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National Institute for Working Life – Ergonomic Expert Committee Document No 1

Visual Display Unit Work and Upper Extremity Musculoskeletal Disorders

A Review of Epidemiological Findings

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arbete och hälsa vetenskaplig skriftserie
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National Institute for Working Life

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Förord 1

TCO anförde i en skrivelse till Arbetslivsinstitutet (Arbetslivsinstitutets diarienummer 732/95) att den forskning som idag bedrivs avseende belastningsskador har ingen eller mycket liten relevans för tjänstemän. Erfarenheterna vid TCO-förbunden och vid TCO:s arbetsskadeenhet visar dock att belastningsskador förekommer i stor utsträckning på tjänstemannasidan, särskilt hos kvinnor. TCO begärde en kartläggning beträffande belastningsskador och skaderisk framför allt hos kvinniga tjänstemän. Därutöver angavs att även psykosociala faktorers påverkan när det gäller dessa skador skulle närmare undersökas. Arbetslivsinsitutet avsatte ekonomiska medel för att handlägga begäran från TCO (Arbetslivsinstitutet E 51/96). En projektgrupp bildades bestående av chefsjurist Stig Gustafsson och förbundsjurist Lill Dahlberg från TCO:s arbetsskadeenhet, professor Ulf Lundberg, Psykologiska institutionen, Stockholms universitet, professor Francesco Gamberale och professor Mats Hagberg på Arbetslivsinstitutet. Diskussioner har också förts med professor Niklas Bruun och jur lic Lottie Ryberg, Arbetslivsinstitutet.

Projektgruppen initierade tre kartläggningar:

”Arbetsskadeförsäkringen – bedömningen i domstol av belastningsskador hos kontorister och sjuksköterskor” av jur kand Maria Sundström, Arbete och Hälsa 1997:17.

”Visual Display Unit Work and Upper Extremity Musculosceletal Disorders: A Reveiw of Epidemiological Findings” av professor Laura Punnett och dr med sci Ulf Bergqvist, Arbete och Hälsa 1997:16.

”Ländryggbesvär vid sjukvårdsarbete” av fil dr Monica Lagerström, professor Tommy Hansson och professor Mats Hagberg, Arbete och Hälsa 1997:xx.

Dessa arbeten kan utgöra en bas för fortsatta prioriteringar för fortsatt forskning inom det angelägna forskningsområde som TCO pekat ut. Ett varmt tack riktas till alla de som bidragit till framtagningen av de tre dokumenten.

Rapporterna ”Visual Display Unit Work and Upper Extremity Musculoskeletal Disorders: A Review of Epidemiological Findings” och ”Ländryggsbesvär vid sjukvårdsarbete” har godkänts av Arbetslivsinstitutets Ergonomiska Expert Kommitté, se nedan.

Solna i september 1997

Mats Hagberg
Koordinator

Förord 2

Arbetslivsinstitutets Ergonomiska Expertkommitté har granskat och godkänt slutsatserna i detta dokument. Kommitténs ordinarie ledamöter är professorer inom enheten för ergonomi och psykologi.

Francesco Gamberale, professor i arbetspsykologi
Mats Hagberg, professor i arbets- och miljöfysiologi
Åsa Kilbom, professor i arbetsfysiologi
Anders Kjellberg, professor i arbetspsykologi
Jörgen Winkel, professor i tillämpad arbetsfysiologi

Detta dokument har författats av professor Laura Punnett, Lowell University of Massachusetts, och med sci Ulf Bergqvist, Arbetslivsinstitutet.

Målsättningen för arbetet har varit att med stöd av en genomgång och värdering av föreliggande litteratur om möjligt komma fram till ett dos-respons- och dos-effektsamband. Fastställande av dos-respons- och dos-effektsamband är i de flesta fall inte möjligt och då blir uppgiften att i samma förebyggande syfte utvärdera den litteratur som finns. Det insamlade materialet har värderats och ett dokumentsförslag utarbetats av författarna på uppdrag av kommittén. Förslaget har diskuterats och bearbetats innan det blivit antaget som ett kommittédokument.

Endast vetenskaplig litteratur som bedöms vara pålitlig och ha betydelse för just denna diskussion åberopas i dokumentet.

Detta dokumentsförslag har diskuterats med kommittén, bearbetats och vid kommitténs möte 1997-09-09 antagits som dess dokument.

För Arbetslivsinstitutets expert kommitté för arbetshälso- och ergonomiska frågor.

Solna i september 1997

Mats Hagberg
Ordförande

Preface

The National Institute for Working Life – Ergonomic Expert Committee has reviewed and approved the conclusions in this document. The members of the committee are professors at the Department of Ergonomics.

Francesco Gamberale, professor of work psychology
Mats Hagberg, professor of work and environment physiology
Åsa Kilbom, professor of work physiology
Anders Kjellberg, professor of work psychology
Jörgen Winkel, professor of applied work physiology

For this document the authors, professor Laura Punnett, University of Lowell, Massachusetts, USA, and Ulf Bergqvist, Ph D, from the National Institute for Working Life, were appointed by the expert committee as authors. The authors searched for litterature in different data-bases, such as Medline and NIOSHTIC. Evaluation was made of all relevant scientific original literature found. In exceptional cases information from documents difficult to access were used. The draft document was discussed within the expert committee and was finally accepted as the group's document September 9, 1997.

The document aims at establishing a dose-response/dose-effect-relationship and the effect is based only on the scientific literature. The task is not to give a proposal for numerical occupational exposure limit value.

The topic of this document was initiated and discussed in a project group initiated by the Swedish union ”TCO” . Advise to the authors has also been provided by the TCO-project group, chief lawyer Stig Gustavsson (TCO) and lawyer Lill Dahlberg (TCO), professor Ulf Lundberg, Department of Psychology, University of Stockholm, Ronnie Eklund, Stockholm University Law School, professor Francesco Gamberale, National Institute for Working Life and professor Mats Hagberg, National Institute for Working Life.

Solna in September 1997

Mats Hagberg
Chairman

Executive Summary

Laura Punnett and Ulf Bergqvist. Visual display unit work and upper extremity musculoskeletal disorders: A review of epidemiological findings. *Arbete och Hälsa* 1997;16:1-161.
A review has been undertaken of the epidemiological literature on work with visual display units (VDUs) and neck or upper extremity musculoskeletal problems among office workers. The questions to be answered are whether there is an increased risk of such disorders among VDU users, compared with people working in other types of jobs, and - if so - which specific feature(s) of the VDU device or the work environment are responsible. In addition, the question of whether women using VDUs are at even greater risk than men, and if so, why, has also been investigated.

Comprehensive and up-to-date reviews summarising current epidemiologic knowledge about such factors for musculoskeletal problems among VDU users are scarce. This report therefore summarises current epidemiological evidence concerning increased risks of upper extremity and neck disorders among VDU users, what specific features of the VDU device or work environment that may be involved; and whether women using VDUs are at even greater risk than men.

A total of 72 relevant reports from 56 epidemiologic studies have been identified. Most were published in peer-reviewed journals, although a few studies have been included from peer-reviewed conference proceedings or technical reports from national research institutions. Only papers written in English or Swedish have been reviewed. These studies cover a range of health endpoints, from non-specific discomfort to median nerve conduction velocity through the carpal tunnel, and a range of exposures from VDU work *per se* to specific task types, rest break patterns, and keyboard configurations. There is also a great variety in study designs and populations; some studies have compared VDU operators to other employed groups, such as non-VDU clerical workers, and others have used internal comparisons, within groups of VDU users, to examine the effects of many specific features of the VDU work environment. In general, however, inadequate attention has been paid to the consequences of the choice of study population and the range of exposures within which statistical associations or dose-response relationships can be examined.

Some general conclusions regarding VDU work and musculoskeletal didsorders emerge from this review. These conclusions are supported both by studies of questionnaire-reported symptoms and studies utilising objective findings from physical examinations or diagnoses. For disorders of the hand and wrist, we found evidence that the use of the VDU or the keyboard was a direct causative agent, mediated primarily through repetitive finger motion and sustained muscle loading across the forearm and wrist. The odds for such disorders among VDU users with at least 4 hours of keyboard work per day appear to be about twice that of those with little or no keyboard work. For neck and shoulder problems, the role of the

VDU or the VDU work seems to be less that of a single source of mechanical stresses and more the central feature around which modern office work is organised. This increasingly common pattern of VDU work organisation, with both physical (repetitive finger motions) and work organisational features (task fragmentation), is perhaps less typical of a number of other work environments. Thus, VDU work is often used as a proxy variable, that is, as a symbol which represents this particular combination of exposures.

Although not all specific factors have been adequately studied, either singly or in combination with each other, there is convincing evidence regarding some. Strong evidence exists for elevated risks of upper extremity disorders with data entry and similar intensive keying tasks, and for hand and wrist disorders, at least, with hours of keying per day. High work demand and postural stress resulting from poor work-station design and layout also increase the risk of upper extremity disorders. Thus, there is - in our opinion - a scientific basis that justifies ergonomic and work organisation interventions to improve work situations characterised by these conditions.

Among VDU workers, upper extremity and neck musculoskeletal disorders are more common among women. Specific reasons for this gender difference have not been fully identified, although they could include differences in job types, housework and childcare, body size and strength, hormonal or other physiological conditions. When men and women were compared within fairly homogenous job groups, they reported similar rates of MSDs. However, few studies have unfortunately been able to compare women and men doing similar VDU tasks.

Svensk sammanfattning

Laura Punnett and Ulf Bergqvist. Visual display unit work and upper extremity musculoskeletal disorders: A review of epidemiological findings. *Arbete och Hälsa* 1997;16:1-161.
En översikt har tagits fram över den epidemiologiska litteratur som inriktats på bildskärmsarbete och muskuloskeletala problem i nacke och övre extremiteter bland kontorsarbetare. Frågeställningarna är om det föreligger en ökad risk för sådana sjukdomar bland bildskärmsarbetare jämfört med individer med andra arbeten, och - i så fall - vilka specifika förhållanden kring bildskärmen eller arbetsförhållanden kring skärmen som är förknippade med detta. Dessutom har översikten också inriktats på frågan om kvinnor vid bildskärmsarbete löper en högre risk än män.

Det saknas för närvarande fördjupade och uppdaterade översikter över nuvarande epidemiologisk kunskap om sådana faktorers inverkan på muskuloskeletala problem bland bildskärmsarbetare. Denna rapport sammanfattar därför våra nuvarande epidemiologiska erfarenhet i dessa frågor.

Totalt identifierades 72 rapporter från 56 epidemiologiska studier. De flesta var publicerade i tidskrifter med vetenskapligt granskningsförfarande, även om några studier har erhållits från konferenssammanställningar med vetenskapligt granskningsförfarande eller tekniska rapporter från nationella forskningsinstitut. Endast rapporter skrivna på engelska eller svenska har tagits med. Dessa studier täcker en rad olika hälsoeffekter, från ospecificerade besvär till mätning av ledningshastigheten i mediannerven i karpaltunneln, och olika exponeringssituationer från bildskärmsarbete *i sig* till speciella arbetsuppgifter, pausmönster och tangentbordutformning. Det finns också en stor variation i studiedesign och val av studerade grupper; vissa studier har jämfört bildskärmsarbetare med andra grupper av anställda, t. ex. kontorsanställda utan bildskärmsarbete, medan andra studier har använt sig av interna jämförelser mellan olika grupper av bildskärmsarbetare för att utröna effekten av specifika faktorer i arbetsmiljön kring bildskärmen. Många studier har inte tagit tillräcklig hänsyn till hur val av studiegrupper och variation av exponeringar kan påverka analysen och dess tolkning.

Vissa allmänna slutsatser beträffande bildskärmsarbete och belastningssjukdomar kan dras ur denna översikt. Dessa slutsatser stöds både av studier som bygger på enkätbaserade symtom, och studier som utnyttjat objektiva fynd eller diagnoser. För sjukdomar i hand och handled fann vi belägg för att användning av bildskärm eller tangentbord var en orsaksfaktor, främst erhållen genom upprepade fingerrörelser och vidmakthållen belastning i underarm och handled. Oddsen för sådana sjukdomar bland bildskärmsarbetare med åtminstone 4 timmars tangentbordsarbete per dag tycks vara ungefär det dubbla jämfört med de som har lite eller inget tangentbordsarbete. För nack- och skuldraproblem tycks bildskärmen eller bildskärmsarbetet spela en mindre roll som en direkt orsak till mekanisk belastning, och mer en roll som den centrala punkt kring vilken modernt kontorsarbete är uppbyggt. Detta alltmer vanliga mönster av bildskärmsarbetets organisation, med både fysisk (repetitiva fingerrörelser) och arbetsorganisatoriska inslag (fragmentering av arbetsuppgifter) är kanske mindre vanligt förekommande i vissa andra arbetsmiljöer. På så sätt har bildskärmsarbete ibland utnyttjats som en "ställföreträdande" variabel, d.v.s. en symbol som representerar denna kombination av faktorer.

Även om inte alla specifika faktorer har studerats tillräckligt, varken var för sig eller i kombination, så fann vi övertygande belägg avseende vissa faktorers påverkan på muskuloskeletala sjukdomar i bildskärms-sammanhang. Starka belägg föreligger avseende ökade risker vid inmatningsarbete och arbetsuppgifter med liknande intensiv användning av tangentbordet, och, åtminstone för hand- och handledsproblem, med antalet timmar i sådant arbete per dag. Höga krav i arbetet och olämpliga kroppsställningar som ett resultat av dålig utformning av arbetsplatserna ökar också risken för belastningssjukdomar i övre kroppen. Detta innebär att det - enligt vår uppfattning - finns en vetenskaplig grund som motiverar ergonomiska och arbetsorganisatoriska åtgärder för att förbättra sådana arbetssituationer.

Bland bildskärmsarbetare tycks belastningssjukdomar i nacken och de övre extremiteterna vara vanligare bland kvinnor än bland män. De konkreta orsakerna till detta har dock inte klarlagts; de innefattar sannolikt både skillnader i arbetsuppgifter, hemarbete, kroppsstorlek och muskelstyrka eller andra fysiologiska skillnader. När män och kvinnor med mer likartade arbetsuppgifter jämfördes, så var skillnaderna mellan deras rapportering av belstningsbesvär mindre. Tyvärr finns det få studier där man kan jämföra män och kvinnor med lika arbetsuppgifter.

Introduction

Ever since a more widespread introduction of Visual Display Units (VDUs) in many workplaces began in the middle seventies, concerns about adverse health problems occurring among VDU users have been voiced. Some concerns have been directed towards the VDU unit as such (often in terms of "radiation" or electromagnetic fields), while others have been related to changes in work life that is being brought about by extensive computerisation of the work. Ergonomic factors have formed a central part of such concern from the beginning, discussed especially in terms of visual fatigue and musculoskeletal problems. These latter health issues are probably the most prevalent concerns among VDU users, and by now, their relationships to work with VDUs appear to be fairly well documented.

This relationship can be phrased in the following way: 'Some features of VDU work may cause adverse health or discomfort, such as musculoskeletal problems'. In order to enable effective interventions or preventive actions, knowledge is required about what specific factor(s) in the VDU work situation is responsible, however.

Comprehensive and up-to-date reviews summarising current epidemiologic knowledge about such factors for musculoskeletal problems among VDU users are scarce. This report was written in an attempt to fill this need. The literature review presented here seeks to answer the questions of 1) whether there is an increased risk of upper extremity and neck disorders among VDU users, compared with people working in other types of jobs; 2) if so, which specific feature(s) of the VDU device or work environment are responsible; and 3) whether women using VDUs are at greater risk than men, and if so, why.

Musculoskeletal disorders

Musculoskeletal and related soft-tissue disorders (MSDs) may affect any part of the neck or the upper extremity, from the shoulder out to the fingers. They include a variety of clinical syndromes such as nerve compression or entrapment disorders, tendon inflammations and related conditions, muscle inflammations, and degenerative joint disease. They also include less well standardised conditions such as myositis, fibromyalgia, and focal dystonia, as well as regional, sometimes poorly localised pain and paresthesia not attributable to other pathologies (29, 49, 64, 121, 148, 156, 160, 206). The most widely known peripheral nerve entrapment is carpal tunnel syndrome, which involves compression of the median nerve where it passes through the wrists or carpal tunnel; it produces numbness, tingling, pain, and eventually loss of muscle function in the thumb and first two and one-half fingers of the hand. Other peripheral nerve compressions may occur in the ulnar tunnel of the wrist, the forearm, and the thoracic outlet. Tendon inflammatory conditions are generally known as tendinitis or tenosynovitis; at various locations of the upper extremity they are named for the specific point of inflammation, such as epicondylitis or shoulder bursitis. Tension neck syndrome (TNS) is the collective term given several non-articulate syndromes of the neck region. Generally, this syndrome is characterised by pain and a feeling of tiredness and stiffness in the neck, as well as tenderness over the descending part of the trapezius muscle (77, 206). Cervical disorders is also a collective term used (here) to describe cervical syndrome and cervical degenerative disease or spondylosis, where the former is based on anamnestic and physical examinations, while the latter would (normally) require radiographic evidence of disc degeneration (77). However, few of the reviewed studies appear to have included x-ray examinations.

These disorders are often discussed collectively, in part because they are not always well diagnosed and therefore distinguished from each other, and in part because they share several epidemiologic features, including particularly that they often result from a common group of risk factors or ergonomic stressors and that they tend to develop after months or years of exposure, rather than as point-in-time injuries. While they are not rare in the general population, there is evidence that various occupational groups are at higher risk because of the physical demands of their work (*e.g*., (58, 155, 177, 178, 192)).

Occupational risk factors for musculoskeletal disorders

The physical features of work that are frequently cited as risk factors for MSDs include rapid work pace and stereotyped repetition of motion patterns; insufficient recovery time; forceful manual exertions; anatomically non-neutral body postures (either dynamic or static); mechanical stress concentrations (direct pressure of hard surfaces or sharp edges on soft tissues); vibration; and low temperature.

The literature on soft tissue physiology and biomechanics demonstrates several plausible pathomechanisms by which these ergonomic factors may injure the soft tissues of the musculoskeletal system (see the review by Armstrong and colleagues (4). For example, viscous strain and deformation of tendons accumulate as a function of work pace (frequency and duration of loading), level of muscular effort, and recovery time between exertions, indicating the importance of these dimensions of physical loading for cumulative tissue damage (5, 35, 67). Symptoms and tolerance of physical work demands for repetitive wrist motion are similarly determined by hand posture, frequency and force of wrist bending, and task duration (184). EMG measurements show that the shoulder muscles fatigue quickly when the arm is elevated at or above shoulder height, especially if the exposure is prolonged or repeated frequently (73, 76, 194, 201).

The epidemiologic studies of MSDs in workers occupationally exposed to these generic ergonomic factors are too numerous to list here. Many reviewers of this literature have concluded that there is substantial epidemiological evidence of the etiologic importance of occupational ergonomic stressors for neck and upper extremity MSDs (*e.g*. (4, 7, 75, 77, 185, 193, 211)), although some authors still dispute the importance of these factors, especially relative to non-occupational causes (23, 72, 127, 135, 137, 198).

The ergonomic effects of work in seated postures have been studied, in general, with two distinct questions in mind. One of these is the effect of prolonged sedentary work or specific seating designs on low back morbidity; since we restrict this review to upper extremity and neck disorders, we do not discuss that literature here. The other issue is the nature of the restrictions on postural mobility that result from the seated position, with the trade-off of greater postural stability in order to support precise manual and visual work such as are required in computer use tasks (161). Here we assume that most individuals work at computers in the seated position, and the importance of workstation dimensions and other postural constraints in VDU work is considered in that context of limited mobility.

Another type of stressor that has received increasing interest with respect to MSDs is that of psychological and social factors. These often occur as consequences of objectively definable features of the work organisation such as task allocation, incentive wages, and work pace (see below). Psychological and social factors have already been demonstrated epidemiologically to have etiologic importance for cardiovascular disease (97, 106, 173, 195). On the hypothesised etiologic pathway from psychological and social job characteristics to MSD development lie several well-known physiological mechanisms which could explain the associations observed. Among these are adverse circulatory patterns (173); high levels of sympathetic nervous symptom arousal with general central nervous system consequences as well as endocrine system impacts on circulating hormones (12, 30, 79, 107, 209); tonic activation or ”psychogenic” muscular tension (9, 202, 207); and interference with normal muscle and tendon repair processes. The occupational psychological and social stressor most consistently associated to date with musculoskeletal disorders is decision latitude or autonomy (24). While understanding of the role of psychological and social factors in the development of MSDs is still evolving, it is important to assess these work environment factors and include them in an overall evaluation of job stressors.

Psychological and social variables used in the studies reviewed here are typically based on both the worker´s own perceptions and his/her judgement about the situation - *i.e.,* cognitive, perceptual, and affective processes may all be involved. Psychological and social dimensions of the work environment are commonly divided into the following subcategories, mainly based on the work by Karasek and colleagues (96):

- The psychological demands of the job, including the amount of work and the time available to complete it.
- The worker´s opportunities to exercise control in the job, defined variously as influence, job control and decision latitude.
- The degree of social support by supervisors or workmates.

- Job insecurity, the worker´s fear of being replaced, or perceived opportunities for future employment.

Individual risk factors

The most important non-occupational risk factors are age, gender, socio-economic status, certain systemic diseases, and for carpal tunnel syndrome possibly female endocrine conditions; other factors of possible importance for upper extremity and neck MSDs include race or ethnicity, smoking, alcohol use, obesity, and recreational sports (25, 37, 43, 155, 177, 178, 192, 199).

The possible impact of gender as a risk factor or an effect modifier for MSDs is - by request - specifically considered in this review. Otherwise, the main emphasis of this review is on occupational factors, in particular, specific aspects of VDU work. Socio-economic factors may be closely linked to occupational demands in general population studies, and could thus cause some confounding. Likewise, individual factors such as age may also cause considerable confounding. Apart from such considerations this review has not attempted to present a comprehensive overview of possible associations between non-occupational factors and MSDs.

Musculoskeletal risk factors in visual display unit operation - an overview

Work at a visual display unit (VDU) represents a complex, multifaceted physical work environment, with interactions among the various dimensions of the work station and equipment, speed of data entry, position and lighting of visual targets (screen and documents), and job content. As in the classic ”person-machine environment” model, these features of the work interact as a dynamic system and together determine the presence and intensity of ergonomic exposures, both in physical and psychological or social terms. The widespread use of VDUs makes it important, for public health reasons, to understand these different components and their interactions in terms of adverse health effects. For some further discussion, see *e.g.* Gerr (65), Hendrick (80) or Smith and Carayon (181).

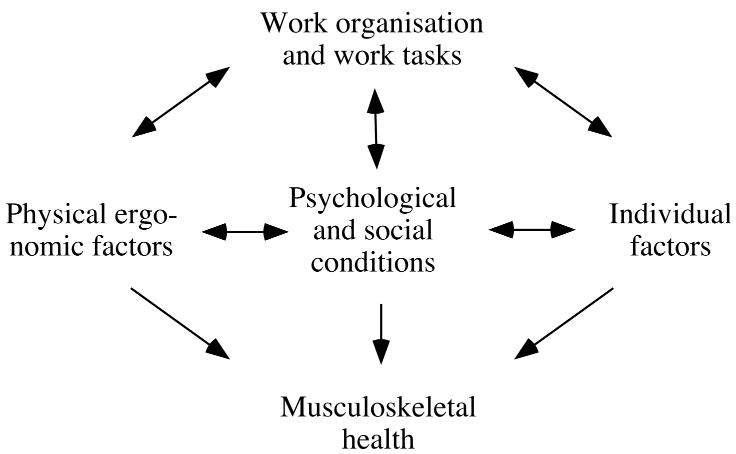

Figure 1. Some interrelationships between different aspects of VDU work, that are important for the aetiology of musculoskeletal pains.

A conceptual model of various features relevant to the development of musculoskeletal problems among VDU users is presented in figure 1. The model provides a structure used within this review for ordering the information. Among physical ergonomic factors, considerable emphasis is given in a number of studies to certain postural determinants, especially workstation design features, input devices and visual demands - as these features are often major sources of physical strain in VDU work. Likewise, some work organisation and work task descriptors are also typical of many work situations utilising VDUs. Psychological and social factors encompass a broad range of influences. We are here primarily concerned with factors which are prevalent in and have been studied in VDU jobs. Some of these may be specific for VDU work while other may be prevalent also in other types of work. Of individual factors, apart from gender, which is treated here in some detail, special consideration is given in some studies to the use of corrective glasses.

While separating the various risk factors in accordance with figure 1 may help organise the available information, it must not be taken as a statement that these factors can *a priori* be seen as independent. For example, when describing a situation where visual demands may influence posture, it is necessary to include a large number of factors from different parts of figure 1, such as the workstation layout, the specific task performed, the familiarity of the operator with the keyboard (need to look at it or not), use and type of corrective glasses, presence of glare, work load and stress and pre-existing neck pain.

A further discussion of some of these risk factors is found below.

Workstation dimensions and input devices

The keyboard is the primary mode of data input to the VDU. Its location, height and slope, in combination with other workstation dimensions, determines the angles of the wrist, elbow, and shoulder joints and the magnitude of static muscle loading as the operator maintains the arm positioned over the keyboard (8, 11, 12, 14, 34, 68, 69, 119, 126, 129, 175, 186). For example, placement of a keyboard on a work surface that is too high causes shoulder elevation, elbow flexion and wrist extension. In experimental sessions, a poor workstation layout resulted in markedly greater upper extremity pain than a workstation adjusted to optimise the operator's posture (38), while ergonomic workstation modifications improved postures (51). In addition, keyboard height and other dimensions may lead to contact pressure at the base of the wrist with subsequent bone and nerve damage (*e.g.* (167)).

Keyboard operation requires inherently repetitive hand motion (finger flexion and extension) in order to depress the keys. Recent laboratory studies show increases in EMG levels and pressures within the carpal tunnel as a consequence of finger keying motions, as well as in ulnar deviation, flexion and extension of the wrist (157, 158, 159, 209). Considerable attention has been given to the possibility of alternative designs, such as the split keyboard or keyboard with different key layouts (*i.e.* other than the standard QWERTY layout), in order to reduce muscle loading (13, 31, 51, 53, 63, 107, 134, 162, 209).

Non-keyboard computer input devices, such as the increasingly used computer ”mouse,” may also be related to additional ergonomic strain. Sustained pinching required to hold and move the mouse may cause increased tendon tension and sustained finger muscle activity (74, 91, 92). Disadvantageous upper extremity postures such as shoulder rotation and flexion and ulnar deviation of the wrist may also occur as a result of positioning the body so that all components of the computer work station can be utilised simultaneously (99). Fernström and co-workers (52) measured shoulder and forearm muscular load in a laboratory study comparing the use of mouse and trackpoint (small joy-stick located in the center of the keyboard) pointing devices in word processing tasks. They found that work with the mouse produced higher loading in the shoulder muscles. Shoulder load could be reduced by either use of the trackpoint device or a movable arm support while operating the mouse, but both of these alternatives increased the muscle load in the hand and forearm. It should be kept in mind that for someone using both a keyboard and a mouse, the mouse work represents an added stressor that acts in combination with the keyboard operation.

Visual demands

The other main mode of interaction is the visual contact with the computer screen, which may have consequences in terms of postural demands. Several components of the visual work situations can contribute to this including reading at a downward angle, use of corrective lenses, screen glare, and the need for visual contact with several task objects (screen, document, keyboard etc.).

A classical problem is that of bifocals not designed for the VDU working situation causing a backwards position of the neck in order to utilise the lower, ”near” segment of the glasses. Experimental studies have indicated increased EMG signals and muscle discomforts associated with incorrect glasses and visual work (113, 114). Furthermore, multifocal lenses have been shown to induce higher neck muscle tension than monofocal glasses (85, 86), whereas monofocal glasses may cause increased visual problems among older individuals (17).

Another area of potential conflict between visual and neck comfort may arise in relation to screen height; De Wall and co-workers (40) indicated that a VDU placed at eye level or higher would result in a better sitting posture, while observations of preferred postures suggested a lower VDU screen position (69, 143) - where presumably also the visual demands of the individuals were taken into account. Some experimental and epidemiological investigations also suggest that a VDU placed high would increase visual discomforts (2, 17, 112, 149, 196, 200, 208).

VDU work load, task design and work organisation

Different types of VDU work exhibit obvious differences in physical and mental demands, such as the amount of data input performed or of visual information processing. The categories proposed originally by the NRC Panel on Impact of Video Viewing on Vision of Workers (140) have often been used as an approximate characterisation of different task designs; ”data entry”, ”data acquisition”, ”interactive communication”, ”word processing” and ”programming, computer-assisted design and computer-assisted manufacturing”. These categories represent not only differences in work content or objectives, but also potential differences in ergonomic exposures: speed of keying, lack of variability in motion patterns, opportunities for rest breaks, and decision latitude, among others.

Task design has been shown to have at least short-term consequences for the operator in VDU work. For example, rapid speed of typing on a keyboard (as is often found in intensive data entry jobs) increased muscle loading (measured by EMG) as well as perceived exertion and discomfort levels (62). Incentive pay, compared with non-incentive pay, significantly increased operators' tension in data entry tasks; both upper extremity discomfort and tension were also found to increase linearly as a function of the hours per day spent performing the task, regardless of the pay system (171). The frequency and nature of rest breaks further influence both the discomfort experienced (171) and the total measured load on the neck and shoulder muscles (76, 194).

Psychological and social factors and stress-mediated effects

Worker´s control and decision latitude, social support and co-operation and fear and insecurity are - in this review - to be found under this heading. In addition, stress symptoms as an intermediate descriptor is also included here. Some other factors closely linked to this area are found in the section of work organisation (above). The distinction between work organisational and social or psychological parameters is not always obvious and the nomenclature varies among authors. The terminology used in this text is for convenience and an attempt to adhere to common usage in much of the literature reviewed. In principle, a distinction should be possible between observable job organisation features in the external work environment and intermediate effects that are experienced subjectively by the individual. However, in epidemiologic studies the distinction may be less clear-cut, since the intermediate psychological effects are often at least partially consequences of the objective environmental conditions, and furthermore because the dimensions actually measured by the investigators may be a mix of objective and subjective variables.

For example, work pace can be quantified objectively, such as in terms of keystrokes per hour, yet the effect may actually be more dependent on the worker´s experience of time pressure. Monotonous work has both physical consequences (repetitive loading on the same soft tissues) and psychosocial (boredom, low decision latitude). Bergqvist *et al.* (see below) obtained several different characterisations of work pace and stereotypy by questionnaire from the members of their cohort, and found an elevated risk of neck/shoulder symptoms with the combinations of data entry work with limited opportunity to take rest breaks and VDU use for at least 20 hours per week with repetitive movements (19). Thus, combinations of exposures may interact with each other, and their joint effect cannot be neatly assigned to a single category of risk factor.

It should be noted that although the model(s) proposed by Karasek *et al.* (96) have been frequently quoted, few of the analysis reported in this review have actually utilised the specific suggestions in that model, that it is the *combination* of a high job demand and low decision latitude that is the cause of worker strain. Most analyses have instead used job demand and decision latitude (control) variables as separate (independent) factors. On the other hand, a critical test of the Karasek model can be found in the study by Carayon (33), where such combinations apparently failed to produce worker strain (including ”physical health”) in excess of additivity, *i.e.* in excess of what should be expected if these factors worked independently (see that study for further discussion). There is a comment in the only study here that investigated such interactions (47), stating that decision latitude did not significantly modify the effects of workload - thus essentially agreeing with the comments of Carayon (33).

