besvär, psykiskt välmående och funktionsförmåga, tre år efter den anmälda belastningsskadan, följdes genom en brevenkät, som besvarade av 181 av de arbetsskadeanmälda (93%). För att möjliggöra jämförelser baserades formuläret på frågor, som ingår i andra publicerade undersökningar. Respondenterna ombads även beskriva hur mycket de varit i arbete sedan skadeanmälan. Jämförelser mellan grupper prövades med x^2-test, varvid en signifikans nivå på $p<0.05$ accepterades.

Gruppen av arbetsskadeanmälda hade som helhet mer fysiska och psykiska besvär än jämförelsegrupper. Hälften av de intervjuade uppgav att de hade svårigheter med vardagliga aktiviteter och över hälften bedömde sina besvär som oförändrade eller värre jämfört med då arbetsskadan anmäldes. 109 personer uppgav att de var aktivt yrkesverksamma. De flesta av de 72 som ej arbetade hade ej arbetat alls under de tre år som förflutit.

För att identifiera vilka individ- och arbetsknutna faktorer som har betydelse för en lyckad rehabilitering efter anmälda belastningsskador användes data från olika delar av projektet. Från arbetsskadeblanketterna hämtades persondata, diagnos vid anmälningstillfälle samt uppgifter om yrke och näringsgren. Även den bedömda kvalitén i blankettens beskrivning av orsaken till skadan ingick liksom uppgifter om belastningsreducering på arbetsplatsen och om sjukskrivning, som samlats in vid arbetsplatsbesöket 18 månader efter anmälnings-tillfället. Slutligen ingick också uppgifter om utbildning och yrkesverksamhet, vilka hämtades från tre års uppföljningen.

Som två mått på lyckad rehabilitering användes 'reducerad belastning arton månader efter anmäld belastningsskada' samt 'yrkesverksamhet tre år efter anmälan'. Multipel logistisk regression utnyttjades för att analysera vilka oberoende faktorer som hade samband med de två effektmåtten. Den chans som respektive oberoende variabel betingade beräknades i form av ett OR värde och ett 95% konfidensintervall angavs för varje sådant estimat.

En väsentligt förhöjd chans till reducerad arbetsbelastning förelåg vid en informativ beskrivning av arbetsskadans orsak, medan chansen till förbättrad ergonomi var liten vid arbetsolyckor. När det gällde yrkesverksamhet var kön, utbildning och sjukskrivningslängd inflytelserika faktorer. Män och personer med högre utbildning hade större chanser till yrkesverksamhet. Chansen att vara i arbete efter en sjukskrivningsperiod som överskridit sex månader, under året efter anmälan, var mycket liten.

Studien visar att de besvär, som föranledde anmälan av belastningsskada, var mycket långvariga och det fanns indikationer på att sekundärpreventiva åtgärder kom allltför sent. Tidig prevention av belastningsskador torde därför vara viktig. Att identifiera och definiera problem samt att verbalisera dem på arbetsskadeanmälningar och i inspektionsmeddelanden förefaller att vara av högsta värde. Där en anlyserande process satts igång har samtidigt ett första steg mot problemlösningar tagits - resultat som är värda att ta fasta på när det gäller att förbättra preventionen av arbetsskador. Beträffande yrkesverksamhet var individuella faktorer som kön och utbildning inflytelserika, vilket är svårare att bemöta inom ramen för prevention.

Det finns all anledning att pröva och fortsatt utveckla både enkla screening metoder för identifiering av ergonomiska risker och kvantitativa metoder för storleksbedömning av specifika variabler.

Nyckelord: Arbetsplatsbedömning, belastningsskada, ergonomi, pay-back beräkning, prevention, rehabilitering, yrkesinspektion.