As pointed out by Frese (60), there are some conceptual issues that need to be resolved when studying stress-mediated health effects and VDU work:

- First of all, the work performed is a vector for or primary cause of stress in VDU situations; current understanding does not allow for a direct and general effect of VDUs on stress or stress-mediated effects independent of the work performed. In other words, the psychological demands and opportunities for decision-making are determined by specific aspects of the job description, hardware components and software packages used by the operator. Thus, different studies that examine groups of workers doing different types of VDU work should perhaps not be expected to result in similar findings regarding psychological and social factors and stress-mediated musculoskeletal effects.
- Secondly, the dynamic relationships between the work content and the stress-mediated reaction(s) could include an acute and reversible effect, an accumulated effect, an adjustment, and a latent effect (appearing only after cessation of the exposure). For example, an individual may experience immediate stress when a new computer system is introduced. This may lessen over time, as she/he both learns the necessary skills and adapts his/her work pace and approach to accommodate the system´s demands. Nevertheless, long-term frustration may build up, some of which may, in fact, not be apparent to the user until after she/he is no longer economically dependent on that job. Few, if any studies have specifically examined this, even if indirect suggestions relevant to these models could be derived from studies that characterise VDU work duration in hours per week *vs*. number of years employed.
- Finally, the studies on psychological, social and work organisational factors reviewed here have basically been concerned with such factors that do also - in principle - occur both in VDU and non-VDU work situations, even if their prevalence may vary. Stressors unique to VDU work have been studied in a few other investigations, one example being computer failure and adrenaline/ epinephrine responses (90), but not, to our awareness, in relation to musculo-skeletal endpoints. Other factors such as abstractness of work, understanding of work processes, ”virtual reality,” etc., have been discussed in general, but - so far - with little specific application to studies of musculoskeletal problems.

Interaction between VDU work and gender

Many studies on upper extremity and neck musculoskeletal disorders have found higher prevalences among women than among men. (This observation is not specific to VDU work.) However, the variable gender may be confounded by occupational demands, such as less variety in work content or lower decision latitude (96), or serve as a proxy for differences in exposure or other unmeasured variables (128).

Possible causes of such observations can tentatively be summarised in the following groups:

- Differences in task type allocations or work tasks between men and women.
- Higher physical or stress load of women from non-work activities such as childcare and household work.
- Physiological differences, such as different body size or mass or endocrine functions.
- Differences in the willingness to report or seek medical care for pain or discomfort.

Utilising the variable ”gender” to evaluate the difference between men and women in a study does not, by itself, help to clarify these possible explanations. In a few studies only, added insights have been achieved due to the inclusion of variables describing some of the specific factors above, such as child care or presence of children at home, or details of work task design.

The possible differences between men and women in the risk of upper extremity and neck musculoskeletal disorders related to VDU work can be described in two different - but complementary - ways:

- Do women working with VDUs have a higher occurrence of such disorders than men who work with VDU? In other words, is gender - or some factor(s) related to gender - a risk factor for such disorders, conditional on exposure?
- Is the risk associated with VDU work different for men and women? That is, is gender an effect modifier of work related risk factors?

Exposure categories and effect modification

In the reviewed studies, major attention is often given to some ”global” descriptors of VDU work; whether work is performed at a VDU or not, and/or the number of hours per day (week) that is spent doing work on the VDU. Such data may be used to evaluate the possibility that VDU work - irrespective of specific details - may increase the occurrence of muscle problems. Nevertheless, the large variations found between different VDU work situations make it imperative to look in more details also at more specific work descriptors.

Therefore, it is often appropriate and necessary to compare multiple dimensions of exposure in order to examine adequately the specific features of VDU use that are associated with upper extremity morbidity. Combinations of exposures may result in an effect that is the sum of the effect of each factor applied separately, but it may also result in an interaction, where the effect of both factors together are greater (or less) than the sum of each. There are also examples of a conditional association, where one factor has an effect only if another factor is present. (See also the discussion on the Karasek model above.)

As already indicated above in the case of work load, separating exposure variables into categories such as ergonomic factors, task design/work organisation and psychological and social factors etc. is not always straightforward - substantial conceptual overlap may exist. Furthermore, it must be remembered that VDU work is an integrated situation, where clear distinction in terms of these categories do not exist. These categories are kept for the purpose of organising the large material available, but should not be seen to imply that factors placed in different categories are really independent, either in their origin or in their impact.

Many of these various measures of exposures (rapid work pace, static muscle loading, limited job control etc.) are also not necessarily unique to VDU work; in epidemiological studies, they should ideally be characterised for the non-VDU users as well as for the operator group.

Methods and review of methodology

Aim and organisation of this review

In the past ten years, there have been few comprehensive reviews of the epidemiologic evidence bearing on VDU work and its musculoskeletal health effects. The reviews published to date have primarily described the ergonomics issues and recommendations for work station layout and chair design (8, 34, 126). Two articles partially summarised the epidemiology about 10 years ago (77, 127). This review was therefore designed to examine critically the epidemiologic literature on musculoskeletal problems of the upper extremity and the neck and the occupational use of VDUs, in order to evaluate the strength of the evidence with respect to causal inference and to identify the specific physical, psychological and social demands or job features of VDU work that might be associated with these disorders.

The review is based on analytic epidemiologic investigations that compared the frequency of one or more upper extremity disorders among VDU operators or between workers with occupational exposure to keyboard use and persons without exposure either to keyboard use or to other significant ergonomic stressors acting on the upper extremity. The following were excluded:

- analyses of other health endpoints (back pain, psychological mood states, reproductive disorders, sick leave from all causes, etc.);
- descriptive or ecologic studies of exposure or of health status that did not contain analyses of the relation between exposure and musculoskeletal health;
- experimental studies with only short-term outcomes, such as muscle activation forces, productivity or error rates, operator satisfaction or discomfort during the experiment; and
- studies of upper extremity disorders in which keyboard operators were combined with other occupational groups and the data could not be separated.

Studies comparing upper extremity disorders among VDU users before and after well-defined ergonomic or work organisational intervention were also included. We have made an effort to include not only positive, but also non-positive ("negative") findings from the reviewed studies. However, we can not assume that all non-positive findings were reported by all authors, and we can therefore not fully exclude the possibility of a publication bias.

As described above, a large number of various predisposing factors have been implicated as causes of these disorders. For the sake of discussion, they can be seen as belonging to one of three groups; a/ individual or physiological factors, b/ ergonomic factors related to the work organisation or the physical work station, and c/ psychological and social stressors in the work environment. As discussed above, the distinctions between such groups are - in practice - less clear, partly because they can be seen to exercise their impact in combinations, and partly because many variables used in the research are descriptors that, in themselves, cover several of these factors. Some examples are ”VDU work,” ”data entry work,” ”gender,” ”repetitive and monotonous work”. Within the framework of this review, we discuss the groups of possible risk factors with the following definitions and caveats:

Work performed using a visual display unit (VDU) has been described in some studies only as ”VDU work” without further specification of task content or types of exposures present. Since we are restricted by the information available in the authors´ presentations, these papers must be summarised in a general section on VDU operation, including;

- VDU work *vs*. other (non-VDU) work situations;
- full-time versus part-time VDU work
- hours of VDU work per day or per week; and
- the duration (years) of employment in VDU work.

Papers that provide more specific and etiologically relevant descriptions of the work environment are discussed under each of the headings to which they contribute information.

Physical factors, as they occur and have been studied in VDU work situations, are a varied group of characteristics. We include under this heading results of studies on:

- Workstation dimensions and upper extremity postures that results from the need to accommodate to those dimensions;
- The specific design or model of the keyboard.
- The use of a mouse or other input device than a keyboard; and
- Visual work demands, the use of corrective lenses, monitor placement, glare on the screen, and the postural stresses that originate specifically in these aspects of visual work demands;

As mentioned previously, several aspects of work organisation which are conceptually similar are often found to be strongly correlated with each other in actual workplaces, and therefore their effects may be very difficult to separate in epidemiologic studies. For example, fast work pace, infrequent rest breaks, and highly monotonous work are often found in data entry jobs. Nevertheless, to the extent possible we have attempted here to address these separate dimensions in separate sections. These include:

- Type of VDU task (*e.g*., data entry versus interactive communication).

- Work load and work demands, including factors such as time pressure, work pace, typing speed, extensive overtime, presence of deadlines, insufficient resources and requirements for ”close attention;”
- Repetitiveness or monotony, which covers physical stereotypy of motion patterns; low task variability (work flexibility, work variance, and task rotation); and the degree of skill utilisation (the routine character of the work and whether the work material ”makes sense” or not);
- The temporal organisation of the VDU work, with specific factors such as work task duration and rest break patterns; and
- External control mechanisms such as electronic monitoring, quality of supervision, and production quota systems.

Psychological and social factors are less clearly VDU-specific factors; nevertheless, a number of observations testify to the commonality of their occurrence in many VDU work situations, probably as a consequence of the changes in work organisation that often accompany computerisation of clerical tasks. This motivates - in our view - a summary of research findings dealing with such factors in VDU work situations, as defined above:

- Decision latitude and influence within the organisation;
- Social support from supervisors, peers or family and co-operation among colleagues; and
- Job insecurity, fear of job loss and job dissatisfaction.

Note that job demands are often considered in the category of ‘psychological’ stressors. However, because of the close connection between work load and task design - and thus with physical ergonomic conditions such as work pace - this aspect has been covered under the work organisation heading. This should be understood as an attempt to avoid a false dichotomy between the physical and psychological aspects of work load, as explained above.

Gender can be investigated either as a direct risk factor for musculo-skeletal problems or as an ”effect modifier” for other risk factors. This review is limited to conditions and research findings as they have appeared in VDU work situations.

A large number of other factors, such as age or non-occupational recreational activities and smoking, are dealt with only as confounders, *i.e.*, we are here in principle not concerned with their impact on muscle problems per se, but only to adjust for their possible impact on the research findings relative to VDU work-specific factors.

Subsequent to the review of etiological findings and a reappraisal of the methods used in these studies, a short description of a few intervention studies is provided and summarised (see Table 19). It should be noted that this literature is very limited to date.

Definitions of common epidemiological methods and measures

Some general comments are appropriate on epidemiological research methods, in order to familiarise the reader with the concepts. The fundamental principles of study design and measures of risk are widely accepted. However, it is acknowledged that different researchers may take different approaches, especially with regard to statistical analyses, and this summary is not intended to address the merits or demerits of competing choices of statistical measures. The interested reader is referred to the general epidemiologic literature for further discussion (for example (103, 164) or other texts.)

The prevalence of a disorder describes how many - out of a certain group - that have this at a given point in time, divided by the total number in the group. The odds is a similar measure, describing how many have the disorder divided by the number of individuals in the same group that do not. The incidence, on the other hand, describes how many - out of a certain group that does not have the disorder at the start - develop it during a specified time, again divided by the total number in the group. The term “risk” is sometimes used in a loose manner to describe any of these concept (”risk of having”, *vs.* ”risk of getting”).

Just reporting the prevalence of a muscle disorder among VDU users would not be very informative, without showing the background or expected prevalence. Thus, epidemiological studies - as reviewed here - are basically comparisons of these measures in one group with a defined exposure with the same measure in a nonexposed group, to indicate the impact of that factor. The results of such comparisons may be expressed as a prevalence ratio (PR), odds ratio (OR), risk ratio (RR, sometimes referred to as relative risk) or incidence density ratio. These ratios describe the disease frequency in the ”exposed” group divided by the frequency in the ”nonexposed” group. A ratio of 1.0 indicates that the prevalence (odds, incidence) are the same in both groups, suggesting that the factor(s) that was investigated does not increase the risk of disease. The uncertainty in this ratio is often given as a confidence interval - the ratio is ”reasonably” expected to fall within this interval. As already suggested, many other measures of comparisons exist, such as correlation coefficients, p-values from tests of significance etc.

To a large extent, the choice of a measure of effect depends on the study design and the types of data that have been collected. Case-control studies can only generate odds ratios, while the calculation of incidence (ratios) requires that the study population has been followed for a defined period of time. In cross-sectional studies, prevalence rather than incidence of disease is estimated, since the participants are studied only at one moment in time. However, prevalence data can be compared with either prevalence ratios or odds ratios, and there is currently some discussion among epidemiologists about the situations when it is and is not appropriate to report odds ratios. Without burdening the reader unduly, we simply note here that when more than one of these measures can be calculated from the same study, they will not give the same numerical results, even though they are mathematically related to each other. Thus the exact value of the measure of effect should not be given undue importance; in this review we are more interested in the general consistency among the findings from multiple studies.

For epidemiological comparisons to be valid, the groups must be comparable in the way that they have been studied and in their background risk of disease, otherwise a bias may be said to exist. This could be due to the erroneous selection of individuals in the groups, or to the presence of other factors that influence the results (confounding). Say that one group is younger than the other, and the risk of disease changes with age, then this would be called confounding by age - causing uncertainty as to whether the difference between the groups is due to the exposure or to age. Various methods exist to adjust for this. When the phrase ”adjusted odds ratio” is used, it indicates that the odds ratio has been adjusted for one or more specified factor - thereby reducing or removing the confounding impact of that factor. Failure to adjust for age, gender, or other variables, when necessary, is another reason that the estimated measure of effect may not have the true (correct) value.

More detailed and specific comments as to epidemiological methods are given in the text below at appropriate places and also summarised below (page 101-107).

Criteria for causality

A statistical association found by epidemiologic methods between an exposure and a disorder does not necessarily mean that this association is causal. The establishment of causality requires the ruling out of alternative competing explanations for the observed association, interpretation of the findings in light of what is known about the biological processes involved (often from experimental studies), as well as replication of the epidemiological findings.

There have been several proposed sets of criteria for determining causality, the most well-known being that of Hill (82), which includes considerations of the strength of associations, consistency between observational studies (replications), specificity of effect from a factor, temporality - the exposure precedes the effect, biological gradient or “dose-response”, biological plausibility and coherence, experimental evidence and analogy with other known processes. As pointed out by Hill, as well as others (*e.g.* Rothman, (164)), these criteria are not strict in the sense that they “bring indisputable evidence for or against the cause-and-effect hypothesis” (apart from the criterion of temporality). Establishing causality is fundamentally a process of judgement.

To formalise such a judgement process, the terms established”, “probable” and “possible” when describing the causality of an association, based on both epidemiologic and experimental findings, have been used by groups such as the International Agency for Research on Cancer (IARC). The results of evaluations of epidemiologic studies alone are, however, not described in such terms. In this review of epidemiologic findings, we have therefore refrained from such formalised statements, as they would necessitate a detailed review also of existing experimental studies and other evidence in line with the above process.

Nevertheless, the outline of such processes has served as a general guidance in our evaluations.

Finally, it should be emphasised that a study that fails to find an association between an exposure and a disease does not necessarily prove that none exists. There are two different situations where caution in such an interpretation is warranted. First, with studies of limited power, although the estimator may be close to the null value, the wide confidence interval would not give any confidence in the statement. Secondly, various types of systematic errors may cause an underestimate of the effect, *i.e.*, the risk is estimated as closer to the null (expected) value than it really is. (See further discussions by *e.g.* Ahlbom *et al.* (3)). (See also the section below on "exposure contrast".)

Acquisition of data

Epidemiologic studies were sought through computerised databases (NIOSH-TIC, MEDLINE, ARBLINE); in the citations of review articles and articles found from the literature search; in the authors' personal files; and by contacting researchers active in this field.

At this stage, articles were included even if they had serious methodological shortcomings or failed to define the population or methods sufficiently for evaluation of potential misclassification or bias. In the Summary and conclusions section and Appendix III, we indicate which studies were judged to be methodologically valid and informative (III A), and which were too weak to be relied upon (III B), together with comments regarding the reasons for this selection. Further details are found in Appendix I, and these are also discussed in the appropriate sections of the review.

A few investigators were contacted with queries regarding study methods and findings. Where necessary, relative risks (RRs), odds ratios (ORs) and tests of linear trend in effect with exposure level were calculated by the authors from raw data in the articles. In some cases the raw data had first to be estimated from graphs.

Several studies were compared to an external population that had estimated the prevalence of hand/wrist disorders in low-exposure (industrial) jobs (176), since all of the authors had used a comparable case definition. This permitted an external comparison of the disorder frequencies in VDU or keyboard work with the expected or background prevalence in the U.S. working population.

Descriptions of the design of those observational studies that were judged to be relevant to the question of musculoskeletal disorders and VDU work are found in Appendix I. The results of these studies are tabulated in Tables 1-18 and commented on in the text. Intervention studies are tabulated in Table 19. A few epidemiological studies that were excluded from the review - and the reasons for the exclusions - are found in Appendix II. Finally, Appendix III separates the methodologically stronger studies that - in our judgement - should form the basis for conclusions from other studies.

Exposure contrasts

In the studies on upper extremity and neck disorders and occupational VDU use that met the search criteria, a variety of exposure conditions were compared by the original investigators (see Appendix I). In some studies, musculoskeletal disorder rates were compared between VDU users and clerical employees who did not use keyboards, permitting analysis of the main effect of keyboard use, overall, or subdivided into data entry *vs*. conversation, hours per day, etc. In other studies, internal comparisons of postural stressors and other job features were made among VDU operators; this design does not allow analysis of the effect of VDU use per se, but does permit identification of factors that increase the risk of upper extremity disorders within the broad range of activities called ”VDU operation”. Some of these may also be thought of as effect modifying factors that might also be independent risk factors in the absence of keyboard work.

VDU work hour contrasts
Figure 2 illustrates three possible comparisons of “hours of VDU work performed per day”, based on differences in the underlying task distribution of the study population(s).

Situation a/ shows a work-force in which individuals spend very different numbers of hours per day at the VDU, ranging from none to 8 hours but covering all the possibilities in between. Often, an investigator will decide to divide this

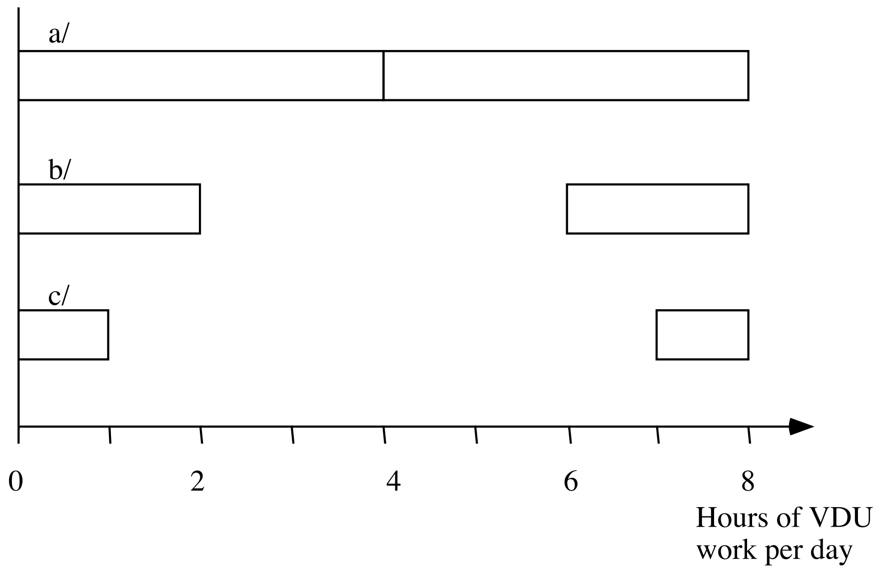

Figure 2. Some examples of different contrasts in terms of hours of estimated VDU work per day. In situation a/, individuals in the study cover the full range of VDU working hours, and the delineation has been (arbitrarily) set at 4 hours, for a comparison between “working more than 4 hours/day” with “working less than 4 hours/day”. In situation b/ the distribution of working hours is bimodal, with two distinct groups of VDU users (“at least 6 hours/day” *vs*. “less than 2 hours per day”). Situation c/ essentially describes full-time VDU users compared with office workers without VDU use.

range in the middle - in this example, to compare those doing VDU work for at least 4 hours with those at the VDU for less than 4 hours per day. However, what cannot be seen from this diagram is what number of people are at each level of exposure, which can have a large effect on the study results. For example, one possibility is that most of the study participants actually work from 3 to 5 hours per day at the VDU. In this case, even though the contrast is labelled "4 to 8 hours versus 0 to 4 hours," in reality it is closer to "5 hours per day versus 3 hours per day." Because there is only a narrow range in the exposure variable, there is very little power to study the effect of duration of VDU work, and the risk ratio will be smaller than might be expected, even if there is a strong underlying exposure-response relationship.

On the other hand, if the study subjects are spread uniformly over the range from 0 to 8 hours per day of VDU work, then the same apparent comparison will have more information because there will be a bigger difference on average between the exposure levels of the two groups. In fact, if it is big enough, this population would ideally be divided into more than two levels of exposure, in order to study the shape of the exposure-response trend (*i.e.*, to see if the disease rate increases steadily as the level of exposure increases).

A third possibility exists if close to one-half of the subjects work less than one hour per day at the VDU, and almost half work 7 to 8 hours per day, with very few people in the middle. This situation will actually be more like figure c/ in reality, even though it is still labelled as "4 to 8 hours versus 0 to 4 hours," and it will likely give a much bigger relative risk estimate because the contrast in actual hours worked is so much greater (again assuming that there is a true exposure-response relationship).

Situation c/ would more or less describe many studies found in the section “VDU operation in general, compared to non-VDU work” (if the VDU operators are full-term users of VDUs). A complication is that in this case, different choices of the comparison group (“non-VDU users”) may also lead to different results, as discussed further on page 71-72.

Epidemiologic investigators must generally study "natural experiments" - in this case, the work situations of real people - rather than being able to decide the number of people who will be exposed for each daily duration (or to any other occupational factor). Thus, even though figures b/ and c/ illustrate cleaner contrasts that are simpler to analyse, these situations are not always available for study. The epidemiologist must decide how to analyse and present the available data in order to learn as much as possible about the risk factors in a given work situation.

In addition, it would not be desirable if only situations like b/ and c/ were studied. Both of them show workplaces where at least one half of the population (the highly exposed) probably performs very monotonous work, spending almost the entire workday at the VDU. However, we are also interested in knowing whether the risk changes when people's jobs are more varied. If the "non-VDU work" performed by the study subjects does not involve some other type of repetitive hand motion, then the group of people who spend neither all nor none of the work day at the VDU provide us with an important opportunity to learn about the variety in activity that might reduce people's risk of musculoskeletal disorders.

Thus, a large number of contrasts are possible and have been studied in the literature reviewed here. We have attempted to categorise these contrasts appropriately in the various tables and to discuss in the text the actual contrast provided by each study. Unfortunately, the actual population distribution of VDU work hours has not been reported in all of the reviewed studies.

Contrasts in other exposure factors
A recurrent problem in several studies is that of inadequate contrast in terms of various specific exposure factors. If all or most of the study population is characterised by similar conditions in terms of one factor under study, then obviously that study will not provide adequate information as to the impact of variations in that factor. Figure 3 provides some graphical illustrations. This issue of contrast is, of course, factor specific, since one study may provide adequate contrast in one factor but not another (see figure 3a and b). Ideally, of course, studies should have adequate contrast for all factors being investigated (figure 3c), practical consequences *e.g.* in terms of populations available for study may often make this difficult. It is, however, essential that such limitations in variations in some factors are taken into considerations, especially when examining “negative” results - *i.e.* data suggesting the absence of associations between some factors and disorders. (In Bergqvist 1995b (20), the authors comment that “since the study group may be favourably selected for, *e.g.*, certain ergonomic conditions, it may not be appropriate to generalise from the lack of associations.....”.) It should also be recognised that studies of interactions between two factors would - generally - require a broad range of contrasts in terms of both, and little correlation between them in the population under study.

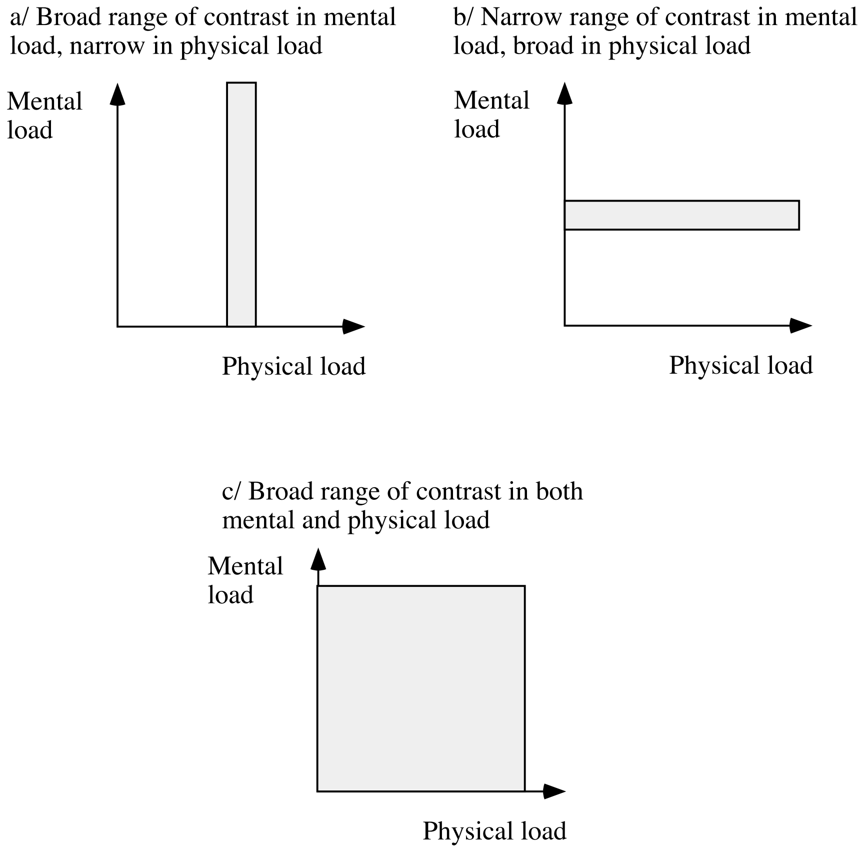

Figure 3. Contrasts in two factors, using “physical load” and “mental load” as two examples of exposure factors. In study a/, only mental load can be adequately investigated, and its estimated effect may be conditional on the physical load experienced by the study subjects. In study b/ only physical load may be studied, and there may be a similar lack of generalisability to other workplaces because of the specific level and narrow range of mental load. Study c/ would enable investigations of both physical and mental loads as well as possible interactions between them, assuming that there is a sufficient number of subjects in relevant combinations of these factors.

VDU work per se

The most common comparison in the studies identified was that of VDU use versus no or little VDU work in offices or other similar occupations. VDU use was defined variously, for example, at least 4 or 5 or 8 hours per day, and the reference groups were also defined in various ways, such as no use at all or less than 2 or 4 hours per day. Thus the magnitude of the estimated relative risks were likely affected by the study design and the exposure differentials between study groups, as already discussed above in the section of exposure contrasts (page 22-25). In an attempt to clarify these distinctions, we list results for VDU work compared to no VDU use (table 1) separately from the comparison of full *vs*. part-time VDU work (table 2); the effects of hours of VDU use per day or week (table 3) here represents exposure-response relations estimated from at least 3 levels of exposure.

VDU operation in general, compared to non-VDU work

In the 18 reports that compared VDU or keyboard operators to non-users, a majority found clear and consistent increases in musculoskeletal disorder prevalences associated with keyboard use. The results are shown in Table 1 and commented on below.

Bernard and colleagues studied employees of a large newspaper and found that keying for at least 60% of the work day conveyed a marked increase in risk of hand/wrist disorders in both the cross-sectional and the prospective phases of their investigation, compared to individuals keying less than 2 hrs/day (21, 22, Table 1).

Bozi Ferraz and colleagues (26) compared keyboard operators with "traditional office workers" not using computer keyboards. The former were implied to work full-time at the keyboard, although this was not stated explicitly. The operators had much higher prevalences of upper extremity symptoms and diagnoses than the non-keyboard workers (Table 1). However, a higher percentage of the operators was female, so the results may have been confounded by gender. Subjects with and without disorders were also compared on the average number of keystrokes per hour during the previous month (obtained from company records) and no significant difference was found. Unfortunately, the authors did not state whether this comparison was made only within the keyboard operators, or whether the non-keyboard workers were included as a referent group for this analysis. Camerino and colleagues (32) found a significantly elevated prevalence of cervical spine disorders among female VDU operators aged 26 to 35 years, compared with female workers in the same age range without occupational exposure to prolonged fixed postures (Table 1).

Table 1. Effect of visual display unit use (Yes/No) on frequency of upper extremity musculoskeletal disorders: Relative risk with 95% confidence interval (CI) and/or p-value for test of linear trend in exposure-response relationship (E-R).

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Bergqvist, 1992 (18)	Nk, Sh sx:		Arm sx:		Hand/wrist sx:	
	Cross-sectional (1981)	OR=1.0 (0.7-1.4)	Follow-up (1981-87)	RR= 1.3 (0.6-2.5)	Cross-sectional (1981)	OR= 1.0 (0.6-1.7)
	Cross-sectional (1987)	OR=0.8 (0.5-1.4)			Cross-sectional (1987)	OR= 1.3 (0.6-2.8)
	Follow-up (1981-87)	RR=1.0 (0.6-1.6)			Follow-up (1981-87)	
					- All VDU use	RR= 2.8 (0.8-10.1)
					- New VDU use during follow-up	RR= 4.0 (1.1-14.9)
Bergqvist, 1995a (19)	Any symptoms	OR= 1.4 (0.8-2.4)			Any symptoms	OR=1.2 (0.6-2.2)
	Intense symptoms	OR= 0.5 (0.2-1.8)			Any diagnosis	OR=0.7 (0.3-1.7)
	TNS diagnosis	OR= 1.0 (0.5-1.9)				
	Cervical diagnosis	OR= 1.3 (0.6-2.6)				
	Shoulder diagnosis	OR= 0.6 (0.3-1.5)				
Bernard, 1993, 1994 (21-22)					Phase I	
					Keying 6-8 vs 0-2 hr/day	OR=2.5 (1.6-3.9)
Bozi Ferraz (26)	Sx in any UE region, past 7 days	PR=3.9 (2.5-6.2)			Hand/wrist tenosynovitis dx	PR=4.9 (1.9-12.5)
	Sx in any UE region, past 12 months	PR=3.7 (2.6-5.3)				
	Tension neck syndrome	PR=5.3 (1.2-23.8)				
	Any UE MSD dx	PR=4.4 (2.5-7.9)				

(for notes, see end of the table)

Table 1. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Camerino, 1995 (32)	Cervical disorders	PR=1.9 (1.0-3.4)				
Kemmlert, 1988 (102)	Neck: VDU primary machine Shoulder: VDU primary machine	OR=2.0 (0.8-4.9) OR=2.1 (0.9-5.2)				
Knave, 1985 (104)	VDU use (>5 hr/day) vs none: Neck, upper arms, and shoulder symptom intensity	Higher for neck and upper arm (left side) and both shoulders (p<0.05)	VDU use (>5 hr/day) vs none: Forearm and elbow symptom intensity	Higher for both forearms (p<0.05) but neither elbow	VDU use (>5 hr/day) vs none: Hand symptom intensity	Higher for both hands (p<0.05)
Krapac, 1994 (105)	Cervical syndrome Cervicobrachial syndrome	PR=2.3 (0.8-6.4) PR=1.0 (0.3-3.0)				
Marcus, 1996 (125)	Nk/sh sx: Current use vs. never use Former use vs. never use	 PR=2.3 (1.4-3.7) PR=2.5 (1.5-4.2)	Arm/hand (see to the right)		Arm/hand: Current use vs. never use Former use vs. never use	 PR=1.1 (0.7-2.0) PR=1.7 (0.9-3.0)
Murata, 1996 (133)					Subclinical CTS, by NCV: wrist-to finger (wf) wrist-to-palm ratio of wf to palm-to-finger value number of symptoms	 p=0.03 p=0.02 p=0.003 p<0.001

(for notes, see end of the table)

Table 1. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Nishiyama, 1984 (138)	Nk sx: Sh sx:	p>0.05 p<0.05	Arm sx:	p>0.05	Fingers sx:	p>0.05 (right) p<0.05 (left)
Ong, 1981 (142)	Arm/shoulder aches (2 VDU groups combined)	PR=1.9 (1.1-3.5)	Arm/shoulder (see to the left)			
Onishi, 1982 (144)	VDU vs other office machines	Highest median trapezius EMG levels	VDU vs other office machines	Highest median forearm extensor EMG levels		
Starr, 1982 (189)	Nk: VDU vs paper task Sh: VDU vs paper task	OR=2.0 (1.1-3.6) OR=1.6 (0.9-2.8)	Upper arm: VDU vs paper Elbow: VDU vs paper	OR=1.1 (0.5-2.5) OR=0.8 (0.3-2.0)	VDU vs paper task	OR=0.7 (0.3-1.6)
Starr, 1984 (187)	Nk: VDU vs paper task Sh: VDU vs paper task	OR=1.0 (0.5-1.7) OR=1.3 (0.7-2.2)	Upper arm: VDU vs paper Elbow: VDU vs paper	OR=1.0 (0.4-2.5) OR=1.3 (0.5-3.4)	VDU vs paper task	OR=1.2 (0.5-3.0)
Stellman, 1987 (190)	All-day VDU use	OR=1.7 (1.1-2.6)	All-day VDU use	OR=2.0 (1.2-3.6)	All-day VDU use	OR=2.8 (1.6-4.9)

* All comparisons are for current VDU use (some) versus no VDU use, unless otherwise specified.

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electromyography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist.

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses. E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

Hocking (83) presented selected data from passive surveillance of "repetition strain injury" (RSI) at the Australian national telecommunications agency from 1981 through mid-1987. RSI reports were included from multiple data sources, with no case criteria specified; in fact, the author stated that "the clinical details of the cases had not been reviewed." Furthermore, individual subjects could have contributed multiple reports, and exact denominators for each job group in each year do not appear to have been available. The highest incidence rate was found for telephonists and the lowest for telegraphists, but insufficient exposure information is provided for the three job categories to interpret these differences in terms of ergonomic factors. No unexposed group or reference rates are provided. The author states that the incidence rates showed an inverse relationship with keystrokes per hour and no association with length of employment, but no data are shown and the sources of these data are not specified. The rates peaked in 1984-85 and then declined; this may have been in response to ergonomic measures undertaken in the company before and during that period, although inadequate information is available to conclude this with certainty. (These results are not shown in Table 1).

Kemmlert and Kilbom (102) investigated those with primary use of VDUs *vs*. other office workers and found elevated but non-significant excesses of neck and shoulder discomforts (see Table 1). Similar increased odds ratios were also found for non-VDU users who (primarily) used typewriters. This study did adjust for other factors, though.

In a large cross-sectional study in Sweden, Knave et al (104) used symptom severity as the endpoint, so prevalences and odds ratios could not be calculated from published data; symptoms of the neck, shoulder, and upper arms were scored as more intense among VDU users (more than five hours per day), although only the differences at the shoulder reached the statistical significance of $p=0.05$ (Table 1). In other results, not shown in the paper, male subjects with musculoskeletal disorders of any body region worked more hours per day at the VDU than their counterparts without disorders ($p<0.05$). The authors did not use multivariate analyses to examine multiple exposure dimensions simultaneously, and they reported large differences in both symptom severity and total hours worked per day among different industries, so these data may have been confounded by total hours or by task characteristics.

The same population was followed up by Bergqvist and colleagues over a seven-year period as a closed cohort with a series of cross-sectional surveys; of the several articles published to date, two have examined the dichotomous variable of VDU use (18, 19, Table 1). In both the cross-sectional and the follow-up studies, VDU use (all types combined) was not associated with neck and shoulder morbidity after controlling for covariates; for hand and wrist disorders there were some elevated odds ratios but these were not statistically significant at $p=0.05$ except among those subjects who began using VDUs during the follow-up period. However, several categories of more intensive use, or use in adverse conditions, did appear to increase the risk (19); these are described under the various specific headings below. There was also a suggestion of a self-selection process ("healthy worker effect"), in that among the subjects who dropped out of the cohort, the VDU users were more than twice as likely to have had hand/wrist disorders at baseline. Upon contact, however, few among this dropout confirmed that muscle problems experienced during VDU work had contributed to their leaving the work place.

Krapac and colleagues (105) also compared VDU users and non-users in a small cross-sectional study of office workers. Pain and fatigue in the musculoskeletal system (neck, upper extremity and back combined) during work were about 50% more frequent in the operators, and cervical syndrome was diagnosed in more than twice as many VDU users as non-users (Table 1). The study suffered from potential confounding, as a higher proportion of the VDU users were women; they were also slightly younger and had slightly less seniority than the non-VDU workers.

Marcus and Gerr (125) also reported a cross-sectional study, comparing hours per week and duration in years of VDU use within a large group of young women office workers. Both neck/shoulder symptoms and hand/arm symptoms were more prevalent among current users than workers who had never used a VDU. Perhaps more importantly, the prevalence ratios were even higher for former VDU users compared with never users. This provides further evidence that workers who develop VDU-related symptoms are disproportionately likely to seek jobs without VDU exposure, when able to do so, and thus that cross-sectional studies likely systematically underestimate the risk associated with VDU work. However, the subject participation level was only 70%, suggesting possible selection bias, although participants and non-participants did not differ in their distributions of age or job title.

Murata *et al.* (133) compared the sensory nerve conduction velocities (NCV) in the right median nerve between a group of VDU operators and a referent group of students with only occasional work processing activity. Despite the small study size, the VDU operators were found to have markedly lower NCV values across the carpal tunnel than the comparison group (Table 1). The operators also had many more self-reported CTS and other upper extremity symptoms; the authors stated that there was no correlation between symptoms and NCV, although that analysis may have been diluted by inclusion of some symptoms not usually considered typical of CTS, such as shoulder stiffness.

In a Japanese study in the newspaper industry (138), prevalences of dullness or pain were significantly higher among VDU users than other keyboard operators not using a VDU in the shoulders and (left) fingers. For the neck and left arm, these differences were not significant, and for right arm, no differences were found. The authors made the comment that the left hand was used for keying, while the right hand was used for operating the cursor keys or the joy stick. It should be noted that the operators used Kanji characters, not alphanumeric characters, which involves more complex motion patterns in text entry (see *e.g.* (131)). The two groups were of similar ages, but no adjustments for gender or other covariates was performed, and the response rate was not stated, limiting the conclusions that could be drawn from this study.

Two groups of VDU users investigated by Ong (142) had (combined) about twice the prevalence of aches in the arm and shoulder than the non-VDU users. In another study of female office workers operating a variety of office machines (144), shoulder stiffness and fatigue of the hands, arms, and shoulders increased across the shift, while staying higher for office machine operators; shoulder compression tenderness thresholds decreased across the day and the work week. Sustained contractions of the forearm and shoulder muscles were documented among operators of all six machines studied; the median forces (as a percentage of maximum strength capacity) were highest for VDU operators, about four times the level recommended to prevent muscle fatigue and its sequelae (144, see Table 1).

In a pair of studies by Starr *et al.* with comparable methods, symptom prevalences were compared between directory assistance operators who used VDUs and those who used paper records to perform similar tasks (187, 189, Table 1). In one of these studies (189, but not in the other) neck and shoulder conditions were about twice as frequent among VDU operators; no other differences were observed between the two types of work. Several weaknesses limit the utility of these results. The physical demands of the non-VDU jobs were not described, so it could not be verified that the non-VDU work represented an appropriate ”control” (*i.e.*, low exposure) group. In the first of the two surveys there was differential participation between the VDU users and non-users (76% and 95%, respectively); it was also not clear whether subjects were assured of the confidentiality of their questionnaire responses. Lastly, there was inadequate adjustment for potential confounding, even though in the second paper the VDU users were older and age was negatively associated with symptoms.

Smith and colleagues (180) studied 283 employees of a large newspaper. Pain and stiffness in the arms, hands and legs combined was stated to be more frequent in VDU users than non-users (no data presented) but was negatively associated with length of employment. No results were shown for upper extremity symptoms alone. This study was flawed by low participation (48%) of the target population; data were available for about one-half of the non-participants, who had less education and less VDU experience than the participants (results not shown in Table 1).

Finally, a study by Stellman *et al.* examined the effects of three types of VDU work (keypunch, data processing, and word processing) among women employed in the public sector (190). The risk of neck and shoulder, arm, wrist and hand disorders were about twice as high in full-time VDU users as in clerical workers using only paper records, with neither VDUs nor typewriters (Table 1). The subjects were all women of similar ages, although the authors did not adjust for other covariates.

Although not strictly a study of VDU operators, an older study of accounting-machine operators (87, 122, 123) deserves some interest. These operators were compared to non-clerical workers (retail saleswomen) as the basis for estimating the symptom frequencies that would be expected in workers with neither clerical nor other significant ergonomic stresses to the upper extremity. All subjects were women of comparable ages. The right hand and arm exclusively were used to operate the keyboard, and the operators had higher prevalences of arm and hand symptoms on the right than on the left (non-operating) side. In addition, pain in the arms and hands was more common among the operators than the saleswomen, especially on the right side (relative risks of 3.4 and 2.0, respectively, Table 1). Thus, accounting machine operation was found to present a risk of arm and hand pain which was significantly elevated relative to other, non-clerical work that women of the same age might perform and which was localised to the limb performing the keyboard work.

In summary, the overall comparisons between people doing VDU work and people in other kinds of work produced numerous indications of the former group being at higher risk of neck, shoulder, arm, wrist and hand musculoskeletal problems. In general, the highest odds ratios and relative risks were found for hand and wrist disorders. To the extent that these studies are not all consistent, there are several possible reasons that might explain the discrepancies. One is that, as discussed previously, "VDU work" in one study may represent full-time, intensive keying with high psychological demands at a poorly designed workstation and in another study may refer to jobs with frequent rest breaks, fully adjustable workstations and a good psychosocial environment. Workers in the first situation would likely have much higher risks than the workers in the second; this may explain why, to some extent, high increases are found in the older studies (*e.g.*, Ong *et al.* (142), Onishi *et al.* (144), Stellman *et al.* (190)) and those carried out in developing countries (*e.g.*, Bosi Ferraz *et al.* (26) or Krapac and Sakic (105)) but not in some of the recent studies in countries with high attention to workplace ergonomics (*e.g.*, Bergqvist *et al.* (18, 19)). A related consideration is the choice of the reference group. Some authors were able to define and recruit workers not exposed to upper extremity stressors (*e.g.*, Camerino *et al.* (32)), while others utilised workers in jobs that may have involved a great deal of repetitive hand motion (*e.g.*, Starr *et al.* (189) and Starr (187)).

Third is the issue of the "healthy worker effect," *i.e.*, negative selection or self-selection out of the job by people who develop work-related health problems. It has been shown previously that workers who develop musculoskeletal disorders are disproportionately likely to transfer out of jobs that are ergonomically stressful (135, 145, 179). The effect of this transferring or leaving employment is to produce an underestimate in the risk observed from the study data (152). This type of selection effect could here explain the failure to find associations with VDU use or duration of employment in some of the studies that examined those variables. Indirect evidence for this effect has already been noted in the study by Bergqvist *et al.* (18); furthermore, in that study, the odds ratio for hand/wrist disorders in new VDU users during the follow-up period was somewhat higher than that estimated for continuing users. Marcus and Gerr (125) showed that former VDU users had a higher relative risk for upper extremity disorders than current users (both groups compared with never users). Indirect evidence for this effect was also found in Starr *et al.* (187), where age was associated with fewer symptoms and VDU operators were somewhat older than the non-VDU clerks.

Full-time *vs.* part-time VDU operators

Studies of people performing VDU work all or most of the time, *vs.* those who spent less time at the VDU, are reviewed here and summarised in Table 2.

The Swedish investigation described above included several analyses of the effect of hours of VDU use. In the follow-up of the cohort (18), VDU users were subdivided into those with up to and more than 30 hours per week of operation; the longer duration demonstrated an increase in the risk of arm and hand/wrist disorders (both 95% confidence intervals included 1.0), but not neck/shoulder disorders (Table 2). The authors failed to find associations between overtime on short notice and muscle problems, but frequent overtime was associated in the final multivariate model with arm/hand discomforts (20).

Grieco *et al.* (71) studied a very large population of VDU operators at the Italian Telecommunications Company. They presented prevalences of "frequent" neck and upper limb disorders but did not specify the case definitions or any data collection methods. Age-standardised morbidity ratios (SMR) were computed for male and female VDU operators separately, using the entire work-force at the same company as the reference group. Overall, both neck and upper extremity disorders were strongly associated with VDU use for at least 4 hours per day (Table 2).

In another large study of keyboard users in a mix of industries, Rossignol *et al.* (163) reported the prevalences of several upper extremity endpoints by four strata of hours of daily operation. Neck, shoulder, and arm disorders were all at least twice as frequent among subjects with at least 4 hours exposure per day; the odds ratios for hand pain and hand paresthesia were lower and not statistically significant, except among banking, communications, and hospital employees (Table 2).

In the only other cohort extensively studied to date, by Nathan *et al.* (135, 137), nerve conduction velocity (NCV) measurements of the median nerve were obtained as a clinical test for evidence of carpal tunnel syndrome (CTS). In the baseline survey, an odds ratio point estimate of 2.75 for bilateral median nerve slowing was calculated for more than 4 versus less than 4 hours of keying per day among clerical workers (”occupational hand use” Classes I and II, (137), Table 2). In addition, a test of linear trend in the odds of slowing across all classes was highly statistically significant ($p = 0.001$). However, the data were not stratified by gender, so potential confounding could not be ruled out. (This study was reported as negative by the authors, who made some arguably inappropriate choices in statistical analysis methods; several other reviewers (*e.g.*, Stock (193) and Hagberg *et al.* (75) have concurred that it contains positive findings.) NCV findings were also reported after five years of follow-up (135). The study design

Table 2. Effect of full-time versus part-time visual display unit work on frequency of upper extremity musculoskeletal disorders. Relative risk with 95% confidence interval (CI) and/or p-value for test of linear trend in exposure-response relationship (E-R).

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Bergqvist, 1992 (18)	Follow-up (1981-87) VDU >30 vs ≤ 30 hr/wk (among users)	RR=0.6 (0.4-1.0)	Follow-up (1981-87) VDU >30 vs ≤ 30 hr/wk (among users)	RR=1.4 (0.8-2.7)	Follow-up (1981-87) VDU >30 vs ≤ 30 hr/wk (among users) New VDU use >30 vs ≤ 30 hr/wk (among users)	RR= 1.3 (0.6-2.9) RR= 1.6 (0.7-3.6)
Bergqvist, 1995b (20)			Arm/hand (see to the right)		Any arm/hand sx: Extensive overtime	OR= 2.2 (1.2-4.4)
Fahrbach, 1990 (46)	Nk: VDU use >4 vs ≤4 hr/day) Sh: VDU use >4 vs ≤4 hr/day)	OR= 1.3 (0.5-3.8) OR=10.3 (2.4-43.3)				
Grieco, 1989 (71)	Nk: 4-6 hr/day (men) Nk: >6 hr/day (men) Nk: 4-6 hr/day (women) Nk: >6 hr/day (women)	SMR=152 ($p<0.05$) * SMR=165 ($p<0.05$) * SMR=108 ($p>0.05$) * SMR=125 ($p<0.05$) *	UE: 4-6 hr/day (men) UE: >6 hr/day (men) UE: 4-6 hr/day (women) UE: >6 hr/day (women)	SMR=144 ($p<0.05$) * SMR=201 ($p<0.05$) * SMR=102 ($p<0.05$) * SMR=125 ($p<0.05$) *	UE (see to the left)	
Hales, 1992, 1994 (78-79)	Overtime in past year	E-R (neg.)				

(for notes, see end of the table)

Table 2. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Heyer, 1990 (81)	Nk: VDU use ≥4 vs ≤2 hr/day	PR=1.4 (0.9-2.2)	VDU use ≥4 v ≤2 hr/day	PR=2.0 (0.8-5.5)	VDU use ≥4 vs ≤2 hr/day	PR=2.3 (1.1-4.4)
	Nk: VDU use >6 vs 4-6 hr/day	PR=1.1 (0.9-1.4)	VDU use >6 v 4-6 hr/day	PR=0.9 (0.6-1.3)	VDU use >6 vs 4-6 hr/day	PR=1.0 (0.7-1.3)
Kamwendo, 1991a (94)	Nk: Work with office machines ≥5 vs <5 hr/day	OR=1.7 (1.0-2.7)				
	Sh: Work with office machines ≥5 vs <5 hr/day	OR=1.9 (1.2-3.0)				
Karlqvist, 1996 (101)	Mouse use ≥5.6 vs <5.6 hr/day:		Mouse use ≥5.6 vs <5.6 hr/day:		Mouse use ≥5.6 vs <5.6 hr/day:	
	- Neck	OR=1.1 (0.8- 1.7)			- Left wrist	OR=3.4 (1.1-11)
	- Left scapular	OR=1.2 (0.7- 2.0)	- Left elbow	OR=4.3 (1.4-13)	- Right wrist	OR=2.0 (1.0- 4.3)
	- Right scapular	OR=1.1 (0.7- 1.7)	- Right elbow	OR=2.0 (1.0- 4.1)	- Left hand/fingers	OR=2.6 (1.0- 6.8)
	- Left shoulder	OR=4.0 (1.6-10.1)			- Right hand/fingers	OR=3.1 (1.5- 6.6)
	- Right shoulder	OR=3.9 (1.8- 8.1)				
Nathan, 1988 (137)					Median nerve function: Keyboard operator (>4 hr/day) vs. clerical (<4 hr/day)	OR=2.8 (0.8-9.6)

(for notes, see end of the table)

Table 2. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Oxenburgh, 1987 (146)					VDU use >4 hr vs <3 hr/day	OR=7.9 (2.6-32)
Rossignol, 1987 (163)	Nk: VDU use (4 vs 0-3 hr/day)	PR=2.8 (1.8-3.9)	VDU use (4 vs 0-3 hr/day)	PR= 2.0 (1.2-3.7)	Numbness/tingling: VDU use ≥4 vs 0-3 hr/day	PR=1.2 (0.3-5.7)
	Sh: VDU use (4 vs 0-3 hr/day)	PR=3.0 (1.9-4.4)			Hand/wrist pain: VDU use ≥4 vs 0-3 hr/day	PR=1.5 (0.8-2.6)
					Hand/wrist pain: VDU use ≥4 vs 0-3 hr/day in banking, communications, and hospitals	PR=2.4 (1.0-6.0)

* Reference group for all SMRs shown: the entire telecommunications company workforce.

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electromyography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist.

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses. E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

placed more emphasis on exposures in industrial jobs and the association between Classes II and I alone could not be determined from the data provided; however, occupational hand use at baseline, across all five classes, was a statistically significant predictor of NCV slowing, along with age and hand dominance.

Oxenburgh (146) compared 46 cases of ”repetition strain injury” with a sample of referents without injury (all women). The two groups differed little with respect to workstation and physical environment, but the cases worked many more hours at a keyboard (87% using VDUs). No cases used keyboards fewer than 3 hours per day, so the odds ratio could only be calculated for the effect of at least 4 hours of operation (Table 2).

Karlqvist *et al.* (101) carried out the only epidemiologic study to date to focus specifically on computer mouse users. They selected the CAD operators (n=542) from a total study group of 652 telecommunications laboratory workers and examined the associations of neck and upper extremity symptoms with hours per day of mouse use and mouse location (see next section). After adjusting for age and gender (see Tables 2), the odds ratios with prolonged mouse use were 2.2 or higher for shoulder/upper arm, elbow, wrist, and hand/finger symptoms. Somewhat surprisingly, even though most of the subjects operated the mouse with the right arm, symptoms in the left shoulder and arm were as likely to be associated with mouse use as the right side. Possible explanations for this may include the effect of keyboard work with the non-mouse hand, operators having changed sides of mouse use after developing symptoms, and sympathetic muscle coactivation.

Odds ratios could also be computed from three further studies, and in general the increase in risk of upper extremity morbidity for 4 or more versus less than 4 hours per day was approximately two (46, 81, 94, Table 2). However, two of these studies suffered from potential selection bias (46, 81) and none of them controlled for potential confounding by gender and/or the simultaneous effects of multiple exposures (46, 81, 94).

Three studies were judged to have inadequate power to examine the relationship because there was so little variability in exposure (*i.e.*, all of the subjects used VDUs 6 or more hours per day) (78, 84, 170). Nevertheless, Hoekstra *et al.* found an association among telephone service workers with more than 8 hours per day (the question was worded with respect to telephone use, but subjects used both the telephone headset and the keyboard continuously during work, so the effects of these two items could not be separated (84).

Hours of VDU operation per day

A number of studies compared the risk of MSDs at multiple levels of exposure, characterised either as hours of keyboard operation per day or per week or as percentage of the day spent keying (Table 3).

In the follow-up study of Bergqvist *et al.* (18), increases were found in cumulative incidence of hand/wrist disorders ($p<0.05$) and arm/shoulder disorders ($p>0.05$) per hour of weekly VDU use.

Table 3. Effect of number of hours of VDU work per day or week on frequency of upper extremity musculoskeletal disorders: Relative risk with 95% confidence interval (CI) and/or p-value for test of linear trend in exposure-response relationship (E-R).

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Bergqvist, 1992 (18)	Follow-up (1981-87) Change in cumulative incidence, per 10 hr/week VDU use	-4.6% (-10.5 - 1.2%)	Follow-up (1981-87) Change in cumulative incidence, per 10 hr/week VDU use	+2.6% (-2.0 - 6.1%)	Follow-up (1981-87) Change in cumulative incidence, per 10 hr/week VDU use	+3.2% (0.2 - 6.1%)
Bernard, 1993, 1994 (21-22)	Keying 6-8 vs 0-2 h/day	p>0.05 in multi-variate analysis			Phase I 2-4 h/day 4-6 h/day 6-8 h/d ≥8 h/day (cf with <2 h/day) Phase II Keying 60-79% of day Keying 80-100% of day One-year increase in hr/day keying	ORs: 1.0 (0.6-1.8) 1.3 (0.8-2.2) 2.1 (1.3-3.6) 3.3 (1.2-8.9) ORs: 7.6 (1.8-32) 2.3 (1.0-7.8) 9.1 (7.1-11.6)
Burt, 1990 (30)	Nk: Keying 20-39% of day Nk: Keying 40-59% of day Nk: Keying 60-79% of day Nk: Keying 80-100% of day	OR=2.0 (1.0-7.7) OR=2.6 (1.4-5.0) OR=2.2 (1.0-4.7) OR=2.8 (1.4-5.4)	Keying 20-39% of day Keying 40-59% of day Keying 60-79% of day Keying 80-100% of day	OR=1.2 (0.6-2.5) OR=1.7 (0.8-3.5) OR=1.9 (0.9-4.3) OR=2.8 (1.4-5.7)	Percent of time keying	p<0.01 in intial, p>0.05 in multivariate analysis
DeMatteo, 1993 (41)	MS sx, all UE regions: VDU hr/day	E-R, p<0.03				

(for notes, see end of the table)

Table 3. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Evans, 1987 (45)	Nk/sh pain "often:" VDU hr/day	E-R, $p<0.0001$				
Faucett, 1994 (47)	Nk/sh disorders: Per hr/day VDU use	OR=1.5 (1.1-2.1)			Disorders: Per hr/day VDU use	OR=1.5 (1.1-2.1)
Hales, 1992, 1994 (78-79)					dx: Per hr/day VDU use	E-R (neg.)
Jeyaratnam, 1989 (89)	Nk sx: VDU hr/day Sh sx: VDU hr/day	E-R, $p<0.05$ E-R, $p<0.05$	VDU hr/day	no E-R	VDU hr/day	no E-R
Kamwendo, 1991b (95)	Nk/sh fatigue and pain: Typing hr/day	Positive correlations within shift ($p<0.05$) for 33% of subjects				
Knave, 1985 (104)	MS sx, all body regions	$p<0.05$	MS sx, all body regions (see to the left)		MS sx, all body regions (see to the left)	
Marcus, 1996 (125)	Nk/sh: hr/week current VDU use	no E-R	Arm/hand (see also to the right)		Hand/arm: hr/week current VDU use	no E-R

(for notes, see end of the table)

Table 3. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Oxenburgh, 1987 (146)					Per hr/day VDU use	E-R, p<0.0001
Rossignol, 1987 (163)	Nk: VDU hr/day Sh: VDU hr/day	E-R, p<0.001 E-R, p<0.001	Hours VDU use/day	E-R, p=0.01	Pain Numbness	E-R, p=0.14 no E-R. p=0.50
Sauter, 1983, 1984 (168-169)	Neck/shoulder/back: VDU hr/day	r=-0.15 (p<0.05)	Arm/wrist (see also to the right)		Arm/wrist/hand: VDU hr/day	p>0.05 in multi-variate analysis
SHARP, 1993 (174)	Sh sx: per hr/day keying	OR=2.5 (p<0.10)			Sx: per hr/day of keying Sx/PE: per hr/day of keying	OR=3.1 (1.2-8.4) OR=1.8 (0.9-3.8)

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electro-myography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist.

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses.
E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

DeMatteo *et al*. (41) compared full-time data entry clerks in highly repetitive jobs with clerical workers who used the VDU fewer hours per day and had more varied tasks. A correlation was found between the number of symptoms and hours at the VDU, although this may have been confounded by the primary contrast between job titles. No data were presented on gender, age, or other covariates, so the potential for uncontrolled confounding could not be ruled out.

Evans (45) analysed 3,819 questionnaires received from a mail-in survey of VDU users. The occurrence "often" of neck and shoulder pain increased three-fold among respondents working more than 8 hours per day at the VDU compared to those working 1-2 hours per day. However, this association is difficult to interpret in the light of potential selection and information bias and lack of statistical adjustment for covariates.

Jeyaratnam and colleagues (89) carried out a large cross-sectional study in which they compared female VDU operators on several occupational and non-occupational factors. An increasing prevalence of neck and of shoulder symptoms was found with hours per day of operation, although this was not the case for elbow or wrist/hand symptoms. Large differences were found among ethnic groups and age strata, but no statistical adjustment was carried out for these variables (Table 3).

In a nested case-referent study among 156 office workers, Oxenburgh (146) found a distinct exposure-response relationship between VDU use and hand/wrist problems. An exact test comparing at least 2 with less than 2 hours was also highly significant ($p<0.01$). In contrast, Marcus and Gerr ((125)) did not find significant exposure-responses with arm/hand problems, nor with neck and shoulder problems in a larger, cross-sectional study (Table 3).

In the study by Rossignol *et al*. already described above (163), tests of linear trend across all four strata of exposure duration, and pooling all industries, were highly statistically significant for neck, shoulder, and arm pain (Table 3). Examining the possible effect of modest amount of VDU work, the authors found - in general - little difference in risk between 0 hours and 0.5 to 3 hours per day, except for neck and shoulder symptoms in computer and data processing services, public utilities, and state agencies.

Rubino *et al*. (165) carried out a very large study, the methods of which were not described at all in the paper. Musculoskeletal symptoms of the neck, upper limbs and lower limbs were combined into a single factor, which increased in intensity with increasing number of hours per day at the VDU (no statistical test reported). However, interpretation of these findings is difficult without more knowledge of the study methods (data not shown in Table 3).

Sauter (168, 169) recruited a sample of 248 VDU users *vs*. 85 "traditional" office workers and found a negative association between hours per day of VDU use and upper torso musculoskeletal discomforts. A non-significant association was found between extremity discomforts and VDU use (Table 1). Separate analyses were not performed, however, for specific body locations such as the neck or shoulder.

Three studies examined VDU use among newspaper employees. Two of these, originally undertaken as health hazard evaluations by the US National Institute of Occupational Safety and Health (NIOSH), were large investigations that achieved sufficient variability in hours of exposure to obtain stable estimates; both also utilised data on numerous covariates in multivariate analyses. Bernard and colleagues found that keying for at least 60% of the work day conveyed a marked increase in risk of hand/ wrist disorders in both the cross-sectional and the prospective phases of their investigation, with odds ratios ranging from 2.3 to as high as 9.1 for an increase in daily hours of keying in the previous year (21, 22, Table 3). The results of Burt *et al.* (30) demonstrated clear exposure-response relationships for both neck and elbow/forearm disorders with proportion of the day keying (Table 3). Similar relationships for shoulder and wrist/hand disorders were observed in univariate analyses but were no longer statistically significant when typing speed was included in the multivariate models.

A smaller study of VDU operators in a newspaper editorial department demonstrated strong dose-response trends with hours per day of VDU use and disorders of both the hand/arm and the neck/shoulder/upper back, using multivariate statistical analyses (47, Table 3). Each of the odds ratios exceeded 2.0 for as little as two hours per day of keyboard use. Gender and age were not included in the regression models in the article, but unpublished data showed no change in results with inclusion of either covariate (Julia Faucett, Univ. Calif. San Francisco, personal communication, 1994-95). The participation was only 56% among recruited individuals, but respondents and non-respondents were similar in age, job title, and duration of employment at the newspaper. More women than men responded, but gender was only weakly associated with the outcomes and did not confound the crude analyses.

In an office of workers' compensation claim clerks, a follow-up intervention study was carried out in which the third cross-sectional survey was also analysed separately for associations with prevalent cases (174). Within this small group (n=34), the number of hours keying per day was about one hour higher for each of the shoulder, elbow, and wrist/hand, using both symptom-based case definitions and case definitions based on physical examination (PE) (although only the comparison for shoulder symptoms was significant at the level of $p<0.05$). From multivariate analyses, the risk of shoulder symptoms, hand/wrist symptoms and hand/wrist PE cases increased from two to three times per hour of daily keying (Table 3).

In multiple measures of symptoms across the work shift, neck and shoulder fatigue and pain increased as the number of hours worked (95). In contrast, Hales *et al.* (78) found that hours per day were weakly but negatively associated with severity of hand/wrist pain (78).