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References

1. Aarås A. The impact of ergonomic intervention on individual health and corporate prosperity in a telecommunications environment. *Ergonomics* 1994; 37: 1679-1696.
2. Ahlbom A. *Biostatistics for epidemiologists*. Boca Raton, Florida, USA Lewis publishers, 1993.
3. Ahonen G. *The costs of occupational accidents and diseases in the Nordic countries*. Niva, Helsinki, Finland 1994; 3.
4. Ahonen M, Ilmarinen, Kuorinka I, Launis M, Lehtelä J, Leskinen T, Luopajärvi T, Saari J, Seppälä P, Stålhammar H. *Ergonomic workplace analysis*. Finnish Institute of Occupational Health, Ergonomics section, Helsinki, Finland 1989.
5. Amendments to the Work Environment Act etc. with effect from 1st July, 1991. *Newsletter* 1991; 3: 1-5.
6. Andersson K, Hahne M. Compilation and testing of questionnaires in occupational health. Experiences from the Örebro system. In: Eustache IE, ed. *XXI International Congress on Occupational Health*, Dublin, Ireland 1984: 706.
7. Andersson R. *The role of accidentology in occupational research*. Department of Social Medicine, Karolinska Institute, Stockholm, Sweden 1991. PH. D. Thesis.
8. Andersson R, Kemmlert K, Kilbom Å. Etiological differences between accidental and non-accidental occupational overexertion injuries. *J Occup Accid* 1990; 12: 177-186.
9. Andersson R, Lagerlöf E. Accident data in the new Swedish information system on occupational injuries. *Ergonomics* 1983; 26: 33-42.
10. Andreoni D. *The cost of occupational accidents and diseases*. Occupational safety and health series, International Labour Organisation, Geneva 1986; 54.
11. *Anmälda arbetssjukdomar i Norden*. Nordiska Ministerrådet, Copenhagen, Denmark 1996.
12. *Annual survey of occupational injuries and illnesses*. Bureau of Labour Statistics, US Dapartment of Labor, Washington, DC 1995.
13. *Arbetssjukdomar och arbetsolyckor 1994* (Occupational diseases and occupational accidents 1994, in Swedish, summary in English). National Board of Occupational Safety and Health, Solna, Sweden 1996.
14. *Arbetsställninar arbetsrörelser och lyft* (Work postures, work movements and manual materials handling, in Swedish). Swedish University of Agricultural Sciencies, Lund 1987.
15. Aronsson T, Malmquist C. *Rehabiliteringens ekonomi*. Utbildningsförlaget, Brevskolan, Stockholm 1996.
16. Berg M, Sandén Å, Torell G, Järvholm B. Persistence of musculoskeletal symptoms: A longitudinal study. *Ergonomics* 1988; 31: 1281-1285.
17. Bongers PM, de Winter CR, Kompier MAJ, Hildebrandt VH. Psychosocial factors at work and musculoskeletal disease. *Scand J Work Environ Health* 1993; 19: 297-312.
18. Burdorf A. Exposure assessment of risk factors for disorders of the back in occupational epidemiology. *Scand J Work Environ Health* 1992; 18: 1-9.
19. Bylund B, Remaeus B. Den kostsamma ohälsan. *Miljön på jobbet* 1996; 1: 28-37.
20. Carmines EG, Zeller RA. *Reliability and validity assessment*. London: Sage Publications, 1979.
21. *Characteristics of injuries and illnesses resulting in absence from work 1994*. Bureau of Labor Statistics, US Department of Labor, Washington, DC 1996.
22. Cohen S, Syme L, eds. *Social support and health*. New York: Academic Press, 1985.
23. Corlett EN. Static muscle loading and the evaluation of posture. In: Wilson JR, Corlett EN, eds. *Evaluation of human work*. London: Taylor & Francis, 1990.
24. Cumulative trauma disorders: prevention evaluation and treatment. In: Michael E, Dickerson B, eds. *Library of Congress cataloging-in-publication data*. New York: Van Nostrand Reinhold, 1997.
25. Dahlén P. *Labor stability in the justification of advanced manufacturing systems*. Department of Production and Materials Engineering, Lund, University, Lund, Sweden 1995. PH. D. Thesis.