In summary, when comparisons were made between individuals performing more *vs.* fewer hours per day, the great majority of studies showed a substantial increase in neck, shoulder, arm and hand problems among those working for longer hours on a VDU. The exceptions were primarily the three studies with inadequate power, and those that failed to control for potential confounding.

Duration (years) of exposure to VDU or keyboard operation

Years of employment in a VDU-exposed job was used in several of the studies reviewed as an estimator of cumulative exposure to VDU or keyboard work. In one study, calculated person-years of VDU work was used. Results are shown in Table 4, and discussed further below.

Duration of employment in VDU work type jobs was found to be associated with an increased risk of neck and/or shoulder symptoms in several studies (22, 30, 32, 41, 71, 94, 125, 174) and of arm/elbow or hand/wrist symptoms in some (71, 125, Table 4). Some additional results merit further discussion, though.

Camerino and colleagues (32) combined female VDU operators aged 26 to 35 years with a group of female office workers not using VDUs, whom they found to have a similar index of postural fixity and a prevalence of cervical disorders intermediate between the VDU operators and the reference group. In the same age group, the prevalence of cervical disorders was significantly associated with years of occupational exposure to fixed postures (Table 4). This indicates that some, but perhaps (?) not all, of the elevated risk for the VDU operators can be attributed to the static postural demands associated with prolonged sitting at a desk. In the study by Jeyaratnam and colleagues (89) already described, no or even a negative association was found with years of VDU work.

Knave *et al*. reported a small difference (not statistically significant) in length of employment between subjects with any musculoskeletal disorder versus those with none (104). However, in a later examination of the same cohort, with adjustments for some confounders, Bergqvist *et al*. (19) failed to find increased prevalences among individuals with more than 5 person-years of accumulated VDU work compared to those with less. As already pointed out above, in this study population, individuals who began VDU work during the follow-up period (7 years) were at higher risks of hand and wrist problems. Furthermore, dropouts during this period were also more likely to report hand/wrist problems prior to dropout. Both of these factors may contribute to this lack of association with person-years.

A very small study by Pickett *et al*. of intensive data entry work showed no association with length of employment for any upper extremity symptoms, but there was no adjustment for age or any other covariates, including poor workstation ergonomics (150).

In summary, the comparisons of individuals with longer and shorter duration of VDU work have not produced consistent results. However, all of the methodological concerns discussed above with respect to studying the effect of VDU work per se are equally relevant here. It should be noted that the analyses that failed to find such significant differences were either small (Picket et al), or belonged to the Swedish study (Knave/Bergqvist) that overall gave the weakest support for an association between VDU work per se and muscle (neck) prob lems. Furthermore,

Table 4. Effect of years of employment or person-years in VDU work on frequency of upper extremity musculoskeletal disorders. Relative risk with 95% confidence interval (CI) and/or p-value for test of linear trend in exposure-response relationship (E-R).

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Bergqvist, 1995a (19)	Nk/sh sx: ≤5 p.y	OR=1.5 (0.8-3.1)	Arm/hand		Arm/hand sx:	
	>5 p.y	OR=1.3 (0.7-2.5)	(see to the right)		≤5 p.y	OR=1.3 (0.6-2.9)
	Intense nk/sh sx: ≤5 p.y	OR=0.9 (0.3-3.1)			>5 p.y	OR=1.4 (0.7-2.8)
	>5 p.y	OR=0.8 (0.3-2.5)			Arm/hand dx:	
	TNS dx: ≤5 p.y	OR=1.2 (0.5-2.8)			≤5 p.y	OR=0.8 (0.3-2.3)
	>5 p.y	OR=1.0 (0.4-2.1)			>5 p.y	OR=0.6 (0.2-1.6)
	Cervical disorders ≤5 p.y	OR=1.3 (0.6-3.0)				
	>5 p.y	OR=1.1 (0.5-2.3)				
	Any shoulder dx: ≤5 p.y	OR=0.6 (0.2-1.6)				
	>5 p.y	OR=0.7 (0.3-1.6)				
Bernard, 1993, 1994 (21-22)	Sh: Per year of employment	OR=1.4 (1.2-1.8)			Length of employment	p>0.05 in multivariate analysis
	Nk: Length of employment	p>0.05 in multi-variate analysis				
Burt, 1990 (30)	Neck: As reporter:		Length of employment	p>0.05 in multi-variate analysis	Length of employment	p>0.05 in multivariate analysis
	≤1 year	OR=4.6 (1.3-15.7)				
	>1 - <5 years	OR=6.5 (2.6-15.9)				
	5- <10 years	OR=10.7 (3.6-32.5)				
	≥10 years	OR=7.6 (2.4-20.4)				
	Neck: Other jobs:					
	≤1 year	OR=1.0 (reference)				
	>1 - <5 years	OR=2.8 (1.3-6.4)				
	5- <10 years	OR=4.4 (1.8-10.7)				
	≥10 years	OR=7.4 (3.1-17.7)				

(for notes, see end of the table)

Table 4. (Continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Camerino, 1995 (32)	Nk: Years exposed to fixed postures (ages 26-35 years)	E-R, p=0.001				
DeMatteo, 1993 (41)	MS sx, all UE regions: Years of VDU experience	E-R, p<0.03	UE sx (see to the left)		UE sx (see to the left)	
Grieco, 1989 (71)	Nk: > 4 years of VDU work (men) Nk: >4 years of VDU work (women)	SMR=1.30 (p<0.05) * SMR=1.12 (p<0.05) *	UE: > 4 years of VDU work (men) UE: >4 years of VDU work (women)	SMR=1.20 (p>0.05) * SMR=1.14 (p<0.05) *	UE sx (see to the left)	
Kamwendo, 1991a (94)	Nk: Years employed Sh: Years employed	E-R, p=0.01 E-R, p=0.002				
Marcus, 1996 (125)	Nk/sh: VDU use: <3 years 4-6 years > 6 years	 OR=4.1 (1.5-11.2) OR=5.6 (2.0-15.7) OR=4.3 (1.4-13.6)	Arm/hand (see to the right)		Arm/hand: VDU use: <3 years 4-6 years > 6 years	 OR=1.9 (0.7-5.2) OR=1.9 (0.7-5.3) OR=3.9 (1.2-12.0)

(for notes, see end of the table)

Table 4. (Continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Pickett, 1991 (150)	Nk: Years employed Sh: Years employed	p=0.53 p=0.76	Years employed	p=0.83	Wrist: Years employed Hand: Years employed	p=0.85 p=0.22
SHARP, 1993 (174)	Nk sx: Years in current job Sh sx: Years in current job	p<0.05 p<0.08				

* Reference group for all SMRs shown: the entire telecommunications company workforce

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electromyography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist.

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses.
E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

Marcus and Gerr (125) showed that, in the population they studied, former VDU users had higher rates than never users, providing clear evidence of the difficulty in studying this issue in cross-sectional studies.

VDU work in general, compared to low-exposed industrial jobs

In order to address, in part, the problem posed by the lack of appropriate comparison groups, external reference rates were obtained from a study by Silverstein and colleagues (176, 177) that quantified the prevalence of hand/wrist disorders in US industrial employees according to their exposure to forceful manual exertions and to repetitive manual work. The disorder rates in the jobs that were scored both low in force ("LoF" in Table 5) and low in repetition ("LoR") were 9% based on symptoms alone and 2% for symptoms plus physical examination findings (Table 5). Workers in highly repetitive manual tasks that required low forces ("LoF.HiR") had rates that were more than twice as high (22% and 7%, respectively, for the two case definitions).

Five of the US studies reviewed here used a case definition based on symptoms alone (22, 30, 84, 174), or on symptoms plus physical findings (78, 174) that was identical to or slightly more restrictive than that of Silverstein *et al*. (176, 177). Two of these described groups of newspaper employees, two were of telephone service workers, and one a group of clerks in a state agency (Table 5). All of the groups were of comparable ages except for the last, which was marginally younger on average.

The relative risks for these five groups of office workers were estimated by standardising the reference rates from the industrial workers in low exposure jobs ("LoF.LoR") to the gender distributions of each VDU population in turn. The relative risks for hand/wrist disorders using the symptom-based case definition, adjusted for gender, ranged from about 2 to 5; using the physical examination case definition, the relative risks were about 5 to 9 (Table 5). In other words, the magnitude of these risks was significantly higher than the background population risk, and even exceeded that which would have been expected if they had been employed in highly repetitive, low force jobs in an industrial setting.

In conclusion, there appears to be a substantial body of evidence showing that VDU workers are at increased risk (probably more than doubled) of upper extremity disorders, relative to the risk that they might expect if employed in low-exposure office or industrial jobs. In light of the fact that almost all of these studies are cross-sectional, which suffer from the particular limitation that they likely underestimate the true increase in risk due to exposure, the number of studies that show positive associations and have ruled out most or all competing explanations for their findings is even more impressive.

Table 5. Frequency of hand/wrist disorders in full-time VDU operators compared to industrial workers with low ergonomic exposures (studies with comparable case definitions): Sex-standardised risk ratios (RR) with 95% confidence intervals (CIs).

Study, author year	Population (% female)	Age: Mean ±SD (or range)	Prevalence of symptoms Male	Female	Both	Standardised relative risk
A. Symptoms on interview						
Silverstein, 1985 (176),	Industrial LoF.LoR† (45%)	39±10	3 %	16%	9%	
	Industrial LoF.HiR† (70%)	41±11	12 %	27%	22 %	1.8 (1.3-2.6)
Bernard, 1993 (22)	Newspaper employees (56%)	39±11 (19-72)			22 %	2.2 (1.9-2.5)
Burt, 1990 (30)	Newspaper employees (55%)	40 (20-72)			23 %	2.2 (1.9-2.6)
Hoekstra, 1994 (84)	Teleservice representatives (64%)	42 (23-64)			30 %	2.6 (1.8-3.7)
SHARP, 1993 (174)	Workers' compensation clerks (67%)	35±9 (20-55)			50 %	4.2 (2.5-6.8)
B. Symptoms plus findings on physical examination						
Silverstein, 1986 (177)	Industrial LoF.LoR (45%)	39±10	0%	3%	2%	
	Industrial LoF.HiR (70%)	41±11	2%	9%	7 %	3.1 (1.5-5.6)
Hales, 1992 (78)	Telecommunications employees (78%)	38±10 (19-68)			12 %	4.7 (3.6-6.0)
SHARP, 1993 (174)	Workers' compensation clerks (67%)	35±9 (20-55)			21 %	9.3 (3.8-19.2)

* Standardized by adjusting the overall prevalences in reference (176) (Table 5.16, page 89) to the proportions of female and male workers in each of the other populations in turn

† "LoF.LoR" = Low force, low repetition; "LoF.HiR" = Low force, high repetition

We have reached this conclusion even while acknowledging that the comparison of VDU workers to non-VDU workers is often difficult to interpret with regard to the range of, and degree of contrast in, ergonomic exposures. In order to define better which aspects of VDU work are implicated as causal factors, and in order to understand the degree of risk in VDU work compared with other types of clerical work with other ergonomic stressors present, the sections that follow examine specific dimensions of exposure that occur both in VDU and in other office jobs.

Physical ergonomic factors in VDU work situations

Workstation dimensions and postural stress

In 17 of the reviewed studies, direct observations or self-reports of body posture or measurements of workstation dimensions were used to evaluate ergonomic stress on various body parts during keyboard operation. One other author had intended to examine such associations but found too little variance in workstation configurations (78, 79).

The Swedish cohort study (19, 20) found that three of four neck/shoulder endpoints were strongly associated with a high keyboard or VDU placement and two of four with static work posture (Table 6). Wrist/hand disorders were consistently associated with low keyboard height, lack of forearm support, and non-neutral hand position. In a retrospective part of the study (15), new furniture were - among men - associated with an increase in neck and shoulder discomforts over the follow-up period. The authors offered no suggestive explanation for this finding. Furthermore, it could not be determined whether the new furniture was obtained before or after onset of the problems.

Bernard *et al.* (22) found, in a nested case-control study with exposure data on the preceding three years, that at least 60% of the hand/wrist cases had received a new chair or telephone equipment subsequent to their reporting problems to their supervisors. About 40% of the cases who had received such new equipment thought that it had helped to reduce their symptoms, although no comparison group was available and thus no statistical associations could be estimated. Fewer than 50% of the cases had received any other equipment, such as an adjustable desk, footrest, or new keyboard.

DeMatteo *et al.* (41) found that the number of symptoms per worker was statistically significantly correlated with self-reported workstation design problems and indirectly with lack of postural mobility. However, a similar difficulty in interpreting these findings arises as did with the association with hours per day. Since the data clerks had inherently more repetitive jobs, with less variation in arm and hand position and more wrist bending and twisting, it is not possible to distinguish from the data provided whether some excess risk should be specifically attributed to poor workstation features, or whether it is all contained within the more macro-ergonomic aspect of poor work organisation that results in little variability in activities and postures.

Faucett *et al.* (47) found that keyboard height and head rotation were correlated with severity of neck/shoulder symptoms in a subset of 70 newspaper employees, after adjusting for gender and age. In addition, keyboard height interacted with work load, decision latitude and social support in explaining symptom severity for both the hand/wrist and neck/shoulder (see also further discussion under “work load and work demand” and ”psychological and social factors and muscle problems”).

In a retrospective cohort study, Ferreira *et al.* (54) failed to find associations between ergonomic improvements in workstation and VDUs and incidence rates of MSD, but probably these factors could not be evaluated adequately because they occurred close to the end of the follow-up period.

Green and Briggs (70) surveyed the keyboard users employed by a large university, in order to determine the availability of adjustable workstations, the information that workers had received regarding how to adjust their equipment, and their satisfaction with the equipment. However, the response rate was rather low (52%) and there was no analysis of potential confounding by age, gender, or other covariates. Workers with and without symptoms were equally likely to have adjustable chairs, desks, and monitors, although fewer than half of either group had adjustable desks. In a small sample on whom anthropometric and workstation measurements were collected, those with adjustable desks had lower desk heights, on average, compatible with standard ergonomic recommendations. In the total population, workers with symptoms were more likely to have received information from someone without formal ergonomics training. They were also more likely to have readjusted their workstations, where possible, but they were less comfortable and less satisfied with the adjustability available. The authors correctly point out the difficulty in determining whether the association between symptoms and readjusting the equipment was due to coping with symptoms, less adequate equipment, or less information about how to make the adjustments (these results are not shown in Table 6).

Another study found positive univariate associations with postural stress but did not examine multiple exposures simultaneously. In a group of VDU users from various industries, non-neutral neck angle was associated with disorders of the neck, arm, and hand (81). This neck strain was highly correlated with data entry tasks; it may also have served as a proxy for more distal postural stresses on the arm and hand, since these were not measured directly (Table 6).

”Teleservice representatives” of the US Social Security Administration, who all worked full-time with VDUs and telephone headsets, were much more likely to have symptoms and PE findings of all upper extremity regions if they were employed in a facility with non-adjustable workstations and chairs and generally very poor work layout (84). However, these univariate associations were replaced for neck and arm/elbow disorders by more specific postural stresses such as non-optimal chair, desk height, and screen location (Table 6). In the study by Hünting and co-workers (88), those few data entry workers (n=7) with more than 20 degrees of ulnar abduction of the right wrist had almost 3 times more pain in the right arm than those with less abduction.

Among medical secretaries, sitting for at least five hours per day was associated with both neck and shoulder symptoms (94), although this was likely confounded by work with office machines while the operator was seated. Shifting from sitting to standing more often per day was also found to be correlated (95), although it could not be determined whether this was a cause or a consequence of the neck/shoulder discomfort. Karlqvist and colleagues (101) compared workers on the basis of whether or not their computer mouse placement was ’optimal’ and found symptoms in neck, shoulder, elbow, wrist and fingers to be more prevalent with a non-optimal mouse location. Most of the differences between “optimal” and “non-optimal” location, especially for the proximal extremity, were statistically significant.

Kemmlert and Kilbom (102) compared office workers with respect to the ergonomic features of their workstations, and found no or even negative associations with neck and shoulder symptoms. However, the physical dimensions were assessed rather crudely, and exposure misclassification was possible. More importantly, it appeared from workplace discussions (after the data had been collected) that workers who had developed symptoms had subsequently paid more attention to their workstations, so that the observations did not necessarily reflect the conditions that had been in effect at the time of symptom onset (personal communication, Å. Kilbom, June 1997).

Lim *et al*. (116) developed two scales for describing physical activity and body posture in VDU work. They found that working in uncomfortable positions and using awkward motions was strongly correlated with the intensity and frequency of upper extremity symptoms in multivariate analyses. In addition, dynamic (whole body) work activity was strongly negatively correlated with UE symptoms, meaning that being able to change work postures and walk around the office was associated with fewer and less severe disorders. In a group of female office workers operating a variety of office machines, the keyboard heights were measured and found to be too high for all sub-groups (144).

In a study of public sector data entry operators, lack of training in chair adjustment was the strongest single risk factor for neck/ shoulder/forearm disorders (Table 6). Elbow flexion was also a risk factor, in the expected direction, while forward arm flexion and distance to hard copy were negatively associated; as the authors pointed out, in a cross-sectional study it could not be determined whether these work station dimensions were causal or represented the operators’ attempts to accommodate their discomfort at work (166).

Sauter (168, 169) collected self-reported data on the physical environment from 333 office workers, mostly female, and made direct measurements of workstation dimensions for a 25% sample of the 248 VDU users. In multivariate analyses, "upper torso" symptoms were associated with self-reported physical workstation problems, in general, in addition to using an uncomfortable chair. "Extremity" symptoms were associated with self-reported workstation problems, and with observed gaze angle and lack of a keyboard that could be detached and adjusted away from the central processing unit. However, these latter two correlations were not adjusted for age or other covariates.

Table 6. Effect of VDU workstation dimensions or work postures on frequency of upper extremity musculoskeletal disorders: Relative risk with 95% confidence interval (CI) and/or p-value for test of linear trend in exposure-response relationship (E-R).

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome*	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Bergqvist, 1995a (19)			Arm/hand (see to the right)		Any arm/hand sx: Data entry and low keyboard Any arm/hand dx: ≥ 20 h/wk, limited rest breaks, and no arm support	OR=2.8 (0.9-8.6) OR=4.6 (1.2-17.9)
Bergqvist, 1995b (20)	Any dx: Static work posture Any sx: Static work posture Any sx: High keyboard Intense sx: VDU placed high TNS dx: High keyboard	OR=5.1 (0.6-42) OR=4.1 (0.9-1.8) OR=3.1 (1.3-7.2) OR=7.4 (0.9-60) OR=4.4 (1.1-17.6)	Arm/hand (see to the right)		Any sx: Non-neutral hand position Any sx: Keyboard too low Any dx: No forearm support Any dx: Limited rest breaks and no forearm support	OR=3.8 (1.0-15.0) OR=2.0 (0.9-4.5) OR=2.7 (0.9-8.3) OR=10.1 (2.4-43)
Bergqvist, 1995c (15)	Any sx: New furniture (among men)	RR=4.2 (1.6-11.4)				
DeMatteo, 1993 (41)	Any UE sx: Workstation design problems Lack of postural mobility	 E-R, p<0.03 E-R, p<0.03				
Faucett, 1994 (47)	Nk/sh severity: Head rotation Nk/sh severity: Keyboard height	E-R (p<0.01) E-R (p<0.05)			Numbness severity: Work posture	E-R (p<0.10)

(for notes, see end of the table)

Table 6. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome*	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Heyer, 1990 (81)	Nk: Non-neutral neck angle	PR=1.5 (1.2-1.9)	Non-neutral neck angle	PR=2.5 (1.7-3.7)	Non-neutral neck angle	PR=1.9 (1.4-2.6)
Hoekstra, 1994 (84)	Nk: Chair discomfort Sh: Poor overall ergonomics Sh: Non-optimal desk height Sh: Non-optimal screen location	OR=3.5 (1.4-8.9) OR=4.0 (1.2-13.1) OR=5.1 (1.7-15.5) OR=3.9 (1.4-11.5)	Non-optimal chair	OR=4.0 (1.2-13.1)		
Hünting, 1981 (87)	Nk/Sh PE: Neck flexion >56° in data entry work	p<0.05	PE: Ulnar abduction >20° in data entry work Ulnar abduction >20° in conversational work	OR=15.2 (1.5-721) OR=8.8 (0.5-137)	PE: Angle of wrist ulnar abduction (all operators)	E-R (p-value not given)
Karlqvist, 1996 (101)	Mouse location non-optimal: Neck sx: Left scapular sx Right scapular sx Left shoulder sx Right shoulder sx	OR=1.5 (1.0- 2.3) OR=2.3 (1.3- 4.2) OR=1.6 (1.0- 2.7) OR=4.4 (1.3-15.0) OR=2.6 (1.2- 5.9)	Mouse location non-optimal: Left elbow sx: Right elbow sx	OR=4.2 (1.0-18.7) OR=2.7 (1.1- 6.6)	Mouse location non-optimal: Left wrist sx Right wrist sx Left hand/fingers sx Right hand/fingers sx	OR=2.3 (0.6- 8.3) OR=2.4 (1.0- 5.9) OR=3.0 (0.9-10.5) OR=1.9 (0.8- 4.2)

(for notes, see end of the table)

Table 6. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Kamwendo, 1991a (94)	Nk: Sitting ≥5 hrs/day Sh: Sitting ≥5 hrs/day	OR=1.5 (0.9-2.6) OR=1.6 (0.9-2.7)				
Kamwendo, 1991b (95)	Nk/Sh fatigue and pain: Number of shifts from sitting to standing	Negative correlations for 72% of subjects (fatigue) and 61% (pain), but significant (p<0.05) for only 12% (fatigue) and 3% (pain) of subjects.				
Kemmlert, 1988 (102)	Nk/Sh discomforts: Various postural elements	No association with discomforts				
Lim, 1994 (116)	UE MSD sx: Awkward postures Dynamic work activity UE CTD index: Awkward postures Dynamic work activity	 r= 0.41 (p<0.001)[r] r=-0.28 (p<0.001) r= 0.47 (p<0.001) r=-0.35 (p<0.001)	UE MSD (see to the left)		UE MSD (see to the left)	

(for notes, see end of the table)

Table 6. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Ryan, 1988 (166)	Nk/sh/forearm: No training in chair adjustment L elbow (more acute angle) L forward arm flexion Eye copy at closer distance	 OR=5.6 (1.7-18.5) p=0.006 p=0.03 p=0.01	Forearm (see to the left)			
Sauter, 1983, 1984 (168-169)	Neck/shoulder/back - Workstation configuration problems - Chair comfort	 r= 0.16 (p <0.05) r=-0.21 (p <0.05)	Arm/wrist/hand (see to the right)		Arm/wrist/hand discomforts: - Workstation configuration problems - Detached keyboard - Increased gaze angle	 r=0.17 (p<0.05) r=0.28 (p<0.05) r=0.39 (p<0.05)
Sauter, 1991 (170)	Trunk discomforts: Head tilt and viewing angle	Neither predictive of discomforts.	Keyboard height Document reach distance Shoulder flexion Wrist ulnar deviation	E-R (p<0.10) E-R (p<0.10) E-R (p<0.10) E-R (p<0.10)		

(for notes, see end of the table)

Table 6. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
SHARP, 1993 (174)	Sh sx/PE: inadequate arm rests	 $p<0.05$	Elbow sx: inadequate arm rests	 $p<0.04$		
Starr, 1985 (188)	Nk, Sh sx: - Neck angle - Upper arm angle	 $p>0.05$ $p>0.05$	Upper arm, elbow sx: - Upper arm angle - Forearm angle - Elbow angle	 $p>0.05$ $p>0.05$ $p>0.05$	Wrist sx: - Forearm angle - Elbow angle - Hand angle	 $p>0.05$ $p>0.05$ $p>0.05$
Stellman, 1985 (191)	Nk, Sh sx: Ergonomic stressor score	 E-R	Arm/wrist sx: Ergonomic stressor score	 E-R	Hand/finger cramps: Ergonomic stressor score	 E-R

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electromyography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist.

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses. E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

In another study by the same principal author, in which postures and work station dimensions were measured for data entry workers, arm discomfort increased with keyboard height above seated elbow level (170). Right arm discomfort increased with the degree of shoulder flexion, as the right arm reached to the keyboard, and with ulnar deviation required to maintain the hand over the keyboard (Table 6). With the left hand manipulating documents, left arm discomfort was associated with the distance required to reach the documents. These correlations were statistically significant at p=0.05 even though the measurements were only obtained on 40 subjects and the analyses were adjusted for potential confounding variables. Upper extremity symptoms were more frequent on the right side than on the left for data entry, whereas no such difference was found among VDU users with more varied tasks. In the small study of 34 state agency billing clerks (174), both shoulder and elbow disorders were significantly associated with no or inadequate arm rests, in multivariate analyses.

One study of directory assistance operators also examined work postures (measured from photographs) in relation to symptoms, and found no statistically significant correlations (188). However, misclassification of exposure to non-neutral postures (based on one single observation per worker and derived from a two-dimensional image) cannot be ruled out. Other flaws mentioned above for this study include potential selection bias and failure to adjust for age, gender, or other risk factors.

In a pair of studies on a large population of public sector employees, specific job features were compared among office workers who used VDUs, typewriters, or neither (190, 191). A composite scale of ergonomic stressors was constructed from frequencies of awkward postures and of workstation features. The musculoskeletal symptom score was highly correlated with the ergonomic stressor score, both in the total population (191) and when the sample was restricted to female employees (190). However, as noted previously, there was no statistical adjustment for age or other covariates.

In summary, these studies are extremely consistent in showing large adverse health effects of poorly physical workstation ergonomics. With the exception of a few studies (102, 170, 188), virtually every posture and dimension studied was shown to be associated with increased risk of upper extremity disorders. Numerous observations attest, *e.g.*, to associations between postural elements such as ulnar deviation, shoulder flexion or static work position and musculoskeletal problems. Likewise, work station elements related to postural constraints such as too high or too low keyboard height were also found to be associated with musculoskeletal problems. In some studies, an interaction between these observations and the work performed were also suggested - by and large, these relationships were more profound among data entry workers.

Keyboard model

Four studies attempted to examine the effect of keyboard model, in several instances because the employees themselves complained about specific design features to the investigators. However, only Bergqvist and colleagues were able to assess such an effect, reporting that assignment of a new keyboard was associated with recovery from neck/shoulder and upper arm disorders over the seven-year follow-up period (15). The authors assumed (but did not specify) that the new keyboards were ergonomic improvements compared to the old ones.

Burt *et al*. found that the keyboard model depended on department and job, so in order to avoid confounding by job requirements, keyboard was only examined within one department (of five), and no association was found, although statistical power was limited by this constraint (30). The other two authors were unable to study keyboard model because the equipment used by study subjects kept changing during the study period (21, 22, 78, 79). Thus, little substantial epidemiological evidence exists today concerning the different effects of using various keyboard models. However, there are a number of experimental studies in the literature (see the introduction) which provide the basis for strong *a priori* hypotheses that could inform future epidemiologic research in this area.

Use of a mouse or other input devices

Several cases of various adverse hand/wrist problems among mouse users have been reported, sometimes with only a few (*e.g.*, 2-3) hours per day of usage. Disorders included ulnar neuropathy, tenosynovitis affecting the wrist, finger flexors, and lateral epicondyle attachment, and myofascial pain syndrome (39, 57, 130, 139, 148). In the United States, workers' compensation claims for "cumulative trauma disorders of the upper extremity" increased markedly, both as a percentage of all claims and as a percentage of claims for these disorders, from 1986 to 1993 (56). There is no evidence to date that there is a unique syndrome associated specifically with mouse use; instead, the risk of upper extremity disorders among mouse users appears to be similar to those observed in other types of work with repetitive hand motion and static loading of the shoulder and arm muscles (99). In a group of seven graphic artists with intensive mouse usage, three prevalent, clinical cases of carpal tunnel syndrome were found (43%), in contrast to no cases among 39 other office workers (59). Although these data are very sparse and do not permit extensive statistical analysis, the difference between the two groups is suggestive.

Among 652 civil engineers, longer work hours with the computer mouse were associated with higher prevalences of symptoms of the upper arms, elbows, wrist, and fingers, especially of the arm that used the mouse (99). In further multivariate analyses restricted to 542 CAD operators, controlling for age and gender, both mouse location and duration of mouse use were associated with the odds of musculo-skeletal symptoms of the upper extremity on both the left and right sides (see above, Tables 2 and 6). In a smaller study of 12 mouse and 12 non-mouse *i.e.* keyboard users, it was observed that the two devices required different postural deviations of the upper extremity. The keyboard users reported, on average, more intense discomfort ratings, although the differences were not statistically significant (98).

There appear to be no epidemiologic studies relating to the possibility of musculoskeletal disorders from non-keyboard input devices other than the mouse. One experimental study compared several short-term effects between mouse and track-ball use in 15-minute work periods (100). Work with the mouse led to higher shoulder elevation and higher shoulder muscle activity in the arm using the device. More wrist extension was observed with the track-ball, but overall there were no significant differences in discomfort between the two input devices. Any further specific knowledge concerning effects of other input or interactive devices such as haptic devices (118) is limited to predictions based on general knowledge about postures, repetition rates, etc., which in turn are based more on studies of non-VDU work, although still likely relevant.

In summary, there are substantial indications from case reports as well as from experimental studies to suggest that certain aspects of using a mouse as an input device could result in musculoskeletal problems. Current information from epidemiological studies is - in this respect - rather limited. Nevertheless, the few studies available do support the occurrence of adverse health conditions being related to mouse use, especially for more than 5 hours per day or when placed far from the body.

Visual demands, corrective lenses and monitor placement

In a few epidemiological studies, associations between use of various types of spectacles (monofocal, bifocal and progressive) or contact lenses and muscle problems have been investigated (see Table 7). The study by Bergqvist *et al.* (20) reported that among VDU users, the use of spectacles (not specified as to type) was associated with diagnosed cervical disorders. For other disorders or discomforts, use of spectacles were not retained in the final models. Further analysis also suggested that using bifocals or progressive glasses was an effect modifier of VDU use duration - individuals who worked for more than 20 hrs/week at a VDU and used bifocals/progressive glasses had a high odds ratio for tension neck syndrome (TNS) compared to non-VDU users, while individuals working long hours with monofocal glasses or without spectacles or who worked shorter hours were not at a higher risk for TNS (19).

In the study by Hales and co-workers (79), while no association between use (in general) of spectacles during work was associated with neck disorders, using bifocals was so related (Table 7). In some contrast, Sauter *et al.* (170) did not find an impact of use of spectacles on discomforts in *e.g.* trunk discomforts. The fact that neck discomfort was not specifically evaluated may have some bearing on this, on the other hand, neck discomforts was rather highly correlated with upper and lower back, motivating the authors to summarise discomforts in all these regions into one index. In another investigation by the same principal author (168, 169), the use of corrective eyewear was correlated with both upper torso and limb/extremities discomforts. The SHARP report (174) found that neck symptoms were significantly associated in multivariate analysis with not wearing eyeglasses or contact lenses. Presumably corrective eyewear and glare were not significantly associated with shoulder disorders of either type.

The study by Bergqvist and co-workers (19) further suggested that the presence of glare on the screen could be an effect modifier; among individuals who worked more than 20 hours/week, the presence of glare was an apparent predictor of cervical disorders. Associations between discomforts and glare were also reported by Ryan and Bampton (166) for upper extremity symptoms ($p=0.02$, not specified for shoulder/neck or lower arm) and by the SHARP report (174) in terms of the neck ($p<0.05$, no point estimates given) and in terms of hand/wrist discomforts. For elbow symptoms, glare was positively associated ($p<0.01$) in crude but not multivariate analyses (174).

A few studies have also investigated the posture of the neck, specifically the head-neck tilt angle and discomforts (see Table 6). Hünting and colleagues (88) found a positive association between this tilt angle and neck pain or stiffnes. Sauter (168, 169) found a positive correlation between gaze angle and limb/extremities complaints, but not with upper torso complaints. Neither study did apparently adjust for other factors, though. Bergqvist *et al.* (20) noted that a highly placed VDU were associated - in the univariate analysis - with increased neck discomforts. Such a VDU placement is more consistent with a backwards than a forward tilt of the head. However, this factor was not retained in the final multivariate model - and it is conceivable that it may be influenced by the use or non-use of various spectacle types. (When restricting the analysis to intensive neck/shoulder discomforts, a highly placed VDU was retained in the final model - but with a very uncertain estimate, see Table 6.) Finally, neither Sauter *et al.* (170) nor Starr and co-workers (188) could find a relationship between head-neck tilt angle or viewing angle with trunk or neck discomforts. In the study by Hoekstra *et al.* (84), a 'non-optimal adjusted VDU screen location' was associated with shoulder problems (see Table 6).

In a few studies, the use of spectacles, especially bifocals or progressive glasses were found to be associated with increased neck problems, consistent with some experimental data (see page 11). It should be observed, however, that such associations are likely closely interrelated with the work performed, the position of the screen and other visual elements etc. Accordingly, the complex interrelationships between visual and postural demands and thus between visual and neck discomforts should be further investigated.

Table 7. Use of spectacles during VDU work in relation to upper extremity musculoskeletal disorders: Relative risk with 95% confidence interval (CI) and/or p-values based on hypotheses testing.

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome*	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Bergqvist, 1995b (20)	Nk/Sh sx: glasses in VDU use (yes/no) Cervical disorders: VDU use with vs. without spectacles	p>0.05 in multivariate analysis OR=4.0 (1.3-12.5)	Arm/hand (see to the right)		Any arm/hand sx or disorders: VDU use with vs. without spectacles	p>0.05 in multivariate analysis
Bergqvist, 1995a (19)	TNS: Use of bifocals and work >20 h/w at a VDU, vs no VDUs	OR=6.9 (1.1-42.1)				
Hales, 1992, 1994 (78-79)	Nk or Sh dx: VDU use with vs. without spectacles Nk dx:	p>0.05 in multivariate analysis OR=3.8 (1.5-9.4)	Elbow dx: VDU use with vs. without spectacles	p <0.05 in initial analysis, but p>0.05 in multivariate analysis	Hand/wrist dx: VDU use with vs. without spectacles	p>0.05 in multivariate analysis

(for notes, see end of the table)

Table 7. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Sauter, 1983, 1984 (168-169)	"Upper torso" discomfort: VDU use with vs. without spectacles	$p<0.05$	Limb/estremities (see to the right)		"Limb/extremities" discomfort: VDU use with vs. without spectacles	$p<0.05$
Sauter, 1991 (170)	Trunk sx: glasses in VDU use (yes/no)	$p>0.05$ in multivariate analysis	Arm sx: VDU use with vs. without spectacles	$p>0.05$ in multivariate analysis		
SHARP, 1993, (174)	Neck sx: not using glasses or contact lenses	$p<0.05$				

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electromyography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist.

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses.
E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

Types of VDU work and work organisational factors

VDU task types

In a study by Aronsson and co-workers, 2025 Swedish public employees performing various types of VDU work were examined by means of a questionnaire (10). Workers with at least 50% of their worktime allocated to data entry, data acquisition, word processing, programming, system work, graphical production, computer-assisted design (CAD) or mixes of these task types were compared with workers with ”other” types of VDU work. The choice of the latter as a reference group was dictated by a/ that being the most heterogeneous group in terms of tasks and education, and b/ that having the lowest prevalence of muscle problems.

Based on discomfort data obtained by the ”Nordic questionnaire” (109), the data entry group exhibited significantly higher odds ratios for neck and shoulder discomforts compared to the reference group (Table 8). Similar results were obtained for data acquisition workers. For word processors, only shoulder problems exhibited a significant increase *vs.* the reference group. Utilising other work organisational and psychological and social factors as confounders did not result in any changes in the results for the data entry group. For the data acquisition and the word processing groups, the shoulder ORs were somewhat changed in these multivariate analyses (data not shown in the report). All other task types did show increased (but non-significant) odds ratios compared to the reference group.

It must be kept in mind, however, that the choice of the reference group was based on that having the lowest prevalences, so at least part of these observations could be seen as a result of the design of the study. What can be asserted is that - after adjustments for psychological and social factors - the prevalence of neck discomforts was highest in the data entry group, and the prevalence of shoulder discomforts appeared to be highest in the word processing and the data entry groups, when compared to other groups performing VDU work. Of more interest is perhaps the use of psychological and social and other factors as possible effect modifiers. The reported odds ratios were generally higher among men than among women (see further below), higher for those reporting high time pressure and demand for concentration, and reporting limited flexibility and control. For individuals reporting frequently being tired, the contrast between task types appeared to be less than among those not reporting tiredness (10), suggesting that some, but not all, of the effect was mediated through fatigue.

In another Swedish study by Bergqvist *et al.* (19), using the same questionnaires, ”data entry” (data entry and/or word processing) workers and ”interactive” (other types) VDU workers were compared to non-VDU general

Table 8. Effect of different type of VDU tasks on frequency of upper extremity musculoskeletal disorders: Relative risk with 95% confidence interval (CI) and/or p-value for test of linear trend in exposure-response relationship (E-R).

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Studies on questionnaire-derived discomforts - comparisons with non-VDU office workers						
Bergqvist, 1995a (19)	Data entry workers Nk, Sh sx: <20h/wk (at VDU) ≥20h/wk (at VDU)	 OR=3.2 (1.1-9.8) OR=1.7 (0.8-3.4)	Arm/hand (see to the right)		Data entry workers Arm/hand sx: <20h/wk (at VDU) ≥20h/wk (at VDU)	 OR=1.6 (0.6-4.5) OR=1.8 (0.8-3.9)
Burt, 1990 (30)			Arm/elbow sx:	OR=2.5 (1.5-4.0)	Hand/wrist sx:	OR=2.4 (1.6-3.4)
Ong, 1981 (142)	Arm/shoulder (see to the right)		Data entry workers Arm/shoulder aches:	 PR=1.9 (1.1-3.5)		
Ong, 1984 (141)	Data entry workers - R side Nk sx: - L side Nk sx: Conversation workers, Nk:	 OR=7.3 (2.6-20.4) OR=24 (7-80) No differences with non-VDU workers	Data entry workers - R arm sx: Conversation workers, Nk:	 OR=22 (6.3-76) No differences with non-VDU workers	Data entry workers - R hand sx:: Conversation workers, Nk:	 OR=8.2 (2.9-23) No differences with non-VDU workers
Smith, 1981 (183)	Clerical workers: Professional workers:	Significant ($p<0.05$) increased occurrence of 13 UE discomfort types or locations. No significant differences in these discomforts.	UE discomfort (see to the left)		UE discomfort (see to the left)	

(for notes, see end of the table)

Table 8. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome*	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Studies on questionnaire-derived discomforts - comparisons between individuals with different VDU tasks						
Aronsson, 1992 (10)	Data entry, Nk sx:	OR=1.8 (1.2-2.7)				
	- Sh sx:	OR=2.1 (1.4-3.2)				
	Data acquisition, Nk sx	OR=1.6 (1.1-2.4)				
	- Sh sx:	OR=2.2 (1.5-3.4)				
	Word processor, Nk sx	OR=1.3 (0.8-2.0)				
	- Sh sx:	OR=1.7 (1.1-2.7)				
	All compared to mixed VDU tasks (group with lowest sx prevalence)					
DeMatteo, 1993 (41)	Data entry,					
	- at least six muscle symptoms	OR=4.4 (1.7-11.5)				
	- previously diagn MS injury	PR=3.0 , p<0.05				
	All compared to general office work (including VDU)					

(for notes, see end of the table)

Table 8. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Studies on questionnaire-derived discomforts - comparisons between individuals with different VDU tasks (continued)						
Grieco, 1989 (71)	*For women:* Data entry, Nk sx, Data acquisition, Nk sx Dialogue, Nk sx *For men* Data entry, Nk sx, Data acquisition, Nk sx Dialogue, Nk sx All compared to total group of telecom. workers (including VDU)	 SMR= 83 (p<0.05)* SMR=114 (p<0.05)* SMR=110 (p<0.05)* SMR=100 (p>0.05)* SMR= 77 (p<0.05)* SMR= 98 (p>0.05)*	*For women:* Data entry, UE sx, Data acquisition, UE sx Dialogue, UE sx *For men* Data entry, UE sx, Data acquisition, UEk sx Dialogue, UE sx All compared to total male or female group of telecom. workers (including VDU)	 SMR= 77 (p<0.05)* SMR=115 (p>0.05)* SMR=116 (p<0.05)* SMR= 98 (p<0.05)* SMR= 68 (p<0.05)* SMR=104 (p>0.05)*	UE sx: (see to the left)	
Heyer, 1990 (81)	Data entry, Nk sx Compared to interactive VDU work	PR=1.4 (1.1-1.8)	Data entry, arm/elbow sx Compared to interactive VDU work	PR=2.2 (1.5-3.4)	Data entry, hand/wrist sx Compared to interactive VDU work	PR=1.9 (1.4-2.7)
Studies examining disorders based on diagnoses - comparisons with non-VDU workers						
Bergqvist, 1995a (19)	Cervical dx: - data entry < 20 hr/wk - data entry ≥ 20 hr/wk - interactive TNS dx:	 OR=1.2 (0.4-4.3) OR=1.7 (0.7-4.3) No association No association	Arm/hand (see to the right)		Arm/hand dx: - data entry - interactive	 No association No association

(for notes, see end of the table)

Table 8. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Hünting, 1981 (87)	Data entry, Nk/Sh PE: (see further Table 9)	OR=4.8 (1.8-13.4)	Data entry, forearm PE: (see further Table 9)	OR=4.8 (1.8-13.4)		
Studies examining disorders based on diagnoses - comparisons between individuals with different VDU tasks						
Hales, 1994 (79)					Loop Provisioning (telecom) workers, hand/wrist dx: Compared to Mail Remittance (≈data entry) workers	OR=1.9 (0.7-5.1)
Hünting, 1981 (87)	Data entry, Nk/Sh PE: Compared to inter-active workers	OR=1.5 (0.8-3.0)	Data entry, forearm PE: Compared to inter-active workers	OR=2.7 (1.2-6.0)		

* Reference group for all SMRs shown: the entire telecommunications company workforce

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electro-myography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist.

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses. E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

office workers, after adjustment for a large number of individual, ergonomic and work organisational/psychological and social factors. ”Data entry” workers exhibited some excess odds ratios compared to non-VDU workers for neck/shoulder and arm/hand discomforts as well as diagnosed cervical disorders. These excesses were statistically significant only for neck/shoulder discomforts, though, and then only for those with limited VDU work (see Table 8). One tentative explanation for such a peak at an intermediate VDU work time (seen also in a prospective part of the study (18)) is that the parameter ‘task type’ may be able to select adverse conditions better than VDU work time, since data entry individuals may have equally (adverse) conditions also in the part of the work day not spent working at a VDU (18). For ”interactive” workers, no discomforts or disorders were more prevalent among the VDU than the non-VDU workers (19).

Some other conditions modified the ”data entry” effect in this study. Neck/shoulder discomforts were found primarily among data entry workers with limited (spontaneous) rest break ability (OR 4.8; 1.3-18.1) compared to interactive VDU or non-VDU workers (for the latter groups, rest break ability appeared not to be relevant). Similarly, arm/hand discomforts was primarily found among data entry workers who had their keyboard placed low (OR 2.8; 0.9-8.6). There was a linear response - among data entry workers only - between (lower) keyboard vertical position and (higher) odds ratio for arm/hand discomforts (19).

In a study among US newspaper workers, reporters were found to have more elbow/forearm and hand/wrist problems in the past year than non-keyboard workers (Table 8). A Canadian study (41) compared data entry (VDU) workers with general office workers (with and without VDU work). 27% of the data entry users reported 6 or more musculoskeletal symptoms, compared to 7.3% of the general office workers. They also had more often previously diagnosed musculoskeletal injuries (Table 8). No adjustments were made for other factors. Furthermore, the data entry clerks took breaks more regularly but worked more overtime and had less variability in physical activities and postures.

In a large Italian study on telecommunications workers (N=29 759), age-adjusted standardised morbidity ratios (SMRs) were computed, comparing questionnaire derived discomforts in neck and upper limbs among various type of VDU workers with those of the general SIP (Italian Telecom) population. Women with ”enquiry” (data acquisition) or “dialogue” (interactive) work had slightly increased SMR´s for neck discomforts and upper limb problems. In contrast, female ”loading” (data entry) workers had SMR´s below 100 for both neck and upper limb (Table 8). Male SMR´s were generally closer to 100, except for “enquiry”, where substantially and significantly reduced SMR´s were noted. In this study, non-VDU users had higher upper limb SMR´s than the VDU users (71).

In another (US) telecommunication worker study (79), VDU/keyboard task subjects were divided into various job titles. Mail Remittance workers, who primarily performed data entry work, had average prevalences compared to the other VDU workers in the study (20% *vs*. 22%) and were therefore chosen as the reference group. The highest prevalences of diagnosed upper extremity musculoskeletal disorders were found among the 69 Loop Provisioning employees (Table 8). This work was characterised as the ”most intellectually demanding job”. In the multivariate analysis, individuals with this job title exhibited more hand-wrist disorders. It should be noted, however, that the relative ranking of various job titles in terms of disorder prevalences varied substantially across the three study sites.

Heyer *et al*. (81) reported that symptoms were more frequent in data entry than in interactive tasks for all three regions of the upper extremity. However, as noted previously, they did not adjust for the simultaneous effects of multiple occupational exposures.

Hocking (83) reported that the highest annual incidence rates of "repetition strain injury" were among telephonists, rather than clerical workers using VDUs or telegraphists (a small group). Insufficient exposure information was provided to interpret these differences, although the authors stated that they had an inverse relationship with (average) keystrokes per hour. Other problems with this paper include likely incomplete and non-uniform case reporting, possible double-counting of cases through multiple data sources, and very approximate denominators (numbers of workers at risk) for each job group. (Results not shown in Table 8.)

A Swiss study (88) examined - by way of anamnesis, palpation and other tests - various muscle problems in relation to task types, as seen in Tables 8 and 9. All of the sub-groups were similar in age, but the data entry VDU users and the typewriter users had much higher proportions of women than the other groups (see Table 9). No comparisons were stratified by gender - and thus confounding or effect modification may exist in some comparisons. As can be seen in table 9 (which is limited to comparisons of groups with similar gender composition), task characteristics appear to be of primary importance for the risk of some muscle disorders. Both data entry workers and non-VDU typists (presumably both performing data entry work) experienced similar odds for disorders, at least in the neck/shoulder region. In some contrast, substantial differences were found between traditional (non-VDU) office workers and interactive VDU workers. In a continuation of this study, van der Heiden and co-workers (197) compared daily and occasional pain among 69 Computer Assisted Design (CAD) workers with these other groups. Prevalences of neck, shoulder, arm and hand pain were lower among the CAD workers than among all other groups (both VDU and non-VDU groups). No statistical analysis was performed, however, and no information was available on the gender of these CAD operators, precluding any definite conclusion (data not presented in Table 8).

Table 9. Odds ratios for muscle problems in relation to various task types. Data from Hünting *et al.* (88).

	Interactive or (presumably) varied office tasks		Data entry tasks	
	Traditional office work (n=54) (60% women)	Interactive VDU work (n=109) (50% women)	Typewriters (n=78) (95% women)	VDU data entry work (n=53) (94% women)
Neck/shoulder tendomyotic pressure pains	1.0	3.2 (1.2-8.2)	1.0	1.1 (0.6-2.4)
Painful limited head movability	1.0	3.4 (1.2-9.4)	1.0	0.7 (0.4-1.5)
Pain in isometric forearm contrac-tion	1.0 1)	2.9 (0.8-10.5) 1)	1.0	1.6 (0.7-3.4)

Odds ratios and 95% confidence intervals calculated from published prevalences. Note that the odds ratios are given for different comparison, *i.e.* different choices of reference groups - the latter indicated by an odds ratio of 1.0. Thus, for data entry workers, the odds ratio is 1.1 compared to typists, while the odds ratio is 3.2 for interactive VDU workers compared with traditional office workers (see "Neck/ shoulder tendomyotic pressure pains"). Due to varying gender compositions, no comparisons are made between *e.g.*, data entry workers and traditional office workers. No adjustments were made for other factors.

1) Only three cases in the reference group, resulting in very wide confdidence intervals for the odds ratios.

In a Singaporese study by Ong and colleagues (141, 142), VDU workers performing data entry (n=36) or conversational VDU (n=26) tasks were compared to 41 conventional office workers (without VDU work). Discomforts were more prevalent among the data entry workers compared to non-VDU users for the neck, right arm and right hand, whereas differences between conversational VDU and non-VDU workers were not significant (Table 8). Non-VDU workers had slightly higher prevalences of right side shoulder problems than the VDU workers, but the data entry users had slightly higher prevalences in the left shoulder. The authors attributed the preponderance of left side neck and shoulder problems among data entry workers to the different work postures, since these workers had their manuscripts placed at the left side (142).

Workers in newspapers and bank offices (n=412) were examined by Smith and co-workers in the US (183). Professional VDU workers were reporters, editors etc., with substantial control of their workpace. Clerical VDU workers, on the other hand, performed data entry, data retrieval, telephone inquiry work etc., with little control of their workpace. Among "clerical" workers using VDUs, prevalences of a large number of body site complaints were significantly higher compared to control subjects (not using VDUs). Such differences were not found when comparing "professional" VDU users with non-VDU workers, however. No adjustments for other factors were performed and biased self-selection of participants was possible.

Attempting to summarise this information, a strong case can - in our opinion - be made for an increased occurrence of muscle problems among data entry workers compared to non-VDU users, both as to arm and hand problems and as to neck and shoulder problems. For data acquisition or interactive work, a similar conclusion appears more uncertain. A definitive summary statement is slightly compromised by the following considerations, though:

- Different choices of reference groups will have a major impact on the results (see *e.g.* (120)). In these studies, the reference groups varied among other VDU users, non-VDU users with varied work tasks, and all workers within the organisation.
- The different task types do not appear to be well-defined in terms of various psychological and social or work organisation parameters. Some indications of this can be found by the large impact - in some studies - of various effect modifiers. See for example the study by (10), where heterogeneity in these task types is shown in terms of job tasks and educational level.

Nevertheless, these studies provide extensive evidence for an association between certain type of VDU work types - especially data entry type jobs - and musculoskeletal problems. It could be argued whether it is the type of job that should be regarded as the causative agent, or the (likely) components of such jobs such as repetitive, monotonous work situations with static postures, low decision autonomy and skill utilisation etc. The advantages of clarifying the impact of such factors within *e.g.*, data entry work situations would be two; the ability to more precisely design intervention, and the ability to extract and generalise findings into other work types. On the other hand, failure to precisely describe the relative impor-tance of or the interactions between such factors should not detract from the fundamental finding of a strong association between data entry work and musculoskeletal disorders.

A final point is that for many (perhaps most) of these factors, the occurrence and impacts may well be strong also in certain office work situations without VDUs. It could be, however, that such non-VDU work situations (*e.g.* extensive typing) are disappearing with ongoing computerisation. (It should be noted that the Hünting study, which provides the strongest argument for similar risks in ”similar” non-VDU work situations - *i.e.*, extensive typing - was performed in 1981.)

Work load and work demand

Aronsson and co-workers (10) reported ”elevated odds ratios and dose-response relationships” between high work pace and discomforts in the neck and shoulders, unfortunately without any details on the specific associations found. In contrast, Bergqvist *et al.* (20), using the same questionnaire items, failed to find associations between a high work pace or overtime on short notice and muscle problems. Frequent overtime was associated in the final multivariate model with arm/hand discomforts, see Table 2.

The two NIOSH newspaper studies cited above provided strong evidence of the importance of work pace for upper extremity disorders. Bernard *et al.* (21, 22) showed that working under deadline for at least 30 hours per week was associated with neck and hand/wrist symptoms (Table 2) Restricting the analysis to routine workers, the neck odds ratios were substantially increased (OR 2.8; 1.1-7.1). High perceived job pressure was associated with shoulder symptoms The risk of hand/wrist disorders consistent with carpal tunnel syndrome was also associated with an increase in overall workload during the previous year (22). Burt and colleagues found marked exposure-response relationships for both shoulder and hand/wrist disorders with typing speed (30). Similar univariate trends were seen for neck and elbow/forearm disorders but were no longer statistically significant when hours of keying was also included in regression analysis. In addition, reporters, who were observed to work at a faster pace and to get up less often from their work stations than other employees, had more than twice the risk of arm/elbow and hand/wrist disorders, even after controlling for other work characteristics (Table 10).

In an Italian study by Camerino *et al.* (32), spinal/cervical complaints were associated with insufficient personnel situations (p=0.05) and aggressive clients (p=0.01), but not with time constraints. DeMatteo and co-workers (41) also failed to find a relationship between UE symptoms and keying rate. Ferreira *et al.* (54) found that the monthly incidence of cases of hand/wrist disorders increased when there was a new management goal that increased time pressure at work.

In a study of telecommunications workers, Hales et. al (78, 79) found associations in multivariate analyses between neck disorders and work pressure, and with high information processing demands; between hand/wrist disorders and high information processing demands; and between elbow disorders and surges in workload. There was little power to examine the effect of keystrokes per day among directory assistance operators, since data were only available for one job title, in which the average number of keystrokes was low and there was little variability. Surges in workload had an elevated risk of arm/elbow disorders; work pressure, which has both physical and psychological attributes, was associated with neck/shoulder disorders and the severity of arm/elbow and hand/wrist disorders (Table 2). (See also "psychological and social factors," below.)

Hoekstra *et al.*, reporting on "teleservice representatives," also could not examine the effect of hours per day because there was so little variability among study subjects (84). However, they found that neck/shoulder problems were associated with a continuously changing workload during the day. Since this job feature was also present for all study subjects, it suggests that workers with neck/shoulder symptoms were more bothered by the workload (*i.e.*, potential information bias).

Table 10. Effect of VDU work pace or intensity of work demands on frequency of upper extremity musculoskeletal disorders: Relative risk with 95% confidence interval (CI) and/or p-value for test of linear trend in exposure-response relationship (E-R).

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Aronsson, 1992 (10)	Nk and Sh: High work pace	Elevated odds ratios and dose-response (no data given)				
Bergqvist 1995b (20)	Nk/sh sx: High work pace	p>0.05 in multi-variate analysis	Arm/hand (see to the right)		Arm/hand sx: High work pace	p>0.05 in multi-variate analysis
Bernard, 1993, 1994 (21-22)	Nk: Hours on deadline/wk: 30-39 vs 0-10 Nk: Highly variable workload Sh: Job pressure	OR=1.7 (1.4-3.0) OR=1.5 (1.1-1.8) OR=1.5 (1.0-2.2)			Phase I: Hours on deadline/wk: 30-39 vs 0-10 Phase II: One-year increase in overall workload	OR=1.7 (1.2-2.3) OR=3.2 (2.5-4.1)
Burt, 1990 (30)	Sh: Typing speed moderate Sh: Typing speed fast	OR=2.6 (1.1-5.9) OR=4.1 (1.8-9.4)	Typing speed	p<0.02 in initial, p>0.05 in multivariate analysis	Typing speed moderate Typing speed fast	OR=1.3 (0.6-3.1) OR=2.5 (1.0-5.6)
Camerino 1995 (32)	Nk/sh sx: Time constraints	No association (p>0.05)				

(for notes, see end of the table)

Table 10. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
DeMatteo, 1993 (41)	MS sx, all UE regions: Keystroke rates	p<0.41				
Ferreira, 1997 (54)					Increase in time pressure	β=0.05, p=0.008
Hales, 1992, 1994 (78-79)	Nk: Work pressure	OR=2.4 (1.1-5.5)	Surges in workload	OR=2.4 (1.2-5.0) E-R (p<0.05)	Work pressure	E-R (p<0.05)
	Nk: High information processing demands	OR=3.0 (1.4-6.2)	Work pressure		High information processing demands	OR=2.3 (1.3-4.3)
	Sh: Work pressure	E-R (p<0.05)				
Hoekstra, 1994 (84)	Nk: Highly variable workload	OR=1.2 (1.0-1.4)				
Kamwendo, 1991a (94)	Nk: Too much to do	p=0.01				
	Sh: Too much to do	p=0.05				

(for notes, see end of the table)

Table 10. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Lim, 1994 (116)	UE MSD sx:		UE MSD sx (see to the left)		UE MSD sx (see to the left)	
	Work pressure	r=0.07 (p>0.05)				
	Production quota	r=0.11 (p>0.05)				
	UE CTD index:					
	Work pressure	r=0.17 (p>0.05)				
	Production quota	r=0.14 (p>0.05)				
Ryan, 1988 (166)	Neck/shoulder/forearm: Work pressure >3 times/week	OR=3.9 (1.3-12.2)	Nk/sh/forearm (see to the left)			

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electromyography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses. E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

Lim and Carayon (116) compared a number of self-reported job characteristics within a small group of office workers (n=129, 87% female). They posited an etiological model with interactions among physical and organisational features of work and analysed the data in a hierarchical manner consistent with their model. They found that work pressure and production quotas were associated with repetitive motions, awkward postures, dynamic work activity, and psychological anxiety, all of which were in turn associated with upper extremity musculoskeletal disorders. However, once the physical factors had been put into a multivariate model, neither work pressure nor production quotas was associated directly with upper extremity problems. (It should also be noted that there was no adjustment for age or other non-occupational risk factors.)

Work demand was not associated with muscle problems according to Marcus and Gerr (125), whereas Ryan and Bampton (166) did find relationships between muscle disorders and ”pushing oneself more than 3 times/week”.

In summary, a variety of indicators of job demands and workload has been studied by different investigators. Of the two studies that directly examined the effects of typing speed, the one that was larger and methodologically more sound (30) found significant associations with shoulder and wrist/hand problems, while the smaller, weaker one (41) did not. The majority of the studies that examined some other indicator of workload or work pressure did find some evidence of its role in upper extremity and neck problems. The failures of at least one study - after extensive multivariate analysis - to verify an association between work load or work demand and MSDs does, however, somewhat reduce the confidence in this conclusion. It should also be noted that the effect of work load cannot easily be partitioned into physical and psychological components or mechanisms, and that Lim and Carayon (116) may be correct that work pressure may act through (*i.e.*, by causing and intensifying the effects of) physical factors such as repetitive hand motion, rather than having an independent causal effects on MSD risk.

Repetitiveness of keyboard work

Work ”repetitiveness” may be characterised either in terms of the speed of body motions or the extent to which those motions are repeated without variation (”stereotypy”, 4). In the operation of VDUs, repetition has often been assessed through keying speed (*e.g.*, keystrokes per day) or as performance of data entry versus interactive tasks; other variables have been available in a few studies. Comparisons between data entry *vs.* interactive work are discussed above under ”VDU task types,” and typing speed is addressed under “Work load and work demands.” Here, we direct our discussion to more explicit measures of stereotypy, including monotonous work, lack of variation in tasks, and low skill utilisation or opportunity to learn new things.

Table 11. Effect of repetitiveness or stereotypy of VDU work on frequency of upper extremity musculoskeletal disorders: Relative risk with 95% confidence interval (CI) and/or p-value for test of linear trend in exposure-response relationship (E-R).

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Aronsson, 1992 (10)	Nk and Sh: Limited work task flexibility	Elevated odds ratios and dose-response (no data given)				
Bergqvist, 1995a (19)	Intense nk/sh sx: Repetitive movements 320 hr/wk, and stomach reaction (stress)	OR=3.9 (1.1-13.8)				
Bergqvist, 1995b (20)	Intense nk/sh sx: Repeated work movements Any sh dx: Low task flexibility	OR=3.6 (0.4-29.6) OR=3.2 (1.2-8.5)				
Bergqvist, 1995c (15)	Nk/sh sx: Decreased manuscript use	RR=1.5 (0.8-2.7)	Arm/hand sx (see to the right)		Arm/hand sx: - Increased keyboard use at newspaper: - Increased keyboard use at post office: - Increased monotony of work:	RR=5.3 (2.1-13.7) RR=3.5 (0.4-30.3) RR=3.1 (1.2-7.8)

(for notes, see end of the table)

Table 11. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Bernard, 1993 (22) (21)	Nk: Low work variance	OR=1.7 (1.2-2.5)				
Hales, 1992, 1994 (78-79)	Nk: Variety of work tasks	OR=2.9 (1.5-5.8)				
Lim, 1994 (116)	UE MSD sx: Repetitiveness UE CTD index: Repetitiveness	 r=0.18 (p<0.05) r=0.24 (p<0.01)	UE MSD sx (see to the left)		UE MSD sx (see to the left)	

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electromyography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses.
E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

In the study by Aronsson and colleagues (10), limited work task flexibility was associated with neck and shoulders complaints (no data given). Bergqvist *et al.* (20) found an association between the same task flexibility variable with shoulder diagnoses after multivariate adjustment for other factors. In a longitudinal analysis of the same study group, women who (retrospectively) reported increasing monotony in their work tasks during a 7 year period also had a higher incidence of hand/wrist problems during the same time period (15). In addition, decreased use of hard copy and increased use of keyboards were also somewhat associated with upper extremity problems. As noted above, elevated risks of neck/shoulder symptoms were found for the combinations of data entry work with limited opportunity to take rest breaks and VDU use for at least 20 hours per week with repetitive movements (19). The authors also separated their study participants according to whether the work could be classified as ”routine” or not, but did not report any association with MSDs (20).

Among US telecommunication workers (21), limited variance in VDU work was associated with neck/shoulder disorders (OR 1.7; 1.2-2.5) in the final multivariate model. In an analysis on a sub-set of the population with predominantly routine work, this odds ratio was higher (2.4; 0.9-6.9). In a Finnish study (111), the index ”limited satisfaction with the work content” (which included work variety) was associated with neck/shoulder symptoms (numerical details unclear from the report).

In contrast, the study of Hales *et al.* (79) failed to indicate any positive association between limited task rotation or limited task variation and muscle problems. In fact, an opposite association was found for task variation. The authors commented on this ”counter intuitive” finding by suggesting that ”tasks within the present job offered little opportunity for relief of biomechanical or psychic loads,” highlighting the limited value of job rotation or enlargement when the tasks available to be combined all have similar demands.

Lim and Carayon (115, 116) found, when comparing office workers who used VDUs with respect to a variety of ergonomic job features, that two indices of upper extremity disorders were each strongly associated with repetitiveness (Table 11). However, the reported analyses did not examine potential confounding by age or other non-occupational risk factors.