26. Dahlén PG, Wernersson S. Human factors in the economic control of industry. *Ind Erg* 1995; 15: 215-221.

27. Derebery VJ, Tullis WH. Low back pain exacerbated by psychosocial factors. *West J Med* 1986; 144: 574-579.

28. Derriennic F, Iwatsubo Y, Monfort C, Cassou B. Evolution of osteoarticular disorders as a function of past heavy physical work factors: longitudinal analysis of 627 retired subjects living in the Paris area. *BR J Ind Med* 1993; 50: 851-860.

29. Dionne C, Turcotte F. Coping with low-back pain: Remaining disabilities 5 years after multidisciplinary rehabilitation. *J Occup Rehab* 1992; 2: 73-88.

30. *Don't neglect profitable information on work injuries*. ADI 399, National Board of Occupational Safety and Health, Solna, Sweden 1990.

31. Drury CG. Methods for direct observation performance. In: Wilson JR, Corlett EN, eds. *Evaluation of human work*. London: Taylor & Francis, 1990: 35-57.

32. Ekberg K. Rehabilitation of neck and shoulder disorders - a long-term follow up. *The 24th International Congress on Occupational Health*, ICOH, Nice, France 1993: 123.

33. Ekberg K. Workplace Changes in Successful Rehabilitation. *J Occup Rehab* 1995; 5: 253-269.

34. Ekberg K, Wildhagen I. Long-term sickness absence due to musculoskeletal disorders: the necessary intervention of work conditions. *Scand J Rehab Med* 1996; 28: 39-47.

35. Eriksson K. *Jag slutar! Individuell konfliktlösning i arbetslivet* (I quit! Individal dispute resolution in working life. In Swedish, summary in English). Department of Sociology of Law, Lund University, Lund, Sweden 1991. PH. D. Thesis.

36. Feuerstein M, Menz L, Zastowny T, Barron B. Chronic back pain and work disability: Vocational outcomes following multiciplinary rehabilitation. *J Occup Rehab* 1994; 4: 229-251.

37. Fleiss JL. *Statistical methods for rates and proportions*. New York: John Wiley & Sons, 1981.

38. Gervais S, Dupuis G, Véronneau F, Bergeron Y, Millette D, Avard J. Predictive model to determine cost/benefit of early detection and intervention in occupational low back pain. *J Occup Rehab* 1991; 1: 113-131.

39. Gröjer J, Johansson U. *Human resource costing and accounting*. Joint Industrial Safety Council, Stockholm, Sweden 1991.

40. Hagberg M. Occupational musculoskeletal disorders - a new epidemiological challenge? In: Reuterwall C, Hogstedt C, eds. *Progress in occupational epidemiology,* Amsterdam: Elsevier Science Publisher, 1988.

41. Hagberg M. Exposure variables in ergonomic epidemiology. *Am J Ind Med* 1992; 21: 91-100.

42. Hagberg M. Pathomechanisms of work-related musculo-skeletal disorders. In: Rantanen J, Lehtinen S, Kalimo R, Nordman H, Vano H, Viikari-Juntura E, eds. *New epidemics in occupational health*, Helsinki, Finland 1994: 42-53.

43. Hagberg M, Kilbom Å, Buckle P, Fine LJ, Itani T, Läubli T, Riihimäki H, Silverstein BA, Sjögaard G, Snook SH, Viikari-Juntura E. Strategies for prevention of work-related musculo-skeletal disorders: Consensus paper. *Int J Ind Ergon* 1993; 11: 77-81.

44. Hagberg M, Silverstein B, Wells R, Smith MJ, Hendrick HW, Carayon P, Pérusse M. *Work related musculoskeletal disorders (WMSDs): a reference book for prevention*. London: Taylor and Francis, 1995.

45. Hagberg M, Wegman DH. Prevalence rates and odds ratios of shoulder-neck diseases in different occupational groups. *Brit J Ind Med* 1987; 44: 602-610.