In an investigation of 1032 female clerical workers (190), the prevalence of various job characteristics was compared among part- or full-time typists, clerks (these groups without VDU use) and part- or full-time VDU clerical work. For ”understanding of work process” and ”learn new things,” the part day VDU users scored highest and the full day VDU users scored lowest among all the groups (VDU and non-VDU). For ”work ‘makes sense’,” both part and full time VDU users scored low. Full-day VDU users (but not part-time VDU users) reported a higher level of musculoskeletal problems than non-VDU workers, but direct analysis of their association with the work content variables was not carried out.

Overall, there are thus several indications that repetitive work or limited task variability have a role in the development of musculoskeletal disorders among

VDU workers. It is conceivable that this type of factor may be at least partly responsible for the associations seen between upper extremity MSDs and VDU work tasks (*e.g.*, data entry) or other job features in other studies. High work load, few rest breaks, and little task variability often occur together in actual workplaces, which limits the ability to study their separate effects with epidemiological methods. Experimental studies may be more informative, since different combinations of exposure can be created artificially, if necessary. In summary, we believe that the interrelationships between these dimensions of work organisation still remain to be fully explored in relation to musculoskeletal disorders.

Rest break patterns and duration of work tasks

In the study by Bergqvist and co-workers (20), limited spontaneous rest break ability was - after adjustments for other factors - associated with neck/shoulder discomforts as well as several diagnoses (see Table 12). The (non-significant) association with arm-hand diagnoses was in a further analysis (19) shown to be interrelated with some other factors; individuals with limited rest break opportunity and non-use of lower arm support who worked more than 20 hrs/week with a VDU were found to have an increased odds ratio when compared with those performing non-VDU office work. (See also above for interrelationships between rest breaks and data entry work.)

In a Brazilian study (26) of both VDU and non-VDU users, self-reported absence or insufficiency of rest breaks was associated with diagnosed upper extremity musculoskeletal disorders. In an Australian study of data entry operators (166), diagnosed cases of upper limb disorders reported to a lesser extent than non-cases that there was ”enough time for rest breaks” (80% *vs.* 100%, p=0.035). Few further details were given in these two reports, and no adjustments for other factors were made, however. Some other studies have examined the frequency of rest breaks without - in the final multi-variate analysis - finding associations with muscle problems (21, 79).

The duration of VDU work periods between breaks or change of task was not associated with self-reported or diagnosed disorders in two Swedish studies (10, 20). DeMatteo *et al.* (41) actually found a negative association (p<0.005). The authors inferred that this could have been due to other factors. In their study, data entry workers (with shorter work periods) were compared with general office workers (with longer periods), but who had ”greater opportunity to frequently change posture” (41). Thus, they suggest a potential confounding effect of task types with rest breaks, unfortunately without performing an analysis either to verify or to discredit the suggestion. An alternative possibility is that workers with fewer discomforts work longer before taking breaks or varying their activities.

Ferreira *et al.* (54) used multivariate time series analysis to examine factors that predicted upper extremity musculoskeletal disorders in interactive VDU work. In a retrospective, dynamic cohort of 106 operators, 24 cases occurred, all or most in the hand/wrist region. The monthly incidence decreased after a regular

Table 12. Effect of self-evaluated sufficiency or frequency of rest breaks on frequency of upper extremity musculoskeletal disorders: Relative risk with 95% confidence interval (CI) and/or p-value for test of linear trend in exposure-response relationship (E-R).

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Bergqvist, 1995a (19)			Arm/hand (see to th eright)		Insufficiency of rest breaks. non-use of lower arm support and VDU work ≥20 h/wk compared to non-VDU work - any arm/hand dx:	 OR=4.6 (1.2-17.9)
Bergqvist, 1995b (20)	Insufficiency of rest breaks - Nk/sh sx: - TNS dx: - any shoulder dx:	 OR=2.7 (1.2-5.9) OR=7.4 (3.1-17.4) OR=3.3 (1.4-7.9)	Arm/hand (see to th eright)		Insufficiency of rest breaks - any arm/hand dx:	 OR=2.7 (0.8-9.1)
Bernard, 1994 (21)	Number of breaks	p>0.05 in multivariate analysis	Number of breaks	p>0.05 in multivariate analysis	Number of breaks	p>0.05 in multivariate analysis
Bozi Ferraz, 1995 (26)	Any musculoskeletal dx: Insufficiency of rest breaks	Associated, p=0.012				

(for notes, see end of the table)

Table 12. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Ferreira, 1997 (54)					Rest/work schedule (10 min/hr)	linear regression: β=-0.05, p=0.02 logistic regression: OR=0.05, p=.02
Hales, 1994 (79)	Number of breaks	p>0.05 in multivariate analysis	Number of breaks	p>0.05 in multivariate analysis	Number of breaks	p>0.05 in multivariate analysis
Ryan, 1988 (166)	Insufficiency of rest breaks: - neck/shoulder/forearm sx:	Associated, p=0.035				

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electro-myography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses.
E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

rest/work schedule (10 minutes of rest per hour) was implemented. In logistic regression modelling of high incidence rates, the rest/work schedule was the most significant predictor of change (decrease) in monthly incidence.

The study by Ryan and Bampton (166) included insufficient rest breaks as one of 7 examined variables. While they found an association with muscle disorders (Table 12), unfortunately no multivariate analysis was performed, especially since individuals in these workplaces were exposed to so many physical workstation problems. It is plausible that these individuals might have a lower threshold for "insufficient" rest time, because of their poor ergonomic conditions.

Thus, the associations of rest break pattern, flexibility or duration of work tasks with muscle problems appear rather inconsistent. While the strongest suggestion of an effect was found in the study by Bergqvist and colleagues (20), that study formulated the variable in such a way ("opportunity to take unscheduled rest breaks") that a component of decision latitude (see below) may have been included - as is often the case in actual workplaces. Another possible interpretation is that workers with MSDs are more sensitive to or aware of the inability to take breaks than are workers without MSDs. Given the wide variety of other factors that could influence the ability to take rest breaks, further insight into this factor could conceivably be obtained from experimental or intervention studies, examining different fixed or flexible rest break patterns, while holding other conditions constant (see the Introduction).

Monitoring and supervision

In the study by DeMatteo *et al.* (41), muscle problems and use of monitoring and quota systems were analysed. Muscle problems were strongly related to stress (see further below), and that outcome variable was in turn related to monitoring ($p<0.03$). Unfortunately, it is not clear whether any "direct" relationship between muscle problems and monitoring was analysed - no such results were reported. In another North American study which obtained data on monitoring, that of Hales *et al.* (79), 93% of the study subjects were subject to monitoring, and therefore there was little statistical power to detect any association. In this study, an association was found between the absence of a productivity standard and neck disorders (OR 3.5; 1.5-8.3). The authors noted this "counter-intuitive" result, but offered few suggestions as to its cause, confounding with other work factors is one possibility.

In the study by Hoekstra *et al.* (84), 100% of the subjects were continuously monitored electronically (for productivity), and at random by supervisor (for quality and accuracy). Very high prevalences of job dissatisfaction, physical and mental exhaustion were reported, along with very low decision autonomy. However, since no comparison could be made with workers not being monitored, the contribution (if any) of monitoring to MS disorders could not be determined. Another North American study did provide such comparisons (182), and reported significant increases in prevalences of a number of musculoskeletal complaints (*e.g.*, in the fingers, wrists, shoulders and neck). However, no multivariate analysis was performed, so the relative role of monitoring, or (*e.g.*) workload was not ascertained (the authors noted that workload was a predictor of strain also in unmonitored work situations, though). The major obstacle when interpreting this study is the very low participation rate (26%), and the authors rightly caution against making firm conclusions based on these results.

In our minds, these few results can only be summarised with the statement that an association between muscle problems and the type of monitoring or supervision system among VDU users has (so far) not been established. It should also be noted that both national regulatory environments and cultural differences could influence these relationships as effect modifiers, so these factors should at least be specified in future studies and, where possible, their effects should be explored.

Psychological and social factors

Worker's control and decision latitude

In the study by Aronsson and coworkers, limited organisational influence was associated with discomforts in neck, and shoulder (no numerical data reported (10). In another Swedish study (20), there was, however, no such reported association in the final multivariate models. Bernard and co-workers (21) reported an association between "perceived lack of participation in job decision making" and shoulder symptoms, but not between job control and muscle problems (Table 13).

Decision latitude was associated with limb numbness severity in the substudy (n=70, with ascertained ergonomic factors) of the study by Faucett and Rempel (47), and they also found an interaction with keyboard vertical position; individuals with low decision latitude and a highly placed keyboard (above elbow height) reported more upper extremity numbness ($p<0.05$). A similar interaction was also found for upper torso pain and stiffness ($p<0.01$). It should be noted that in the full study (n=150, but without ergonomic factor ascertainment), no association was noted with decision latitude, once workload were entered into the model.

Hales and co-workers (79) found associations between "routine work lacking decision making opportunities" and neck and elbow disorders (Table 13). Marcus and Gerr (125) did not find any associations between decision latitude and muscle problems. The study by Hoekstra *et al.* (84) reported a small but significant association between neck disorders and "continually changing workload during the day" (see Table 10), which also suggests lack of control over tasks and pacing. In addition, shoulder disorders were also associated with working at locations where workers perceived themselves to have less control over work policy.

Linton and co-workers reported associations between ability to influence working conditions and neck and shoulder pain (94). In the same study, using the index "work content" (which apparently included such questions), elevated odds ratios and significant linear trends were found for neck and shoulder pain, respectively (117).

In conclusion, while some studies appear to support a relationship between muscle problems and decision latitude or job control, other studies - including some with multivariate analysis - fail to do so. Thus, in our opinion, a definite conclusion regarding this aspect of VDU work and its importance for MSDs is currently not possible, although, again, the positive results are suggestive.

However, it should also be pointed out that, although numerous investigators have used the Karasek Job Content Questionnaire (96) to characterise decision latitude, as well as psychological job demands, remarkably, none to date have used the corresponding Karasek-Theorell demand/control model to inform the analysis of the data obtained. The model specifically posits the combination of

Table 13. Effect of perceived decision latitude and control on frequency of upper extremity musculoskeletal disorders: Relative risk with 95% confidence interval (CI) and/or p-value for test of linear trend in exposure-response relationship (E-R).

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Aronsson, 1992 (10)	Nk and sh sx: index on low control and influence	Associated (no data given)				
Bergqvist, 1995b (20)	Nk and sh sx or dx: index on low control and influence	p>0.05 in multivariate analysis	Arm/hand (see to the right)		Arm/hand sx or dx: index on low control and influence	p>0.05 in multivariate analysis
Bernard, 1994 (21)	Lack of participation in job decision making -Sh sx: -Nk sx: Job control, Nk and Sh sx:	 OR=1.6 (1.2-2.1) Not associated Not associated			Lack of participation in job decision making, hand/wrist sx: Job control, hand/wrist sx:	Not associated Not associated
Faucett, 1994 (47)					Decision latitude, limb numbness	Severity associated (p<0.05)
Hales, 1992, 1994 (78-79)	Routine work lacking decision-making opportunities, Nk dx:	OR=4.2 (2.1-8.6)	Routine work lacking decision-making opportunities; elbow dx:	OR=2.8 (1.4-5.7)	Routine work lacking decision-making opportunities, hand/wrist dx:	Associated; (linear regression of symptom severity disorders), p>0.05

(for notes, see end of the table)

Table 13. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Hoekstra 1994 (84)	Sh sx: Lack of control on work policy	OR=4.0 (1.1-14.6)				
Kamwendo, 1991a (94), Linton, 1989 (117)	Inability to influence working condition; - Nk sx: - Sh sx: Work content - Nk sx: - Sh sx: Poor psychosocial environment index - Nk sx: - Sh sx:	 Associated (p<0.001) Associated (p<0.003) OR=2.2 (1.1-4.5) OR=2.5 (1.3-4.9) OR=2.3 (1.3-4.0) OR=2.5 (1.5-4.3)				
Marcus, 1996 (125)	Decision latitude, Nk/Sh sx:	p>0.05 in multivariate analysis	Arm/hand (see to the right)		Decision latitude, arm/hand sx:	p>0.05 in multivariate analysis

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electromyography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses. E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

high demands and low control to be injurious, and the evidence with respect to cardiovascular disease is strikingly consistent with this model. Yet all of the studies that we cite here present analysis of associations with job demands and decision latitude independent of each other and fail to examine whether there is a higher risk of upper extremity MSDs specifically in VDU jobs that have both high demands and low control.

Social support and co-operation

Among government employees, individuals reporting extreme peer contacts (defined as both low and high compared to an intermediate level) were found to have higher occurrences of neck and shoulder problems (no data given, 10). Bergqvist *et al.* (20) found relationships between the same extreme peer contact variable and arm/hand discomforts as well as with ”any arm/hand diagnosis” (Table 14). In an a posteriori analysis, separating low and high peer contacts, it was found a/ that both showed increased muscle problems compared to intermediate levels, and b/ that this U-shaped pattern existed only for individuals reporting stomach-related stress reactions. A similar interaction was also found for tension neck syndrome. The authors ascribed the finding of limited peer contact to that associated with limited social support, but could only speculate as to the cause of the high peer contact finding; time-consuming peer contact may be a stress factor, or extensive peer contact may be a reaction to problematic working conditions (20).

Bernard and co-workers (21) found associations between ”perceived lack of support from an immediate supervisor” and hand/wrist symptoms and between ”perceived lack of importance for ergonomic issues by management” and neck symptoms (Table 14). Other support indicators (interaction with co-workers, support from families) failed to exhibit associations with musculoskeletal symptoms, though. In the study by Camerino *et al.* (32), indifferent colleagues, no internal meetings, lack of communication and no support from colleagues were all - in apparently separate analyses - associated with cervical complaints (Table 14).

Faucett and co-workers (47) reported co-worker support being associated with upper extremity numbness (Table 14). Furthermore, low co-worker support and increased relative keyboard height interacted as to upper torso stiffness ($p<0.05$). Supervisor support and supervisor conflict interacted with both relative keyboard height and relative seat back height in rather complex ways (see further (47)).

In the study by Hales *et al.* (79), no associations were reported between interaction with co-workers or others and muscle disorders. A similar lack of findings was reported by Marcus and Gerr (125). In contrast, Linton *et al.* (117) found associations between the social support index and neck pain and (possibly) also with shoulder pain. Finally, Levoska and Keinänen-Kiukaanniemi (111) reported an uncertain tendency for work-related social support being associated with disturbing neck/shoulder symptoms.

Table 14. Effect of social support and co-operation on frequency of upper extremity musculoskeletal disorders: Relative risk with 95% confidence interval (CI) and/or p-value for test of linear trend in exposure-response relationship (E-R).

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Aronsson, 1992 (10)	Extreme peer contact; Nk and Sh sx:	Associated (no data given)				
Bergqvist, 1995b (20)	Extreme peer contact; nk/sh sx or dx:	p>0.05 in multivariate analysis	Arm/hand (see to the right)		Extreme peer contact; -arm/hand sx: -arm/hand dx:	 2.1 (1.1-4.1) 4.5 (1.3-15.5)
Bernard, 1994 (21)	Lack of support from managers or super-visors, Nk sx: Peer contacs, family support, Nk or sh sx:	OR=1.9 (1.4-2.4) p>0.05 in multivariate analysis			Lack of support from managers or supervisors, hand/wrist sx: Peer contacs, family support, hand/wrist sx:	OR=1.4 (1.2-2.5) p>0.05 in multivariate analysis
Camerino, 1995 (32)	Cervical symptoms: - Indifferent colleagues, - No internal meetings, - Lack of communi-cations - No support from colleagues	 Associated (p=0.02) Associated (p=0.03) Associated (p=0.03) Associated (p=0.009)				
Faucett, 1994 (47)					Less co-worker support; upper extremity numbness severity	Associated (p=0.05)

(for notes, see end of the table)

Table 14. (continued)

Study	Neck/shoulder		Arm/elbow		Hand/wrist	
	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings	Exposure, Study Group, Health Outcome	Findings
Hales, 1992, 1994 (78-79)			Lack of co-worker support, elbow dx:	$p<0.05$ in initial, but $p>0.05$ in multivariate analysis	Lack of supervisor support, hand/ wrist dx:	$p<0.05$ in initial, but $p>0.05$ in multi-variate analysis
Levoska, 1994 (111)	Low social support index, Nk/sh sx:	Uncertain association ($p=0.07$)				
Linton, 1989 (117)	Low social support index, - Nk sx: - Sh sx:	 1.8 (1.0-3.2) 1.6 (0.95-2.8)				
Marcus, 1996 (125)	Co-worker or supervisor support, Nk/sh sx:	$p>0.05$ in multivariate analysis	Arm/hand sx (see to the right)		Co-worker or supervisor support, arm/hand sx:	$p>0.05$ in multivariate analysis

Abbreviations: CI = confidence interval; CTD = cumulative trauma disorders, CTS = carpal tunnel syndrome; EMG = electro-myography; E-R = exposure-response relationship; dx = diagnosis; Ha = hand; hr = hours; L = left; NCV = nerve conduction velocity; Nk = neck; PE = physical examination; PR = prevalence ratio; OR = odds ratio; r = correlation coefficient, R = right; RR = risk ratio; Sh = shoulder; SMR = Standardized Morbidity Ratio (by age); sx = symptoms; TNS = tension neck syndrome; UE = upper extremity; VDU = visual display unit; Wr=wrist

Relative risks (expressed as RR, OR or PR) from multivariate analyses if available, otherwise from univariate analyses. E-R p-values from Mantel test for linear trend in proportions, statistical testing on regression coefficient, t-test or analysis of variance. Some raw data estimated from graphics for calculation of odds ratios and confidence intervals.

The majority of the studies reviewed above reported associations between limited social support or some other indication of interaction with others and muscle problems. Unfortunately, the precise ways in which these types of variables were ascertained varied considerably among studies, making it difficult to evaluate the consistency of the findings in more than a general way. In light of this limitation, the following speculative comment is offered: The U-shaped relationship between peer contacts and various muscle problems, found by both Aronsson *et al.* (10) and Bergqvist *et al.* (20), raises the question whether extensive contacts should be seen as only positive. Some other studies asked specifically for both support and conflict (*e.g.* (21, 47)). However, closer examination of the questions used in the two Swedish studies to derive the peer contact index reveal that they were asked in a positive manner ("much contact...help each other", "possibility to talk with others during work" and "...discussing solutions to.....", 10). Another possibility is that extensive peer contact may reflect the need to discuss adverse work conditions. If so, then peer contacts may here be linked to other, more adverse conditions. The complex interactions demonstrated by Faucett and Rempel (47) could conceivably be explainable in this sense, in that the results may perhaps not reflect a direct interaction between a low supervisor support and a high seatback height, but that - in this specific locale - one of these two variables is actually closely related to another (nonmeasured) variable that could better explain the interaction. On the other hand, the authors do offer some possible rational explanations of their findings, such that perhaps lack of results in attempting to improve seating may deteriorate supervisor support.

Fear and insecurity or job dissatisfaction

No association between job security and muscle problems was found by Bernard *et al.* (21). Likewise, job insecurity was not a main factor according to Faucett and Rempel (47) - although an interaction between job insecurity and low relative keyboard height was noted. In a study on telecommunication workers, fear of being replaced by computers was associated with neck (OR 3.0; 1.5-6.1), shoulder (OR 2.7; 1.3-5.8) and elbow disorders (OR 2.9; 1.4-6.1), while neck, elbow and hand/wrist disorders were associated with uncertain job future ($p<0.05$) (78, 79). Marcus and Gerr (125) found that neck/shoulder symptoms were associated with lower perceived job security, although the low participation rate (70%) detracts somewhat from these results. The limited number of studies, and the fact that only two showed a positive association, although suggestive, precludes any attempt at generalisation.

For job dissatisfaction, Burt (30) found associations between this variable and certain MSDs; the adjusted odds ratio was 1.9 (1.1-3.4) for neck, and 2.3 (1.2-4.3) for shoulder symptoms. Elbow, forearm and handds or wrist were not associated with job dissatisfaction ($p>0.05$). The SHARP report (174), in contrast, found no association between, neck, shoulder or hand/wrist disorders, but an uncertain association (p=0.07) with elbow and forearm symptoms. These findings are both inconsistent and difficult to interpret, since it is unclear whether job dissatisfaction should be seen as a cause of, or perhaps consequence of MSDs.

Stress reactions

Aronsson *et al*. (10) reported dose-response associations between stress reactions (both ”stomach reactions” and ”psychological tiredness”) and various muscle problems - although no numerical details were reported. Bergqvist and co-workers (20) used the same two stress variables, and reported numerous associations between ”stomach reactions” with different muscle problems; neck/shoulder discomforts (OR 3.5; 1.5-8.2), intensive neck/shoulder discomforts (OR 5.4; 1.6-17.6), cervical diagnoses (OR 3.9; 2.0-7.7), any shoulder diagnosis (OR 4.8; 1.2-10.7), arm/hand discomforts (OR 3.8; 2.0-7.3) and arm/hand diagnoses (OR 3.4; 1.3-8.4). Furthermore, there was an interaction of stomach reactions with extreme peer contacts for TNS (see above), and with performing repetitive movements for at least 20 hrs/week for intense neck/shoulder symptoms. For ”psychological tiredness”, only cervical diagnoses were associated (OR 1.9; 1.0-3.5). As already commented on above, stress reactions were generally *not* put in the same multivariate model as work organisational/ psychological and social factors, since they could form a link between exposure (*e.g*. adverse psychological and social conditions) and the outcome. It may be more useful to identify this as a psychosomatic indicator of persons who are developing problems, and would benefit from secondary prevention measures.

A strong correlation was also found between stress and musculoskeletal symptoms (p<0.03) by DeMatteo *et al*. (41). In multivariate analyses, Marcus and Gerr (125) found that neck/shoulder and hand/arm symptoms were associated with psychosocial job stress in the previous 2 weeks. In contrast, Camerino and colleagues (32) failed to report any association between cervical complaint and stress.

The (mostly) strong associations found between stress and muscle problems can tentatively be seen as an overall verification of the importance of work organisational, psychological and social factors - especially since such associations were just as strong with objective verifications of muscle problems as with questionnaire based endpoints.

Gender

Gender as a risk factor for musculoskeletal disorders

Odds ratios for the effect of gender on upper body disorders, as ascertained by questionnaires are shown, based on data given in or computed from a number of studies (10, 20, 21, 30, 45, 71, 78, 98, 101, 174), are shown in Tables 15 and 16.

Only three studies failed to indicate a substantial excess of neck and shoulder discomforts among women compared to men (20, 78, 174). However, it should be noted that the SHARP study (174) is small, with only 11 male subjects, so that the higher crude prevalence among women may not have been statistically significant simply because of sparse data (the odds ratios and CIs were not shown). The Bergqvist study (20) was performed at workplaces with a high degree of routine work for both men and women. This implies that observed gender differences actually may represent differences in type of work. Some support for this explanatory suggestion is found in both the study of Aronsson *et al*. (10) and that of Bernard *et al*. (21), where smaller gender odds ratios for neck and for shoulder problems were noted when the study population was limited to men and women with more routine work, or with more comparable jobs (see also references 1 and 12 in the report by Bernard *et al*. (21)). However, the opposite trend was found by Aronsson *et al*. (10) when examining professional (CAD and/or programming) work (see Table 15). Furthermore, in an older investigation of the same study population that was investigated by Bergqvist *et al*. (20), Knave and co-workers (104), found higher discomfort scores (frequency and intensity) for women compared to men in neck, shoulder, upper arm, elbow, forearm and hand. Although there was no detectable difference between men and women in the prevalence of disorders in the stidy by Hales *et al*. (78), female gender had a weak positive association with increasing score of combined severity, frequency, and duration for both neck and shoulder symptoms.

Few studies have specifically reported the influence of other factors on these gender-specific odds ratios, when based on discomforts reported in questionnaires. In the study by Bernard *et al*. (21), the odds ratio for neck, shoulder and hand/wrist symptoms were adjusted for a number of job task and psychological and social factors. (Unfortunately, crude gender odds ratios were not reported, so it cannot be determined whether these covariates had confounded the association with gender.) Also of interest are the findings of substantial differences in the work performed by men and women at the VDU found by Evans (45): men had greater variety of VDU tasks, used the VDU for fewer hours per day in total, and worked fewer hours continuously without a break. Among men only, task type was found to modify the relationships between symptoms and VDU work, with higher prevalences in data processing than in programming and a more rapid rate of increase with increasing hours per day at the VDU.

Table 15. Odds ratios for upper torso musculoskeletal discomfort in women compared to men.

Study,	Study	Odds ratio in upper torso location		Comments
author, date	population	Neck	Shoulder	
Aronsson, 1992 (10)	General VDU	2.2 (1.8-2.7)	2.8 (2.3-3.6)	In the last 12 months, cOR
	Routine VDU	1.5 (1.0-2.2)	2.2 (1.4-3.4)	In the last 12 months, cOR
	CAD or prog. work	2.9 (1.6-5.5)	3.1 (1.6-5.8)	
Bergqvist, 1995b (20)	Routine VDU,	1.3 [1,] 0.7-2.3)	1.3 [1,] 0.7-2.3)	In the last 12 months, cOR
Bernard, 1994 (21)	General VDU	2.1 (1.4-2.4)	2.2 (1.5-3.3)	In the last 12 months, aOR
	VDU jobs with uniform gender distribution	1.9 (0.8-4.5)	1.5 (0.5-4.8)	In the last 12 months, aOR
Burt, 1990 (30)	Newspaper workers	2.3 (1.5-3.5)	1.3, p=0.15	In the last 12 months, aOR (neck only), cOR for shoulder)
Evans, 1987 (45)	General VDU	2.6 (2.0-3.3)	ND	Self-selected, cOR
Grieco, 1989 (71)	General VDU	3.6 [2,] 3.1-4.1)	3.6 [2,] 3.1-4.1)	cOR
Hales, 1992, (78)	Various telecommu-nication workers	No association (p>0.05)	No association (p>0.05)	
Karlqvist, 1995 (98)	CAD work	2.0 (1.2-3.4)	3.0 (1.7-5.2)	Current, cOR
Karlqvist, 1995 (101)	General VDU	2.6 (1.7-3.8)	4.2 (2.7-6.7)	In the last 12 months, aOR
SHARP, 1993 (174)	Billing clerks (routine work)	OR not given p>0.05	OR not given p>0.05	In the last 12 months, aOR

Notes and explanations : [1)] Neck and shoulder discomforts reported together, [2)] Upper limb problems. (For other explanations, see bottom of Table 16.)

Table 16. Odds ratios for extremity discomfort in women compared to men.

Study, author, date	Study population	Odds ratio in extremity location: Elbow	Odds ratio in extremity location: Hand/wrist	Comments
Aronsson, 1992 (10)	General VDU,	2.3 (1.5-3.7)	2.5 (1.8-3.6)	In the last 12 months, cOR
Bergqvist, 1995b (20)	Routine VDU,	ND	1.1 [1] 0.6-2.2)	In the last 12 months, cOR
Bernard, 1994 (21)	General VDU,	ND	1.7 (1.2-2.4)	In the last 12 months, aOR
	VDU work with similar gender occupancy	ND	1.7 (0.8-3.6)	In the last 12 months, aOR
Burt, 1990 (30)	Newspaper workers	1.3, p=0.26	1.2 (0.9-1.7)	In the last 12 months, cOR
Grieco, 1989 (71)	General VDU	ND	3.6 [2] 3.1-4.1)	cOR
Hales, 1992, (78)	Various telecommunication workers	No association (p>0.05)	No association (p>0.05)	
Karlqvist, 1995 (98)	CAD work	1.8 (0.8-4.3)	1.7 [3] 0.7-4.3) 2.1 [4] 0.9-4.3)	Current, cOR
SHARP, 1993 (174)	Billing clerks (routine work)	OR not given p>0.05	OR not given p>0.05	In the last 12 months, aOR

Notes and explanations : OR=odds ratios comparing women with men; cOR=crude OR (no adjustments made for other variables), aOR=adjusted OR for other variables. ND=not determined or reported, CAD=Computer Assisted Design. Prog.=programming. Selfselected= study population self-selected (respondents to questionnaire in newspaper). Current and ”in the last 12 months” refer to period of recall of discomforts.

1) Arm and/or hand discomforts. 2) Upper limb problems, 3) Wrist discomforts, right side only. 4) Hand problems, right side only.

Three studies where data on men and women can be compared have utilised physical examinations resulting in diagnoses in order to obtain diagnoses (20, 26, 79). Table 17 summarises this information.

Some points are noteworthy:

- The one study by Bergqvist *et al.* (20) which failed to exhibit gender differences based on questionnaires now does so (c.f. Tables 15-17; see further discussion below).
- In that study, both TNS (tension neck syndrome) and (any) arm/hand diagnoses appear to be influenced by the womens child-care duties (see Table 17).

The largest of these fewer studies, by Hales *et al.* (79), did not show that gender was a risk factor.

Table 17. Odds ratios for musculoskeletal diagnoses in women compared to men in the reviewed studies.

Study, author, date	Study population	Odds ratios for Tension neck syndrome	Cervical disorders	Any shoulder diagnosis	Any arm/ hand diagnosis	Comments
Bergqvist, 1995b (20)	Routine VDU	2.2 (1.0-4.9)	1.3 (0.6-2.7)	5.1 (ND)	7.4 (ND)	cOR
	Routine VDU	6.4 [1)] (1.9-22)	ND	7.1 (1.6-32)	5.2 [1)] (1.2-2.3)	aOR
Bozi Ferraz, 1995 (26)	Routine VDU	2.6 [2)] (1.2-5.9)				cOR
Hales, 1992, 1994 (78-79)	General VDU	Neck ($p<0.05$) and shoulder ($p<0.05$) associated with gender in crude analysis, however, gender was not associated with any of the four upper extremity disorders in the final model				aOR

Notes and explanations : OR=odds ratios comparing women with men; cOR=crude OR (no adjustments made for other variables), aOR=adjusted OR for other variables. ND=not determined or reported.

[1)] For women with children at home. For women without children at home, the aOR was not significantly different than for men, for *e.g.* tension neck syndrome, the aOR was 2.0 (0.7-5.6) when comparing women without children at home with all men. (There was no discernible difference between men with and without children at home.)

[2)] Reported only for all UE MSD (upper extremity musculoskeletal disorders) combined.

In the study by Bergqvist *et al.* (20), both symptoms and diagnoses were ascertained, enabling a comparison between these endpoints to be made. As already noted (Tables 15-17), differences between men and women in that study were fairly small in the questionnaire data. In contrast, diagnosed disorders were from 1.5 to 10 times more frequent among women than men (see Table 18).

As can be seen in Table 18, women (as a group) were considerably more likely than men to have their upper extremity and neck discomforts "confirmed" by a diagnosis in the relevant region. These data are not consistent with the suggestion that the difference between men and women should result from a higher reporting tendency among women, as such an explanation would be consistent with lower "confirmation" rates among women. Some cautionary notes are appropriate here, though. First, VDU-specific data are available only for this one study; secondly, this study is the only one not suggesting overall differences in questionnaire data; and finally, the published data allow only comparisons of group prevalences, not associations between individuals discomfort and diagnoses ratings.