46. Halperin W. The role of surveillance in the hierarchy of prevention. *Am J Ind Med* 1996; 29: 321-323.

47. Hartmann DP. Considerations in the choice of interobserver estimates. *Am J Ind Med* 1977; 10: 103-116.

48. Heinrich HW. *Industrial accident prevention*. New York: McGraw-Hill Book Company, 1931.

49. Hernberg S. *Introduction to occupational epidemiology*. Chelsea, Michigan, USA: Lewish Publishers, 1992.

50. House JS. *Work, stress and social support*. London: Addison Wesley, 1981.

51. *Identification and control of work-related diseases*. Report of a WHO Expert Committee, WHO, Geneva 1985.

52. Ilmarinen J, Tuomi K, Eskelinen L, Nygård C-H, Huuhtanen P, Klckars M. The aging worker; Background and objectives of cross sectional follow-up studies in the Finnish municipal bransch (1981-1985). *Scand J Work Environ Health* 1991; 17: 1-9.

53. *Inspektionsmetodik*. (Methods for inspection, in Swedish). National Board of Occupational Safety and Health, Solna, Sweden 1983.

54. Jakobsson M. Assessment of the work place by workers and observer. A comparison. In: Nielsen R, Jørgenssen K, eds. *Advances in Industrial Ergonomics and Safety V*, Copenhagen, Denmark 1993: 149-153.

55. Jonsson BG, Persson J, Kilbom Å. Disorders of the cervicobrachial region among female workers in the electronics industry. *Int J Ind Ergon* 1988; 3: 1-12.

56. Karhu O, Kansi P, Kuorinka I. Correcting working posture in industry: A practical method for analysis. *Appl Ergon* 1977; 8:199-201.

57. Kelsey JL, Golden AL. Occupational and workplace factors associated with low back pain. *Occup Med* 1988; 3: 7-16.

58. Kemmlert K. Reduction of reported occupational musculo-skeletal injuries. *12th Triennal congress of the International Ergonomics Association*, Toronto, Canada 1994: 196-198.

59. Kemmlert K, Dallner Örelius M, Kilbom Å, Gamberale F. Treårsuppföljning av 195 arbetsskadeanmälningar av belastningskaraktär (A three year follow up of 195 reported occupational overexertion injuries, in Swedish, summary in English). *Arbete och Hälsa* 1990; 47: 1-39.

60. Kemmlert K, Nilsson B, Kilbom Å, Andersson R, Bjurvald M. Ergonomiska förhållanden och arbetsskadehantering - en studie av 195 arbetsskadeanmälningar. *Arbete och Hälsa* 1989; 33: 1-54.

61. Keyserling M, Punnett L, Fine LJ. Trunk posture and back pain: Identification and control of occupational risk factors. *Appl Ind Hyg* 1988; 3: 87-92.

62. Keyserling WM, Armstrong TJ, Punnett L. Ergonomic job analysis: A structured approach for identifying risk factors associated with overexertion injuries and disorders. *Appl Occup Environ Hyg* 1991; 6: 353-363.

63. Keyserling WM, Brouwer M, Silverstein BA. A checklist for evaluating ergonomic risk factors resulting from awkward postures of the legs, trunk and neck. *Int J Ind Ergon* 1992; 9: 283-301.

64. Keyserling WM, Stetson DS, Silverstein BA, Brouwer ML. A checklist for evaluating ergonomic risk factors associated with upper extremity cumulative trauma disorders. *Ergonomics* 1993; 36: 807-831.

65. Keyserling WM, Wittig SJ. An analysis of experts' ratings of ergonomic stress. *Int J Ind Ergon* 1988; 2: 291-304.

66. Kilbom Å. Intervention programmes for work-related neck and upper limb disorders: strategies and evaluation. *Ergonomics* 1988; 31: 735-747.

67. Kilbom Å. Assessment of physical exposure in relation to work-related musculoskeletal disorders - what information can be obtained from systematic observations? *Scand J Work Environ Health* 1994; 20: 30-45.

68. Kilbom Å, Armstrong T, Buckle P, Fine L, Hagberg M, Haring-Sweeney M, Martin B, Punnett L, Silverstein B, Sjøgaard G, Theorell T, Viikari-Juntura E. Musculoskeletal disorders: Work-related risk factors and prevention. *Int J Occup Environ Health* 1996; 2: 239-46.

69. Kilbom Å, Bjurvald M. Ergonomics and musculoskeletal injuries. *Ind Erg* 1988; 2: 168-172.

70. Kilbom Å, Horst D, Kemmlert K, Richter A. Observationsmetoder för registrering av belastningar på rörelseapparaten - en litteraturstudie (Observation methods for the registration of occupational musculo-skeltal stress - a literature review, in Swedish, summary in English). *Arbete och Hälsa* 1986; 21: 1-90.

71. Kilbom Å, Jörgensen K, Fallentin N. Belastningsregistrering i yrkesarbete- en jämförelse mellan observationsmetoder, fysiologiska mätningar och subjektiv skattning (Assessment of musculo-skeletal stress at work - a comparison between observation methods, physiological/postural measurements and subjective ratings of exertion, in Swedish, summary in English). *Arbete och Hälsa* 1989; 38: 1- 56.

72. Kirjonen J, Häninnen V. Getting a better job. Antecedents and effects. *Hum Relat* 1986; 39: 503-516.

73. Kirkwood B. *Essentials of medical statistics*. London: Blackwell Scientific Publications, 1988.

74. Kirwan B, Ainsworth LK. *A guide to task analysis*. London: Taylor and Francis, 1992.

75. Kleinbaum D, Kupper L, Morgenstern H. *Epidemiologic research*. New York: Van Nostrand Reinhold company, 1982.

76. Kuorinka I, Jonsson B, Kilbom Å, Vinterberg H, Biering-Sörensen F, Andersson G. Standardised Nordic Questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon* 1987; 18: 233-237.

77. Kupi E, Liukkonen P, Mattila M. Staff use of time and company productivity. *Nordisk Ergonomi* 1993; 4: 9-11.

78. Laflamme L. Age-realted accident ratios in assembly work: A study of female assembly workers in the automobile industry. *Safety Science* 1996; 23: 27-37.

79. Laflamme L, Menckel E. Ageing and occupational accidents. A review of the literature of the last three decades. *Safety Science* 1995; 21: 145-161.

80. Laflamme L, Menckel E, Lundholm L. The age-related risk of occupational accidents; the case of Swedish iron-ore miners. *Accid Anal and Prev* 1996; 28: 349-357.

81. Laflamme L, Menckel E, Lundholm L. Ageing and occupational accidents, 2. *Arbete och Hälsa* 1996; 11 1-30 (appendix 13 p).

82. Laflamme L, Menckel E, Strömberg A. Age and occupational accidents among Swedish nurses. *Work after 45?*, Stockholm, Sweden 1996: 66-57.

83. Landis R, Koch G. The measurement of observer agreement for categorical data. *Biometrics* 1977; 33: 159-174.

84. Leamon TB, Murphy PL. Occupational slips and falls: more than a trivial problem. *Ergonomics* 1995; 38: 487-498.

85. *Levnadsförhållanden 1975-83*. (Living conditions 1975-83, in Swedish). Statistics Sweden, Stockholm 1985.

86. Lindén AE. The use of a national information system for work induced injuries. A local and regional perspective. *J Occup Acc* 1990; 12: 191-197.

87. Lindmark B. Evaluation of functional capacity after stroke with special emphasis on motor function and activities of daily living. *Scand J Rehab Med* 1988; 21:1-40.

88. Liukkonen P. *Vad kostar frånvaron* (Costs of absenteism, in Swedish). Svenska Arbetsgivarföreningen, Stockholm 1989.

89. Lundberg L. *Från lag till arbetsmiljö*. (From law to work environment, in Swedish). Department of Business Studies, Uppsala University, Uppsala, Sweden 1982. PH. D. Thesis.