In most but not all of these reviewed papers, the odds for neck, shoulder and wrist/hand discomforts appear to be higher for women than men, at the order of about 2 (possibly slightly higher for shoulder). For elbow discomfort, two studies suggest similar elevated odds ratios, whereas two do not. The exceptions to this general increase in some discomfort locations are the results of the studies by Bergqvist *et al*. (20) and the SHARP report (174) who generally failed to find indications of such differences in discomforts between men and women, and the study by Burt (30) and colleagues, who failed to do so for some endpoints. Among several possible explanations for this, it can be noted that at least two these three non-positive studies were performed at workplaces with a high degree of routine work.

Table 18. Comparison of prevalences of discomforts ascertained by questionnaires and diagnoses obtained through medical examinations in men and women (data from (20)).

	Men	(n=58)		Women	(n=189)	
Location	Discomforts	Diagnoses	Ratio	Discomforts	Diagnoses	Ratio
Neck	45.7% [1)]	32.8% [2)]	0.72	54.4% [1)]	49.2% [2)]	0.90
Shoulder	44.3% [1)]	3.3%	0.07	49.6% [1)]	14.7%	0.30
Arm/hand	28.1%	1.6%	0.06	30.4%	11.0%	0.36

[1)] Separation of neck and/or shoulder discomfort prevalences, unpublished data. [2)] Sum of prevalences of tension neck syndrome and cervical diagnoses.

Data on specific causes of this gender difference are very sparse among VDU use-based studies, but a few indications have appeared that could be seen to support the suggestions that both work-specific and non-work specific factors may be involved, such as child care (20). See also the discussion above on routine *vs*. non-routine work, and by Aronsson *et al*. (10). In the one study that enabled such an analysis, no suggestion for a higher reporting tendency among women appeared - since the women in that study had higher “confirmation” rates than men.

There have been few opportunities to compare the effects of similar job features on men and women, in any industry or sector, because there is so much sex segregation in workplaces world-wide. However, Silverstein *et al*. (177) found that women had an increased risk of hand/wrist disorders compared to men, after controlling for job demands; most of the gender difference appeared to occur in jobs with high manual forces but low repetition rates, jobs where many more male than female subjects were employed. However, when the outcome was restricted to carpal tunnel syndrome by symptoms and physical examination, there was no longer an effect of gender after including job demands in the multivariate model (178).

In a more recent study of automobile manufacturing workers, women were found to have about 1.5 times higher prevalences of upper extremity disorders, by either symptoms or physical examination findings (153), although there was substantial effect modification of physical exposure by gender, in which women had a higher ‘baseline' risk than men in the lower exposure groups but about the same risk in the highest exposure group. It also appeared that there was a healthy worker selection effect which was especially predominant among women employed in the most physically demanding jobs. However, in a one-year follow-up survey of the same population, the risk of new upper extremity disorders associated with physical exposures did not vary between men and women.

Gender as an effect modifier

The study by Aronsson *et al.* (10) also investigated whether the effect of VDU work on neck and shoulder discomforts differed for men and women (*i.e.* gender as an effect modifier of VDU work). For the neck, the male-specific odds ratios were high for data entry (OR=5.5; 2.1-14.7), data acquisition (OR=3.8; 1.6-9.1), word processing (OR=3.5; 1.3-2.1) and programming work (OR=3.0; 1.2-7.5), compared with the reference group (mixed and varied VDU work). For shoulder problems, male data entry workers had higher odds than male reference workers (OR=3.4; 1.2-9.0) - as also illustrated in figure 4. For female workers, corresponding neck and shoulder odds ratios did not differ significantly from 1.0 (they varied between 0.8 and 1.4). Thus, gender was a strong effect modifier, in that men had higher risks for neck and shoulder discomforts in relation to variations in work than women. For CAD workers, however, no such trend was seen. Furthermore, no such tendency was seen for the arm and hand region.

To further illustrate this, it can be seen in figure 4 (which is based on data from Aronsson *et al.* (10)), that a/ the difference in shoulder discomfort prevalences between men and women is larger in the reference group (presumably with more varied task types) than in the data entry group (with presumed more homogeneous and monotonous work), b/ women show higher prevalences than men in both groups, and c/ the difference between the data entry and reference groups is higher for men than women. The authors speculated that: ”in situations with low self control of work, high time pressure etc., the differences between men and women are fairly small - these ‘external’ workplace related conditions dominates. The differences between men and women tends to increase in groups where individual (work-related) conditions are allowed to vary. In such situations, conditions outside of the workplace (‘double work’) may tend to ‘keep’ the women at a higher discomfort prevalence.”

Higher VDU work related odds ratios for men than women were also found by Evans (45) for neck/shoulder discomforts (men 3.4; 1.8-6.3, women 1.9; 1.4-2.7); tendencies in the same direction were also noted by Grieco *et al.* (71) for both neck and upper extremity problems in relation to hours per day at the VDU (Table 3). In contrast to this, Bergqvist *et al.* (15) found an increased risk of hand/wrist discomforts among women with increased monotony of work during a six year period (risk ratio of 3.1; 1.2-7.8), whereas no such risk was found among men.

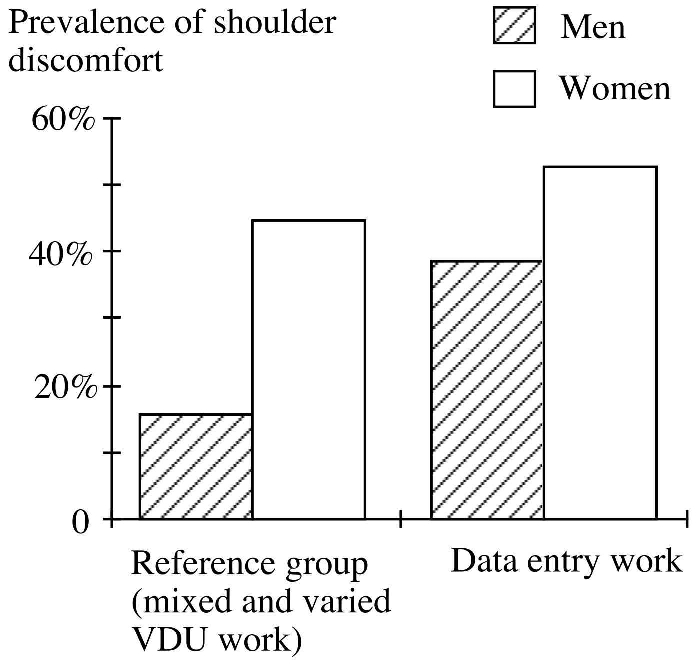

Figure 4. Prevalence of shoulder discomforts in different groups. Data from Aronsson *et al*. (10).

Again, the number of studies are too few to enable any definite summary. However, if it is true that men experience greater neck/shoulder effects of VDU work than women, even though women have higher background risk, then this has both substantive and epidemiological implications. The selection of women only (based on having the highest prevalence of problems) in order to study VDU-related neck/shoulder problems may actually be misleading, since a high prevalence might not necessarily indicate a high contrast in the study.

Methodologic considerations and interpretation of findings in the reviewed epidemiological studies

The studies reviewed above are diverse in their study designs, populations, exposures, and health outcomes. Nevertheless, as a group they contribute important information bearing on the relationship of upper extremity musculoskeletal disorders and computer keyboard operation. The discussion below focuses primarily on the methodologically strongest studies, excluding those that had evidence of substantial potential selection bias or confounding by occupational or non-occupational factors.

Characterisation of ergonomic exposures

In the large majority of the studies reviewed, information on job title or task type appears to have been obtained from employer records or direct observation. In over one-third of the papers (19, 20, 32, 81, 84, 88, 93, 95, 102, 137, 142, 144, 150, 163, 166, 168-170, 187, 188), workplace visits were conducted by the investigators to obtain data on working conditions and exposure to ergonomic stressors. In several of these, the information available suggested that postural stresses were observed on only a single occasion or for a brief period (*e.g.*, ten minutes) per subject. Such limited observations might lead to misclassification if the postures utilised by operators were not constant over time; however, no data are available to indicate how likely this is to occur. Two other studies obtained keystroke or other output data from employer records (26, 78, 79) and six conducted exposure validation studies on a subsample of workers (21, 22, 30, 47, 78, 79, 95, 101).

The remaining investigations utilised questionnaires to obtain self-reports on ergonomic exposures; reliance on self-reported data does imply the possibility of either non-differential misclassification or information bias. There is a body of literature addressing the validity and reproducibility of self-reported ergonomic exposure measures and demonstrating that higher levels of exposure intensity have generally been obtained in occupations and tasks where the exposures were independently documented to be more severe (*e.g.*, (6, 47, 61, 154, 205)). For example, the study by Bernard *et al.* showed that the duration of keyboard use was described consistently by people in the same job titles. Although all subjects tended to over-report their keying time, they did so nondifferentially with regard to their case status (22). Thus, information bias in this measure is unlikely on the basis of the data presented. Similarly, Faucett and Rempel (48) analysed the agreement between individuals' self-reported time at the VDU and average time at the VDU observed for each of two job groups. They found that subjects reported longer durations than observed, although copy editors spent more time at the VDU than reporters by either measure. Self-reported duration was higher than the observed group mean for younger subjects and those with higher reported workload, but did not differ by symptom status. Among the 13 individuals observed, there was a moderate correlation between the two measures (r=0.50, p=0.08), between the values reported by Bernard *et al.* (22) and that found by Burt *et al.* (30). The papers by Nathan *et al.* (136) include one showing very good agreement between observed and self-reported exposures for the entire range of ergonomic exposures studied, including keyboard work.

Characterisation of work organisational and psychological and social exposures

In some studies, standardised questionnaires for work organisational and psychological or social factors were used, enabling a comparison of results between these studies. For example, the Job Content Instrument was used in the studies by Faucett and Rempel (47) and by Marcus and Gerr (125) to define variables such as decision latitude, job demands and social support scales. The studies by Aronsson *et al.* (10) and Bergqvist *et al.* (19, 20) also used identical questionnaires in order to derive indices for limited work task flexibility, high work pace, limited organisational influence and limited or extensive peer contacts (see (10) for a closer description). Similarly, the studies of Bernard *et al.* (21, 22) and Hales *et al.* (78, 79) both used the NIOSH job-stress instrument. With these and possibly some other exceptions, methods used to ascertain work organisational and psychological and social appear to be unique for each study, and - in several studies - not well defined or described.

The interpretation of specific items in terms of work organisational, psychological and social factors is far from self-evident, however. For example, limited rest break opportunity (as used by Bergqvist *et al.* (20)) is (here) placed among the factors describing the temporal organisation of work. Lack of such opportunity may, however, also be a result of a high work load and/or insufficient decision latitude. This example serves not only to illustrate nomenclature difficulties, but also to illustrate the problem of (indiscriminately) using a number of interdependent work organisational, psychological and social and stress variables in the same model, as it may result in insufficient ability to detect associations (see further *e.g.* (164)). In some studies, such problems were addressed by performing a factor analysis on the variables to be used, *e.g.* by Bernard *et al.* (21), by otherwise checking for collinearity (125), or by a priori restricting variables into appropriate models (20). However, in cross-sectional studies this concern cannot be eliminated, because the temporal relationships among these variables cannot usually be determined.

Characterisation of upper extremity disorders

The definition of ”musculoskeletal disorder” varied widely among these studies. One of the investigations under review reported only nerve conduction velocity measures but not symptoms (137). All of the remaining studies utilised questionnaires to obtain information on musculoskeletal pain and other symptoms; some of these also involved physical examinations of some or all study subjects, to validate or elucidate the symptom reports or to separately assess these alternative endpoints; (19, 20, 22, 26, 78, 79, 88, 105, 133, 144, 146, 166, 174). For example, one study found that neck and shoulder pain and sensory discomfort was correlated with lowered hand skin temperature, suggesting a mechanism of compression of the neurovascular plexus (88). Camerino *et al*. (32) stated that their questionnaire had been previously validated with a standardised clinical examination protocol.

Even among the studies that relied on self-reported symptoms alone, the case definition ranged from ”fatigue feelings,” with no minimum duration, frequency or severity (144), to symptoms that lasted for more than one week or occurred at least once a month within the past year and were reported as ”moderate” or worse on a five-point intensity scale (22). The former endpoint represents very short-term effects and provides potentially weaker evidence of musculoskeletal disorders. However, that particular study was one in which physical examinations of the shoulder were conducted on a subset of workers, which served both to validate the self-reported symptom findings and to indicate the presence of chronic health effects associated with those symptoms.

Again, misclassification of outcome might be a concern with respect to self-reported symptoms. Since individuals differ in their experience of and threshold for pain, questionnaire responses (especially to a single question) might differ among study subjects with similar symptom experiences. Subjective symptoms are not as standardised as physical examination findings or objective test results might be.

On the other hand, there is evidence that the available, more objective tests for work-related soft tissue disorders are not sufficiently sensitive (*i.e.*, that they give negative results for too large a proportion of affected individuals). Self-reported symptoms appear to be the most sensitive indicator, especially of disorders still in their early stages. Furthermore, the use of multiple questions to construct a score or a composite outcome variable, as was done in many of these papers, *e.g*. (22, 30, 78, 84, 116, 168-170, 190, 191), produces an outcome with improved precision and validity compared with the use of a single question to determine symptoms.

Questionnaire data have been shown in numerous studies to have great utility in identifying high-risk jobs or job features. It has been shown, for example, that self-reported symptoms are predictive of seeking medical services for musculoskeletal disorders (203). In addition, cases defined by symptoms alone and those defined by findings on physical examination showed extremely similar associations with the force and repetition characteristics of subjects’ jobs; symptom-based case definitions generally appear to be both unbiased and more sensitive (*e.g*., (176, 177, 203). Lastly, there is a strong correlation between the frequency of symptoms among a group of occupations and the frequency of workers' compensation claims and recorded work-related repetitive trauma disorders in those same occupations (55). In studies where similar methods were used (22, 78), similar proportions (about 50%) of symptomatic individuals had physical examination findings, comparable to what has been observed in studies of other populations (*e.g.*, (27, 177)).

With particular reference to carpal tunnel syndrome (CTS), self-reported symptoms have been found to have reasonably high validity when compared with the diagnostic procedure of nerve conduction velocity testing, as well as with other objective tests (121, 136). In the work of Nathan and colleagues there was a strong association between the prevalence of ”probable CTS” (based entirely on self-reported symptoms) and the severity of slowed median nerve NCV for both 1984 and 1989 data, 135). Similarly, the study by Bernard *et al.* (21, 22) utilised nerve conduction velocity (NCV) testing, primarily to validate the symptom-based case definition. The results showed that a subject meeting the case definition was 43 times more likely to have abnormal median nerve latency than a subject who was not considered a case. The odds ratios for both symptomatic cases and abnormal NCVs were strongly associated with the amount of time spent typing at the keyboard.

In some studies the case definitions may include symptoms that are difficult to interpret as a single disease entity from the point of view of clinical medicine. However, the opinion has been advanced that clinical medicine does not yet provide the necessary diagnostic techniques for these conditions, especially in their early stages, or offer the appropriate taxonomy (*e.g.*, (121)). Epidemiology can make a contribution here to the development of an appropriate case definition. In addition, the symptom complexes shown to be statistically associated with physical examination findings may prove to be markers for early stages in pathogenesis. These have value precisely because they offer a greater possibility of identifying affected individuals before clinical disease has developed and when secondary prevention will likely be more effective.

Various questionnaire designs have been evaluated with respect to their validity, reproducibility, and sensitivity to change; standardised questionnaire items have been proposed (*e.g.* (109, 110) and the international comparability of case definitions is increasing. For example, the validated Nordic Musculoskeletal Questionnaire (NMQ) was used is several studies reviewed here (*e.g.* (10, 16, 19, 20, 89, 94, 102, 117). Most epidemiologic studies published now provide a clear and explicit definition of the criteria by which ”cases” were identified and a clarification of whether or not this definition should be considered a clinical ”diagnosis.” Furthermore, the use of questionnaire items to determine case status is not unique to the study of musculoskeletal disorders; a standardised questionnaire for the assessment of chronic pulmonary obstructive disease, developed initially by the British Medical Council, has been widely used by epidemiologists for a number of years.

Temporal sequence of cause and effect

A few studies were designed around changes of exposure and/or disease status; two of those examined cross-shift and cross-week changes (94, 144), and one included a nested case-control study with five-month follow-up of both cases and referents (22). Two fixed cohort studies obtained seven years of follow-up on a population of office workers (18, 15) and five years of follow-up on a mixed industrial population (135), respectively, while a third (16) included a one year follow-up in order to differentiate between immediate effects of computerisation of work tasks and effects remaining after (later) adjustments. (Unfortunately, this last study suffered from a large non-response, effectively precluding conclusions.)

With these few exceptions, the studies reviewed here are cross-sectional, thus evaluating health problems and work situation at the same point in time. As pointed out by several of the authors (*e.g.* (47, 79, 125)), this limits the causal interpretation that can be given the results. Work conditions may have been changed by the worker attempting to reduce his/her exposures subsequent to the development of a disorder (see *e.g.* by Bergqvist *et al.* (20)). It is arguable that such remedies could tend to “hide” an association existing at the point in time when a disorder appeared. However, it is unlikely that workers who had already developed musculoskeletal pain would preferentially transfer into jobs with higher physical exposures such as repetitive motions or awkward postures. On the contrary, as discussed earlier, it has been demonstrated in several populations that workers who develop musculoskeletal disorders seek to transfer into jobs that have fewer physical ergonomic stressors (125, 145, 152, 179), which would again lead to an underestimation of the difference in disease rates. These problems can be addressed, at least in part, if cases are restricted to those with onset reported after first employment in the occupation under study. Of the studies described, four (22, 30, 78, 84) utilised a case definition restricted to onset of symptoms after first employment in the study job.

A second caution is warranted due to the possibility that the existence of a disorder could influence the perception or reporting of work environment features, possibly leading to inflated associations. Most work organisational, psychological and social factors are - in principle - subject to such problems, since they are essentially always derived from the individual´s perception in *e.g.* a questionnaire. However, it should be noted that in some studies, also ergonomic factors were ascertained in this manner. Both problems are in principle avoided in a prospective study of incident cases, where assessment of adverse conditions is done prior to (some) individuals developing muscle problem.

Potential confounding

The statistical data analysis was inadequate in several of the studies reviewed here. About one-half utilised modern, multivariate techniques (stratified or regression analyses) to control for potential confounding variables and to explore the interaction or effect modification of several ergonomic factors simultaneously.

Several investigators also collected data on and examined (in the statistical analyses) various non-occupational factors, such as obesity, educational level, socio-economic status, history of acute injury, outside hobbies and activities

Nevertheless, not all of the remaining studies were likely affected by uncontrolled confounding. The majority of the investigators controlled potential confounding by age and gender, at least, either by restriction in study design or in the analysis. The studies that did not at least restrict or examine gender (16, 26, 41, 46, 70, 102, 105, 137, 138, 165, 189, 188, 191, 197) are weaker and more difficult to interpret with respect to aetiology, as a result. Some studies, where subjects were mostly females, or consisted of females to 85% or more, or where certain comparisons were shown to be unaffected by gender confounding were - in our judgement - acceptable from this point of view (47, 83, 88, 116, 163, 168-170, 182). (See also the discussion on page 99-100.)

Potential selection bias

In a number of studies (71, 83, 105, 116, 137, 138, 142, 141, 144, 165, 197), the authors failed to give any information about how subjects were recruited and what the participation rate was among the workers eligible for inclusion in the study. Evans (45), as noted above, distributed a survey through an occupational health and safety magazine; the study base was undefined and participation level was impossible to determine. Five studies (46, 70, 81, 183, 180, 182) had participation rates below 65%; in the study by Karlqvist (101) it was borderline at 67%, and the authors failed to demonstrate that the participants were not a biased sample of the entire population (*i.e.*, that they were similar to non-participants in their exposure and disease status). Faucett and Rempel (47) reported only 56% participation, but compared participants and non-participants and found that they were similar in age and job title. In contrast, Starr (189) obtained only 76% participation from VDU users versus 95% from hard copy workers, suggesting a response bias in the study population.

Two studies first recruited employers from designated industries to participate and then sought volunteers from the participating firms (81, 163). The number of employers that participated was limited, especially in the first investigation. Possible consequences of this limited employer participation are that subjects may not be representative of the entire industry in their working conditions or there may not be sufficient variability in exposures for a stable measure of effect. However, potential selection bias was not a concern for the second of these two studies, in which the participation of individual employees was 94% to 99% in each site.

A major concern regarding cross-sectional investigations is related to the fact that only active workers are identified for study. This is likely to result in an underestimate of the effect of exposure, due to self-selection of affected workers out of employment (the ”healthy worker effect”). With exception of the cross-sectional part of the Swedish cohort study (19, 20), none of the investigators attempted to contact workers who had left employment prior to the study, although one (22) attempted to reach employees who were absent for medical reasons. Because of this potential selection effect, there is a possibility that the true effects of exposure are greater than that shown by the data in all of these studies. Indirect evidence of this effect is found in the studies by Bergqvist *et al.* (18), as noted above; by Nathan *et al.* (135), where fewer "novice" workers at baseline returned at follow-up, and those who did had markedly reduced frequencies of symptoms and slowed NCVs; and by Starr (187), where age was slightly higher among VDU operators and was also weakly associated with fewer symptoms. This selection effect could also contribute to an explanation of the failure to find associations with duration of employment in several of the studies that examined that variable (see page 44-48).

Intervention studies

Nine intervention studies were identified that evaluated the effectiveness of one or more ergonomic or work organisational control measures in keyboard operation (Table 19), two of these also provided analyses of single surveys that were summarised above as cross-sectional findings. One additional study described a clinical (treatment) intervention. As in the etiologic studies, various dimensions of exposure were identified for the interventions that were undertaken. All of these involved before/after comparisons, but only four studies also included a comparison (non-intervention) group.

Four of the studies (93, 108, 132, 175) described ergonomic intervention programs that incorporated a combination of administrative and engineering measures designed to reduce the frequency of upper extremity disorders. Ong *et al*. reported on 36 young, female data entry VDU operators whose work environment, schedule and workstations underwent multiple modifications (141). After the interventions were implemented, the prevalence of symptoms of the neck, arms, and hands decreased markedly to about one-third of the previous levels. However, the right arm and hand (which used the numeric keypad) were still more likely to be symptomatic than left side.

Kukkonen and colleagues (108) described a comparable effort, in which workstation improvements, training, and relaxation exercises were provided to 60 female data entry operators. Compared with two reference groups of women office workers, the intervention group had more upper extremity disorders at baseline. However, 6 months after the program was implemented, they had fewer symptoms and physical examination findings than the reference data entry group. The authors emphasised that it was not sufficient to install better workstations without training the operators in why and how to adjust their equipment.

Oxenburgh *et al*. described a similar effort that was much larger in scope, with a before/after evaluation of an ergonomics program that covered approximately 500 VDU operators of one employer (147). The frequency of new cases decreased slightly, from 17 to 14 per 100 person-years among clerical staff. More importantly, the new cases were most likely to occur among other workers, who had not been included in the full scope of the program (*e.g.*, training sessions).

In two departments of a state workers' compensation agency, a series of interventions included introduction of new chairs and work patterns, and then a move to a new building with new work-stations and VDUs (174). The prevalences of symptoms and PE findings among billing clerks at the end of the follow-up period were lower for at least one endpoint at each region of the upper extremity, including abnormal NCVs of the median nerve.

Aaras (1) reported on a more limited intervention for workers in two different types of VDU tasks, in which numerous adjustments were made to improve workstation layout and accommodate the workers' anthropometry. Shoulder muscle activity was measured before and immediately following the interventions and was found to have decreased markedly. After 12 months, musculoskeletal pain intensity was assessed and compared with the same operators' scores before the intervention. The primary benefit was found to be in lessened shoulder pain in all three groups.

In two studies of experimental design involving data entry operators, the introduction of easily adjustable work stations and chairs, with training in the use of the adjustable features, led to a reduction in work-related musculoskeletal discomfort at all upper extremity regions (175). In particular, the adjustable workstation alone decreased the frequency of neck symptoms, and the adjustable chair alone reduced the frequency of shoulder symptoms. The two components in combination led to improvements at the neck (incidence and severity), shoulder (incidence and severity), upper arm (incidence) and wrist/hand (incidence).

Kamwendo *et al*. divided a group of medical secretaries that had been previously studied (see above) into a ”neck school” group with additional individual attention to encourage implementation of the measures taught, and a control group (93). The subjects enrolled in the neck school had reduced pain and fatigue at follow-up, with a more marked improvement observed in the group receiving individual attention and who implemented more workplace changes. Thus training alone did not convey a large benefit, but it had an indirect effect by motivating employees to modify work station layout and take other measures to improve their working conditions.

Brisson and colleagues (28, 132) undertook a large evaluation of a training program for university employees using a VDU at least 5 hours per week. They were randomly assigned (by work unit) to a group to be trained in the first year of the program and a group that would be trained in the second year, which could thus serve as a reference group during that first year. The training was highly participative in nature and involved the supervisors in order to enhance their support of participants' later actions. It was found to have a positive effect on the number of workstation improvements carried out by all of the participants (132). In addition, the prevalence of disorders decreased significantly, and more than among the referents, but only among the trainees younger than 40 years of age (28).

Fernström, Åborg and co-workers (52, 210) examined 150 data entry workers before and after an extensive reorganisation of their workplace, including transfer to other groups. However, subjects still had data entry as the main task. While some reported improvements as to job contents, others did not. Reported lack of influence decreased in the whole group (from 57% to 44%). No significant changes were noted as to neck/shoulder discomfort prevalences, nor as to EMG MVC readings during the working days. The authors concluded that reorganisation of the work probably did not change the actual job situations sufficiently, *i.e.*, ”..did not focus enough on providing employees with variation in work load.”.

Table 19. Workplace intervention studies of ergonomic measures in operation of visual display terminals or other keyboards*

Study author, date	Population and intervention(s) or basis of comparison	Follow-up interval; Outcome variable(s)	Findings	Comments
Aarås, 1994 (1)	3 groups of VDU workers: a) female data entry (n=25) b) female data dialogue (n=27) c) male data dialogue (n=29) Ergonomic adjustment of tables, chairs, distance to screen, space for keyboard & mouse	Immediately before/after: Trapezius EMG 12- month interval: Pain intensity (0-10 on VAS)	Decreased static load on trapezius (as % MVC); increased time at rest (<1% MVC) and frequency of rest periods. Decreased intensity shoulder pain ($p<0.01$) in female data dialogue operators; similar results in other 2 groups	Before/after comparisons used subjects as own controls. Intermediate effect provides evidence as to mechanism of effect of intervention.
Brisson et al., 1997 (28) Montreuil, 1997 (132)	Before/after comparisons with reference group: 627 employees using VDUs at least 5 hours/week at large university (81% participation). Study group (n=284) trained, control grp (n=343) not trained.	6 months: Workstation dimensions (by observation); symptoms, PE (only on workers with sx).	Workstation improvements (fewer "postural constraints") more frequent in study group after training. Fewer sx, PE findings only among workers < 40 yrs; bigger effect in study group than control group.	Examined multiple potential confounders and effect modifiers.. Symptoms assessed by 2 widely used, standardized questionnaires; proportion of workers with sx with PE findings was similar to that found in other studies.
Fernström, 1997 (52), Åborg et al., 1995 (209)	150 VDU data entry workers (questionnaires only); 22 female subjects also participated in all other data collection procedures (17 followed up). Intervention = work reorganization, designed to increase work variety and decrease repetitiveness and prolonged static loading.	18 months: Questionnaire, interview, physical examination, video taping, continuous readings of trapezius EMG and upper arm elevation for one day.	Intervention had little effect on work load or job content. Most subjects still primarily did data entry work. No major changes in average shoulder EMG levels, duration of upper arm elevation, frequency of repetitive movements or constrained work postures. No change in neck/shoulder sx.	Small study (except for questionnaire). No physical examination data reported. Study demonstrates that changing job title does not necessarily accomplish goal of changing ergonomic exposure levels.

(for notes, see end of the table)

Table 19. (continued)

Study author, date	Population and intervention(s) or basis of comparison	Follow-up interval; Outcome variable(s)	Findings	Comments
Kamwendo, 1991c (93)	79 medical secretaries, randomly assigned to A) 4-hour "neck school" (n=25); B) neck school plus interviews, workplace visits and exercise instructions (n=28); C) control group (n=26)	Pre-intervention, 4 weeks and 6 months post-intervention: Several ratings per day of neck and shoulder muscle pain and fatigue; active range of motion for neck. Sick leave occurrences and days lost.	At 4 weeks and at 6 months, groups A and B had somewhat less pain and fatigue than group C, especially later in the day and especially in group B. No differences in neck range of motion or sick leave.	Controlled for prior expectancy and daily workload (which subjects could not influence). Subjects at baseline had high prior knowledge, good range of motion at neck and shoulder, few sick days.
Kukkonen et al., 1983 (108)	Study group: 60 female data entry operators (DEOs) at a bank. Ergo improvements to workstations; education; "physical activation" (relaxation exercise). Two reference grps: 44 female DEOs at another bank; 57 women with varied office tasks	Data collected at baseline for all subjects, and at 6 months after intervention for 2 groups of DEOs only: MS symptoms on questionnaire and signs on clinical PE	DEOs had more sx, signs at baseline than workers with varied tasks. Greater decrease in sx and signs among study group than first reference group	Before/after comparisons used subjects as own controls. "Essential to train the workers" in order for them to take advantage of ergonomically adjustable features.
Lie, 1994b (114)	14 of 17 skilled text editors in telecommunications, with "long-standing and severe" oculomotor sx, selected for optometric correction (specialized eyeglasses for VDU work) and followed clinically.	6-month interval: Oculomotor symptoms; visual acuity, zone of clear single vision and near points of convergence.	Significant improvements in 14 of 16 individual sx, number of oculomotor sx per subject and sx severity score. 13 of 14 subjects improved steadily over entire 6-month treatment period.	No comparison group.

(for notes, see end of the table)

Table 19. (continued)

Study author, date	Population and intervention(s) or basis of comparison	Follow-up interval; Outcome variable(s)	Findings	Comments
Ong, 1984 (141)	36 female data entry VDU operators (airline company), all under 40 years of age. Ergonomic workstation adjustments; longer lunch break; improvements in noise, illumination, thermal environment, etc.	18-month interval: Frequency of MS symptoms in upper extremities	Prevalences of symptoms in neck, arms, and hands decreased by about 67%, although right arm and hand (using numeric keypad) still more symptomatic than left side	Baseline characteristics of data entry operators compared with conversational VDU users and office workers not using VDUs.
Oxenburgh et al., 1985 (147)	Approximately 500 VDU operators (one employer). Ergonomics program included health screening, training, work station design, improved work organization, etc.	Cases occurring 1.5 years before vs 1 year after implementation of program: Frequency and severity of repetition strain injury, reported to employer and diagnosed by standardized criteria	Annualized incidence rate decreased from 0.17 to 0.14 among clerical staff; more new cases among other workers, who were not offered training. New cases younger, less severe when reported than before intervention. Fewer absences and alternative duty assignments required.	No data on age or gender distributions of population from which cases arose (in either time period)
SHARP, 1993 (174)	Billing clerks in state workers' compensation agency: 36 in baseline survey (Nov. 1990), 39 in first survey (Feb 1992), 34 in second (Feb 1993) (9 employees in all three). Interventions: new chairs Aug. 1991; new work patterns Nov. 1991; new building, workstations and VDUs Nov. 1992.	Surveys at baseline, 6 months after first intervention, and 3 months after last intervention: MS symptoms and PE findings of neck, shoulder, elbow, hand/wrist in past year; median nerve conduction velocity (NCV)	1991 interventions reduced prolonged sitting and reduced intensive keying in favor of low-paced keying. Prevalences lower in 1993 for neck (sx, PE), shoulder (sx), elbow (sx), hand/wrist (PE), CTS (sx), and abnormal NCV.	No comparison group.