90. Making the Labour Inspectorate more visible. *Newsletter* 1993; 2: 3.

91. Malker H. *Register-epidemiology in the identification of cancer risks*. Department of Work Science, Royal Institute of Technology, Stockholm, Sweden 1988. PH. D. Thesis.

92. Marras W. Quantifying physical exposure at the workplace. In: Sjøøgaard G, Fallentin N, eds. *Risk assessments for musculoskeletal disorders,* Copenhagen, Denmark 1996: 49-52.

93. Marras WS, Lavender SA, Leurgans SE, Fathallah FA, Ferguson SA, Allread WG, Rajulu SL. Biomechanical risk factors for occupationally related low back disorders. *Ergonomics* 1995; 38: 377-410.

94. Mc Atamney L, Corlett EN. R. U. L. A - A survey method for the investigation of work related upper limb disorders. *Appl Ergon* 1992; 24: 91-99.

95. McNamee R, Kemmlert K, Lundholm L. Occupational injury among women due to slips, trips and falls. The 25th *International Conference on Occupational Health, ICOH*. Stockhom, Sweden 1996: 69.

96. Nachemson A. Work for all. For those with low back pain as well. *Clin Orthop* 1983; 179: 77-85.

97. Nilsson B, Andersson R, Kilbom Å, Kemmlert K. *Prevention av belastningsskador genom riktad arbetsskadeutredning*. (Prevention of overexertion injuries by workplace assessment, in Swedish, summary in English). Undersökningsrapport, National Institute of Occupational Health, Solna, Sweden 1990; 9: 1-26.

98. Nordin H. ISA - Sweden's occupational injury information system; inflow of information. Unpublished papers, National Board of Occupational Safety and Health, Solna, Sweden 1993: 1-5.

99. Oxenburgh M. *Increasing productivity and profit through health and safety*. Sydney, Australia: CCH, 1991.

100. *Plan of activities of the Swedish occupational safety and health administration 1997-1999*. ADI 483E, National Board of Occupational Safety and Health, Solna, Sweden 1997 (in press 1977).

101. Punnett L, Fine L, Keyserling WM, Herrin G, Chaffin DB. Back disorders and nonneutral trunk postures of automobile assembly workers. *Scand J Work Environ Health* 1991; 17: 337-46.

102. Punnett L, Keyserling WM. Exposure to ergonomic stressors in the garment industry: application and critique of job-site analysis methods. *Ergonomics* 1987; 30: 1099-1116.

103. Rey P, Bousquet A. Compensation for occupational injuries and diseases: its effect upon prevention at the workplace. *Ergonomics* 1995; 38: 475-486.

104. Reynolds JL, Drury CG, Broderick RL. A field methodology for the control of musculoskeletal injuries. *Appl Ergon* 1994; 25: 3-16.

105. Riihimäki H. *Back disorders in relation to heavy physical work*. Department of Epidemiology and Biostatistis, University of Helsinki, Finland 1990. PH. D. Thesis.

106. Riihimäki H. Low-back pain, its origin and risk indicators. *Scand J Work Environ Health* 1991; 17: 81-90.

107. Rohmert W, Landau K. *A new technique for job analysis*. London: Taylor & Francis Ltd, 1983.

108. Rothman KJ. *Modern epidemiology*. Boston: Little Brown and Company, 1986.

109. Safetysoft I. *Lift guide user's manual*. Westlake, Ohio, USA 1994.

110. SAS Institute Inc. *SAS user's guide: Statistics*. Cary, North Carolina, USA 1985.

111. Silverstein B. Risk assessments for work-related musculoskeletal disorders in US regulatory activity: OSHA draft Ergonomic Protection Standard of 1995. In: Sjøøgaard G, Fallentin N, eds. *Risk assessments for musculoskeletal disorders*. Copenhagen, Denmark 1996: 69-72.

112. Silverstein BA. Evaluations of interventions for control of cumulative trauma disorders. In: *Ergonomic interventions to prevent musculoskeletal injuries*. American Conference of Governmental Industrial Hygienists. Chelsea, Michigan, USA: Lewis Publishers Inc, 1986: 87-99.

113. Silverstein BA, Fine LJ, Armstrong TJ. Hand wrist cumulative trauma disorders in industry. *Br J Ind Med* 1986; 43: 779-784.

114. Simpson G. Economic analysis in ergonomics. In: Wilson JR, Corlett EN, eds. *Evaluation of human work*. London: Taylor and Francis, 1990: 798-816.

115. Simpson GC. The economic justification for ergonomics. *Int J Ind Erg* 1988; 2: 157-163.

116. *Social insurance statistics*. National Social Insurance Board, Stockholm 1990.

117. Sommerich CM, Mc Glothlin J, Marras WS. Occupational risk factors associated with soft tissue disorders of the shoulder: A review of recent investigations in the literature. *Ergonomics* 1993; 36: 697-717.

118. Spilling S, Eitrheim J, Aarås A. Cost-benefit analysis of work environment investment at STK's telephone plant at Kongsvinger. In: Corlett N, Wilson J, Manenica I, eds. *The ergonomics of working postures*. London: Taylor & Francis, 1986: 380-397.

119. Stetson DS, Armstrong TJ, Fine LJ, Silverstein BA, Tannen K. A survey of chronic upper extremity disorders in an automobile upholstery plant. In Karwowski W, ed. *Trends in Ergonomics/Human Factors III, Part B*. Annual International Industrial Ergonomics and safety Conference, Louisville, Kentucky, USA 1986: 623-630.
120. Stock SR. Workplace ergonomic factors and the development of musculoskeletal disorders of the neck and upper limbs: A meta-analysis. *Am J Ind Med* 1991; 19: 87-107.
121. *Swedish work environment legislation*. National Board of Occupational Safety and Health, Solna, Sweden 1994.
122. *The Occupational Safety and Health Reporter*. Bureau of National Affairs, Washington, DC, USA 1995: (Special supplement, March 22).
123. *The working environment. 1995*. Statistics Sweden, 1996.
124. Vingård E, Hogstedt C, Alfredsson L, Fellenius E, Goldie I, Köster M. Coxarthrosis and physical work load. *Scan J Work Environ Health* 1991;17: 104-109.
125. Vink P. Towards a field usable biomechanical typology of work. *International Society of Electrophysiological Kinesiology*, Baltimore, USA 1991: 161-164.
126. Wallace M, Buckle P. Ergonomic aspects of neck and upper limb disorders. *Int Rev Ergon* 1987; 1: 173-200.
127. Waters TR, Putz-Anderson V, Garg A, Fine LJ. Revised NIOSH equation for the design and evaluation of manual lifting tasks. *Ergonomics* 1993; 36: 749-776.
128. Waters TW, Putz-Anderson V, Garg A. *Applications manual for the revised NIOSH lifting equation*. US. Department of Health and Human Services, Cincinnati, OHIO, USA 1994.
129. Wiktorin C. *Occupational physical load in epidemiological studies - developement and evaluation of methods*. Department of Occupational Health, Karolinska Hospital, Solna, Sweden 1995. PH. D. Thesis.
130. Wilson JR. A framework and a context for ergonomics methodology. In: Wilson JR, Corlett EN, eds. London: Taylor & Francis, 1990: 1-24.
131. Winkel J, Mathiassen SE. Assessment of physical work load in epidemiologic studies: concepts issues and operational considerations. *Ergonomics* 1994; 37: 979-988.
132. Winkel J, Westgaard RH. Occupational and individual risk factors for shoulder-neck complaints: Part II- The scientific basis (literature review) for the guide. *Int J Ind Ergon* 1992; 10: 85-104.
133. *Work postures and working movements*. National Board of Occupational Safety and Health, Solna, Sweden 1993.
134. Zätterström P. *The ergonomics programme - follow up and evaluation*. National Board of Occupational Safety and Health, Solna, Sweden 1995.

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