(for notes, see end of the table)

Table 19. (continued)

Study author, date	Population and intervention(s) or basis of comparison	Follow-up interval; Outcome variable(s)	Findings	Comments
Shute et al., 1984 (175)	66 full-time data entry operators (machine-paced VDU work with electronic monitoring): 34 in "table study:" easily adjustable workstations vs non-adjustable, with conventional ("T") and then advanced chair ("T/C"); 32 in "chair study:" easily adjustable vs non-adjustable chairs, with conventional workstation ("C")	8 weeks for "table study" (T, T/C) and 5 weeks for chair study (C): Daily MS discomfort of multiple upper extremity locations (frequency, onset, duration, intensity)	Statistically significant decreases were observed in symptoms: Neck: incidence (T); incidence and severity (T/C) Shoulder: incidence (C); incidence and severity (T/C) Upper arm: incidence (T/C) Wrist/hand: incidence (T/C)	Before/after comparisons; subjects served as own controls in each group

* Abbreviations: CTS=carpal tunnel syndrome; EMG=electromyography; MS=musculoskeletal; NCV=nerve conduction velocity; PE=physical examination; sx=symptoms; VAS=visual analog scale

Another Swedish intervention study was performed in 1991-1992 by Westlander and co-workers (204). This study attempted to carry out interventions in two workplaces, based on a participatory approach, directed both towards physical, organisational and social factors. Unfortunately, changing circumstances of both internal (reorganisation) and external (crisis in the Swedish economy) character resulted in failures to implement the proposed changes in either workplace. Accordingly, no analysis of changes was presented, and the study is therefore not summarized in Table 19. However, the report discusses in some details what can be learned from the dynamics of internal organisational features and external pressures on firms, and the barriers that these can represent to such a research project.

Lie and Watten (114) performed optometric examinations and provided optimal optical corrections for 14 VDU users who reported subjective symptoms (both visual and musculoskeletal) before the intervention. After 6 months, the study group experienced significant reductions in the number and intensity of symptoms, including neck and arm/hand pain (but not shoulder pain). The authors caution against drawing too strong conclusions from the study, since no control (non-intervention) group was used. On the other hand, they quote experimental evidence showing reduced EMG levels in the neck and shoulder after similar optical corrections (113).

Thus, eight studies all suggested that decreases in MSDs could be achieved (over varying periods of time) by ergonomic intervention programmes. These programmes did, in some cases, also include training sessions, which appear to have an effect at least through facilitating operators to adjust their workstations and work routines in the ways that are available to them. Parenthetically, it should also be noted that several studies cited previously (70, 146, 150) found evidence that providing adjustable furniture for VDU operators is not a sufficient measure to ensure good workstation ergonomics. All three authors stated emphatically that training must also be provided to operators as to why and how to adjust the equipment. The optical correction intervention by Lie and Watten (114) is suggestive, but any definite conclusion must await further studies. The work organisation intervention study by Fernström, Åborg *et al.* (52, 210) is rather non-informative, since few actual changes in work content resulted from the intervention.

Summary and conclusions

The reviewed studies were evaluated on the basis of the information presented in the papers plus, in some cases, additional information that was obtained by personal communication with the authors. The methodologically strongest studies were considered to be those that had no evidence of likely major selection or information bias and adequate control of potential confounding by gender, at a minimum, either by subject restriction or statistical adjustment. Objective data collected by physical examination of subjects and direct observation of the workplace were both considered desirable but not necessary, in part because of the evidence that each of these correlated fairly well with the corresponding self-reported data (see above). While control of age and other covariates is also highly desirable, this was not included as a rigid requirement because so few occupational studies of musculoskeletal disorders, especially cross-sectional investigations, have found age to be a confounder or even to be associated with disease frequency. Similarly, non-occupational risk factors for musculoskeletal disorders have rarely been found to be confounders of ergonomic exposures in exposed populations, and in large populations are (especially) unlikely to be associated with such exposures.

By the criteria stated above, the stronger studies were those by Aronsson *et al.* (10), Bernard *et al.* (21, 22), Burt *et al.* (30), Camerino *et al.* (32), Faucett and Rempel (47), Ferreira and co-workers (54), Hales *et al.* (78, 79), Hoekstra *et al.* (84), Hünting *et al.* (88, some comparisons only), Jeyaratnam *et al.* (89), Kamwendo and co-workers (94, 95, 117), Levoska and Keinänen-Kiukaanniemi (111), Marcus and Gerr (125), Murata *et al.* (133), Oxenburgh *et al.* (146), Pickett and Lees (150), Rossignol *et al.* (163), Ryan and Bampton (166), Sauter and co-workers (168, 169), Sauter *et al.* (170), Stellman *et al.* (190), as well as the Swedish cohort study by Knave, Bergqvist and co-workers (15, 18, 19, 20, 104) and the SHARP report (174). These studies, which we judged could be relied upon to draw conclusions, are the only ones discussed in the remainder of this section. In Appendix III part A, these studies are listed together with the pertinent details on the basis of which these judgements were made. Studies not so selected are listed with corresponding details in Appendix III part B.

VDU use per se

Of these twenty-four strongest studies, 10 studies addressed VDU work or extensive VDU work in comparisons with non-VDU or only part-time VDU work, 8 of which included analysis of neck and/or shoulder disorders. All but the study by Bergqvist and co-workers (18-20) and by Hales *et al.* (78, 79) offered at least some evidence that VDU work increased the risk of neck or shoulder disorders (Tables 1 and 2). The six positive papers (32, 94, 104, 125, 163, 190) showed an effect on neck/shoulder disorders, with most odds ratios or other point estimates in the range from 1.7 to 3.

The reasons for the markedly different findings with respect to neck/shoulder disorders in especially the Bergqvist papers, are not understood, although possible explanations discussed above include a low exposure contrast (because of good ergonomic conditions in VDU jobs or possible errors in categorising the varied clerical activities for purposes of analysis), possibly greater importance of other risk factors (*e.g.*, work organisation and psychological stressors) for these versus more distal disorders, and an healthy worker selection effect. Hales *et al.* (78) specifically called attention to the likelihood that workers with shoulder symptoms, for example, would be less likely to volunteer or be selected for overtime work, thus generating an apparent negative association in some cross-sectional studies. On the other hand, when Bergqvist *et al.* (18) did examine the dropout for such a possibility, they did find some indications of this for arm/hand problems, but not for neck/shoulder ones.

In another formulation of the same question, eleven of the stronger studies examined a possible exposure-response relationship between neck/shoulder disorders and hours per day of VDU work. Eight of them (30, 47, 89, 95, 104, 163, 168-169, 174) found evidence of a positive and statistically significant trend (Table 3). Furthermore, six of the eight stronger studies that evaluated the effect of years of employment (21, 22, 30, 32, 94, 125, 174) found positive associations with neck or shoulder disorders or both (Table 4).

For wrist/hand disorders, the methodologically stronger studies were, if anything, even more consistent regarding the effect of VDU work per se. All eight studies (18-22, 104, 125, 133, 146, 163, 190) were indicative of an effect in at least some comparisons, and many point estimates were in the range from a 2 to 4-fold increase in risk (Tables 1 and 2). More than half of those that examined three or more levels of daily use (18, 21-22, 30, 47, 146, 163, 174) provided evidence that the risk of arm, elbow, or hand/wrist disorders increased steadily with each hour per day of VDU use (Table 3). The effect of length of employment was less indicative though; only five of these studies examined this variable for hand/wrist disorders, and only Marcus (125) found a positive trend (Table 4). Nevertheless, these findings are impressive, taken together, especially in light of evidence from the Bergqvist (18) and Marcus (125) analyses that the healthy worker effect is a probable source of downward bias for risk estimates of hand and wrist disorders from cross-sectional studies.

In addition, VDU operators in five US studies (newspaper and telephone service workers) were shown to have rates of hand/wrist disorders ranging from two to nine times higher than would have been expected if they had had done industrial work with low ergonomic exposures (21, 22, 30, 78, 79, 84, 174). These increases in risk were at least comparable to, and in some cases much higher than, the rates that would have been expected in jobs with exposure to highly repetitive manual tasks in an industrial setting (Table 5).

Thus, the evidence for the effect of VDU keyboard use overall, regardless of other task or environment characteristics, was especially pronounced for disorders of the upper extremities (hand, arms and shoulders). For neck, the results were more varied across the studies - but still provided substantial evidence of increased occurrence in relation to VDU use.

This excess occurrence of musculoskeletal problems could either be due to an intrinsic feature of VDU work in general, such as looking at the screen or keeping the upper extremities positioned over the keyboard and other work pieces, or alternatively to the presence of specific risk factors that are typical to VDU work even if not necessarily unique to those jobs, such as the performing of repetitive hand motions. In fact, these two explanations are not at all mutually exclusive. However, we believe that it is useful to attempt to deconstruct 'VDU work,' to the extent that it is possible to do so, and to understand the various characteristics of these jobs that may be injurious, whether they operate independently or in combination with each other.

Some have speculated that the comparison of VDU versus non-VDU office work is confounded by physical ergonomic stressors, and in particular that studies from the early years of widespread VDU use, when the workstation and screen characteristics were in some cases very bad, might have produced stronger associations between upper body disorders and VDU work than might be seen today. However, in the positive studies, which covered a range in calendar time from 1985 to 1996 and were conducted in a number of different countries, there is no trend at all toward higher odds ratios or prevalence rations in the studies conducted in the mid-1980’s compared with those from the mid-1990’s. Nevertheless, because of the different exposures in the VDU operators and the different choices of comparison groups, the increases in risk estimated for use of the VDU per se might not all be attributable to the same features of VDU work.

Therefore, the evidence from the various investigations are summarised below in the same categories that were used previously, separated into consideration of the work tasks, the workstation, the psychological and social circumstances, and the modifying effect of gender. Again, this separation into categories should not be taken as implying that these job features necessarily have independent etiologic consequences for musculoskeletal disorders. On the contrary, there are numerous indications that their effects are inter-related, a point to which we return again below. For example, frequent overtime in association with hand/ wrist problems (20) was shown in Table 2, in relation to the question of full-time versus part-time VDU work, but it could also have been included in Table 10 as a likely indicator of work overload. Furthermore, as Gerr *et al.* (65) have pointed out, epidemiological studies cannot always provide sufficient evidence to separate the effects of component causes that co-exist in (VDU) jobs in the way that experimental studies can define clear exposure contrasts.

Ergonomic considerations of the VDU work stations

The effect of workstation dimensions and postural angles on upper extremity disorders is a common theme in the VDU literature in general, to date. Virtually all of the studies relied upon here which examined the importance of postural stress that results from keyboard work demands found it to be an important risk factor, and most of the associations were relatively large (Table 6). For example, both upper torso and extremity problems have been associated with workstations that could not be or were not adjusted to the operator's body (84, 166, 168, 169), while keyboard location that induced adverse arm postures was associated with upper extremity disorders in other studies (19, 20, 47, 84, 170). Lack of or inadequate forearm support was also implicated in a few analyses of hand and arm disorders (19, 20, 174).

Furthermore, specific non-neutral postures, such as ulnar deviation and wrist extension, were associated with arm, wrist and hand disorders in several studies (20, 47, 88, 170). Neck/shoulder disorders were associated with elbow flexion, shoulder flexion, neck postures (especially head-neck tilt angle), head rotation and gaze angle (20, 47, 88, 166). One study failed, however, to detect an association between upper body discomforts and gaze or neck tilt angle (170). Static posture in keyboard work, in general, was also suggested as a factor in musculoskeletal disorders (20, 95).

Few data were found on the possible impact of different keyboard models, although several investigators tried to examine this issue. For other input devices, only a limited number of studies have hitherto appeared on mouse use, but indications of adverse effects of location and extent of mouse use were found (101).

For neck problems, the use of spectacles - especially bifocal spectacles - was identified as a risk factor in some studies (19-20, 78-79, 168-169) but not in others (see Table 7). This finding is reasonably consistent with the effects of neck posture (see above), in that the use of bifocals, especially at a screen that cannot be adjusted adequately in height, often necessitates an extended neck posture. It is conceivable that the impact of use of various types of glasses, including bifocals, could be related to limitation in movability rather than to an adverse neck position - at least in situations where bifocals are specifically designed for the VDU work situations (”terminal glasses”).

In summary, we find evidence both for the direct effect of non-neutral wrist, arm and neck postures, as well as determinants of postural strain such as poor workstation ergonomics and the use of bifocal glasses to be involved in musculoskeletal problems among VDU or keyboard users.

Type and organisation of VDU work

The characterisation of the work into broad categories such as data entry and data acquisition, have produced fairly strong indications of higher occurrence of muscle problems among data entry workers (10, 19, 30, 88), than among data acquisition or interactive workers or among non-VDU office workers. These indications were not consistently found in all studies, however (79). It should be noted that this broad categorisation may sometimes be insufficient to separate situations prone to cause muscle problems without additional data on more specific circumstances of the work (see *e.g.* (19). In addition, the choice of comparison group is crucial to accurate interpretation of the results (88).

For example, some studies reviewed here obtained information from VDU operators regarding their work load, work pace, frequency of overtime, pressure at work, and similar indicators of work demands (Table 10). In fact, of the methodologically strong studies that collected such data, almost all found these factors to have statistically significant associations with upper extremity problems (10, 21-22, 30, 78-79, 84, 94, 166). A variety of phrases have been used; some suggest the more biomechanical aspects of workload, such as typing speed, and others suggest the cognitive or affective aspects, such as "job pressure" or "too much to do." In any case, as stated previously, the physical and psychological aspects of pressure at work are often indistinguishable from the operator's point of view. Thus, these different findings can be understood as representing a consistent pattern of association that may involve multiple mechanisms.

On a related question, a small number of the stronger studies provided data on the specific effects of monotonous or repetitive VDU work (Table 11). All of them found factors such as limited task flexibility and variation in work activities to be associated with upper extremity problems (10, 15, 19-20, 21- 22, 78-79).

Inconsistent results have appeared for rest break patterns (19-20, 21, 54, 79, 166), precluding any definite statement. For skill utilisation and for electronic monitoring, these reviewed studies did not reveal much information.

In summary, both the general category of ‘data entry work’ and more precise descriptions of work such as high work load, limited variation in tasks and a high typing speed appear to be major contributors to causing increased occurrence of musculoskeletal disorders among VDU workers. Again, it should be kept in mind that these factors may be both direct causes, *e.g.*, through more finger motions performed, and effect modifiers, *e.g.*, through more prolonged exposure to postural stress without rest breaks.

Psychological and social factors in VDU work

A low degree of social support from peers or supervisors was associated with increased muscle problems in most of the reviewed studies (10, 20, 21, 32, 47, 117), although in some studies associations were not significant (111) or not retained in the final multivariate analysis (79, 125). Most studies investigated support by co-workers or peers, while in a few, support from supervisors or family was also investigated. As indicated by some investigations (10, 20, 47), the interaction between social support and other (adverse) conditions appear to be complex.

Likewise, lack of workers´s control and a low decision latitude have been shown to be associated with muscle problems in most of the reviewed studies (10, 47, 78-79, 84, 94, 117), although a few studies failed to do so (20, 125). Bernard *et al.* (21) reported an association with perceived lack of participation in job decision making, but not with job control.

Mixed results have been obtained in the few studies investigating the possible impact of fear and insecurity on muscle problems (21, 47, 78-79, 125). In a few studies, perceived stress levels were found to be strongly associated with muscle problems (10, 20, 125). The interpretation of these findings beyond the general verification of importance of conditions conducive to stress (work organisation, psychological and social factors) is far from clear, however.

In conclusion, various aspects of the ways individuals perceive their work and social environment appear to be related to the occurrence of muscle problems; the indications found in these reviewed studies do suggest fairly strong associations with social support and perceived control over work. As already pointed out above, however, the fact that these findings were generated from cross-sectional studies makes it difficult to determine whether these factors are causes, mediators of other exposures, or consequences of other exposures or of the disorders themselves. There is a great need for further investigations that take both temporal relationships and interrelationships with other factors into account.

Gender as a risk factor among VDU workers

Female gender, as a summary indicator of multiple work and non-work characteristics, appears to be consistently associated with higher occurrences of several upper extremity and neck muscle discomforts among VDU users (Tables 15-17). Definite explanations of the gender differences could not be ascertained from the reviewed studies, although some results within these studies do suggest more specific factors explaining these differences, such as child care (20) or differences in work situations (10, 21). Constitutional differences between men and women remain a possibility. Different reporting tendencies did not appear to explain these differences in the one study that allowed such an evaluation (20).

In one study, it was found that the risk increase for neck and shoulder problems with data entry VDU tasks was actually higher for men than women - although women had (overall) higher occurrence of muscle problems (10). This apparent contradiction can tentatively be resolved by speculating that ergonomic stresses in work have less impact on women because they have additional causes of muscle problems, whereas for men, improved work conditions would more likely lead to less problems. Such an explanation would be consistent with findings from at least one study of industrial workers (153).

Conclusions

A large number of epidemiologic studies have been reviewed regarding the effects of ergonomic, work organisational, psychological, and social stressors in VDU work on the risk of upper extremity and neck musculoskeletal disorders. In light of the criteria discussed earlier for determining whether statistical associations represent a causal relation-ship, this literature is impressive. Biological plausibility has already been demonstrated through experimental studies showing various biomecha-nical and physiological mechanisms. (Obviously, we have not here undertaken a rigorous review of the experimental literature comparable to our in-depth consideration of the epidemiologic studies; however, we believe that in that large number of studies there is ample basis for concluding that multiple pathological mechanisms are possible.)

Among the methodologically strongest epidemiologic studies reviewed here, a common set of implicated exposures has demonstrated a consistent set of findings for the effect of VDU work in general and for several specific aspects of VDU work, including especially continuous work at the VDU for the entire work day, highly intensive or repetitive VDU work such as data entry, and poor workstation ergonomics. This group of 24 studies represents different study designs and data collection protocols, utilised in populations literally around the world. Furthermore, these investigations produced a number of relatively large increases in risk associated with VDU work and numerous exposure-response relationships. Although most of them were cross-sectional studies, this would likely act primarily to dilute associations rather than to cause them by artefact; and several investigators collected retrospective data in an attempt to verify that the disorders under study in fact preceded the exposures. Therefore, we believe that this literature as a whole clearly meets the standard criteria for accepting these studies as evidence of a causal relationship.

The excess risks observed for shoulder, arm and hand problems in these studies may be due to a combination of two sets of risk factors. The inherent features of keyboard design include the repetitive finger motions involved in keying, the forces required to activate the keys, and the wrist postures that result from the (parallel-row) keyboard layout. The second set of factors are those extrinsic to the visual display terminals themselves, *i.e.*, that result from the manner in which they are utilised (workstation dimensions, the nature and content of the tasks performed, the visual interaction with the VDU and other visual components etc.).

To some extent, work pace may be seen as a function of the job description, *i.e.*, the administrative aspects of the work environment, rather than of the keyboard itself. On the other hand, if repetitive use of a keyboard conveys an elevated risk (*e.g.*, in data entry versus interactive tasks), this also may be interpreted as evidence of the consequences of continual, as compared with intermittent, exposure, or of exclusive keyboard work rather than keyboard work combined with other activities.

Because many ergonomic risk factors are often present simultaneously in keyboard work, it is plausible that they interact with each other in producing adverse health effects. For example, the postural stresses on the wrist that result from typing on a parallel-row, QWERTY keyboard could be expected to have an exacerbated effect when combined with a rapid work pace, high key activation forces, or a workstation of the wrong height.

However, the effect of VDU work per se, whether measured in hours per week, intensity of keying, or duration of employment, does not appear to be fully explained by the risk associated with the postures in which that work is performed. In addition, even if the postural strain of the visual work performed appear to be important for at least neck problems, as exemplified by the findings of relationships between use of bifocal glasses and neck discomforts or disorders, other components such as the visual demands of the specific task type would likely also play a major role. The effect of sitting for five or more hours per day on neck and shoulder symptoms among medical secretaries was less pronounced than the effect of using office machines for the same length of time, suggesting that the nature of the work done while seated was the more important stressor.

A number of studies have also investigated various work organisational, social and psychological factors in different VDU work situations. For these factors, fairly strong support for an etiological role has appeared for work load, decision latitude and social support - even if definite conclusions can not be made based on the reviewed studies. It is noteworthy that almost no studies have attempted to investigate interactions between these factors, as suggested by the Karasek model.

In contrast, the most consistent evidence in these studies relates to the intensity of and cumulative exposure to keyboard use, as summarised above. Thus, the literature provides reasonably convincing evidence that the operation of visual display terminals and similar computer or data entry keyboards conveys an elevated risk of musculoskeletal disorders, increasing with the hours of operation per week, with the pace and intensity (data entry *vs*. interactive tasks) of keyboard usage, with the duration (in years) of operation, and with the need to utilise non-neutral postures in keyboard tasks as a consequence of workstation dimensions and layout.

The evidence shows that VDU keyboard usage is associated both with symptoms and with disorders that produce findings on physical examination and clinical testing. To our knowledge, there are no data showing the plausibility of alternative explanations for the associations between VDT use and upper extremity disorders. In the light of laboratory studies demonstrating several biologically plausible pathomechanisms, the epidemiologic evidence is most credibly interpreted as causal.

Recommendations for research

In light of the literature published to date, there is little value, at this point, in conducting additional cross-sectional studies that merely compare symptom frequencies between VDU and other workers, without explicit exposure characterisations of both populations. The widespread and increasing use of computer terminals makes it of great public health importance to deconstruct "VDU use" into its various components and to understand how they interact with each other in relation to adverse health effects. In general, there is a need for prospective studies with exposure data collected in advance of onset of musculoskeletal disorders, preferably by objective methods when possible, and with objective assessment of health outcomes, as well. However, this is not to deny that for several types of variables such as psychological and social work environment situations, questionnaires will remain the only feasible method of ascertainment. The use of standardised and validated questionnaires should always be considered, where these are available.

Among the various associations examined in this literature, some have been explored more thoroughly than others, as discussed above. The effect of VDU work per se has been studied extensively, including efforts to determine relationships between the duration of VDU work (in hours/day or week) and musculoskeletal problems, and thus to establish exposure-response relationships in terms of VDU usage. The results of such investigations, however, may not always represent the same effects, since both physical and organisational exposures often vary considerably from one group of VDU users to another and also between different comparison groups. Other definitions of exposure that have been studied by numerous authors are postural stress imposed by poor workstation ergonomics, data entry and other tasks with intensive keying demands and little variety in work content. Further investigations directed towards establishing exposure-response relationships should preferably be aimed at specific definitions of exposure, such as extent of keyboard use, extent of monotonous, routine data entry work etc.

In addition, further research is needed before firm conclusions can be drawn regarding the effects of mouse or other pointing devices, use of spectacles and other factors related to visual demands, specific rest break patterns, and psychological and social factors (high demand with low control, quality of supervision, etc.) on neck and upper extremity musculoskeletal problems. The changing nature of VDU work, which is related to the continuing introduction of new technology, also means that specific physical and organisational features of VDU work, and perhaps their health consequences, will continue to change. This requires that there be ongoing and proactive surveillance of exposures as well as musculoskeletal and other health outcomes, in order to monitor prospectively the human effects of technological developments.

In general, given the diversity of occupational and non-occupational variables associated with musculoskeletal disorders in the literature, a large number of factors must be examined in future studies. However, such studies should have (in addition to the obvious requirements of any epidemiological study to minimise sources of error and bias) sufficient statistical power, contrast in terms of the specific exposure parameters under investigation and other design features that would permit evaluations of effect modifications. The statistical treatment of these covariates must take into account their spread, correlations with each other, and sequential (intermediate) effects. In our minds, studies performed at multiple work sites should be considered more often, especially to achieve adequate contrast in and independence of the exposures of primary interest.

Whether women are at greater risk than men of developing musculoskeletal disorders (and if so, why), is more a general issue than one specific to VDU work situations. Nevertheless, given the widespread application of VDUs in many different work situations,the issue is both relevant to VDU work and one that can effectively be studied in VDU work situations.

In order to enable thorough evaluations of etiological studies, every report should include a description of the population distributions across - at least - the major variables of interest, as well as their co-variation. All negative results, including variables attempted in multivariate analyses but not retained should at least be mentioned in the results.

Further efforts should also be directed towards intervention studies and randomised control trials, evaluating both physical ergonomic and organisational factors. While it is recognised that several practical obstacles exist in performing long-term intervention studies, it is also of value to describe the nature of these obstacles.

Recommendations regarding prevention and compensability

The literature reviewed here and the conclusions reached in this document have important implications both for individual workplaces and for public policy. First, they show that occupational VDU operation puts individuals at risk of developing work-related upper extremity disorders, a fact that conveys a responsibility both to employers and to manufacturers to inform users of the risk and how to protect themselves against it. Numerous materials have been developed, in many countries and in many languages, for the training of office workers in ergonomic principles, and at least one controlled study discussed here has demonstrated a clear benefit to VDU operators of receiving specifically targeted training. Employers themselves need to become educated in order to support ongoing programs for early disease recognition and preventive interventions, and to recognise the potential consequences of the ways that they organise the performance of VDU work. It should be recognised, that work systems involving the use of VDUs will involve considerations of both the individual work station and the work organisation.

At the level of public policy, primary prevention should be paramount. Guidelines or standards appropriate to the national culture and level of economic development should be promulgated in order to protect workers and those who would advocate on their behalf. Support for changes in individual workplaces or work organisations should be developed and communicated creatively. Last, it should be recognised that, even while these programs are being implemented, VDU workers will continue to develop musculoskeletal disorders as they do presently. Appropriate secondary and tertiary prevention efforts should be put into place, if they do not already exist. Worker compensation programs should be examined with respect to any obstacles or presumptions that affect compensability of upper extremity musculoskeletal disorders in VDU workers. For example, in many compensation systems, the mechanisms for determining causality are biased in favour of acute injuries and, in effect, penalise workers who develop more chronic disorders with insidious onset. It may be appropriate to adopt pre-emptive compensation standards for VDU operators, especially those who fit into clearly high risk categories such as those mentioned above: continuous work at the VDU or keyboard for the entire work day, highly intensive or repetitive VDU work such as data entry, and work at poorly designed or adjusted workstations.

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APPENDIX I. Methodological summary of reviewed studies

All epidemiological/observational studies reviewed in this report are briefly described in terms of study design, study population, primary basis for comparison, outcome variable(s) and covariates.

For references, see the main reference list.

For intervention studies, see that section for descriptions.

APPENDIX I. Reviewed reports from epidemiological studies on upper extremity musculoskeletal disorders and ergonomic, work organisational, psychological or social stressors in occupational VDU/keyboard operation: Study design, population, and methods.

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Aronsson, 1992 (10)	Cross-sectional	2025 VDU users in government offices	Comparisons of different types of VDU users	Symptoms by NMQ in last 12 months in (primarily) neck, shoulder or back	Adjusted for gender, age, smoking and various work organisational variables	Participation 89%
Bergqvist, 1989 (16)	Fixed cohort (1 year follow-up)	67 bank clerks	Before and after computerization of work	Current symptoms by NMQ in neck, shoulder, elbow, and back	No adjustments performed	Participation 75%. Only percentages “before” and “after” reported
Bergqvist, 1992 (18)	Fixed cohort (7-year follow-up)	Baseline (1981): 535 office workers (travel agencies, newspaper, post office, insurance). Follow-up (1987): 353 workers	VDU use: yes vs. "occasional" or less; 30 vs. >30 hours per week, among users.	Current symptoms in neck/shoulder, elbow/upper arm, and hand/wrist/forearm	Adjusted for age, gender, company type, and change in job title or tasks from baseline to follow-up	Participation 91% at baseline; 66% follow-up at 6 years. Subjects representative of many job types. Analyzed effect of loss to follow-up.
Bergqvist, 1995a (19)	Cross-sectional	353 office workers (same as follow-up population in Bergqvist 1992)	VDU use: yes ("data entry" or "interactive") vs. no (< 5 hours/week); internal comparisons on work history, work postures and movements, and organizational factors.	Symptoms in past year by NMQ in neck/shoulder, elbow/wrist/hand. PE* endpoints: tension neck syndrome, either of 2 cervical syndromes, any shoulder diagnosis, and any arm/hand diagnosis.	Adjusted for age, gender, use of eyeglasses, smoking, children at home, and stress reactions	Participation 92% of available cohort at that point in time.

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Bergqvist, 1995b (20)	Cross-sectional	260 VDU users (subset of population in Bergqvist 1995a)	Internal comparisons on work station dimensions, work postures and movements, and work organization factors	Symptoms in past year by NMQ in neck/shoulder, elbow/wrist/hand. PE endpoints: tension neck syndrome, either of 2 cervical syndromes, any shoulder diagnosis, and any arm/hand diagnosis.	Adjusted for age, gender, smoking, children at home, and stress reactions	Most exposures, eg., postures & work stations, observed by investigator (blinded); a few self-reported
Bergqvist, 1995c (15)	Fixed cohort (7-year follow-up)	353 office workers (same as follow-up population in Bergqvist 1992)	Internal comparisons on changes in work conditions from 1981 to 1987	Current symptoms in neck/shoulder, elbow/upper arm, and hand/wrist/forearm	Subjects served as own controls; stratified on age, gender, company type	Participation 84% of available cohort at that point in time.
Bernard, 1993, 1994 (21-22)	Phase I Cross-sectional	973 newspaper employees; 56% used VDUs >4 hr/day	Internal comparisons on work history, practices, hours and organizational factors	Symptoms in past year in neck, shoulder, elbow/ forearm, and hand/wrist	Adjusted for gender, age, race, height, medical conditions, hours typing outside work	Participation 92%. Cases restricted to onset since employment on current job; excluded non-occupational acute injuries. Work sampling substudy: daily reported duration of keying correlated with observed duratyion (r=0.40 for cases and for non-cases).

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Bernard, 1993 (22)	Phase II Nested case-referent, with 5-month follow-up	229 employees randomly selected from Phase I cases and referents, respectively	Cases and referents compared on work history, practices, hours and organizational factors during 1-year intervals for preceding 3 years	PE findings, median nerve conduction velocity, vibrometry (in addition to data from Phase I)	Adjusted for gender, age, race, height, medical conditions, hours typing outside work	Phase I case definition validated by PE; similar effects of exposure for both case definitions. Good inter-examiner reliability.
Bozi Ferraz, 1995 (26)	Cross-sectional	165 keyboard operators and 165 office workers not using keyboards (2 firms)	Computer keyboard use: yes vs. no., length of employment, and rest breaks.	Symptoms in past 7 days and past year; physical examination findings and clinical diagnoses	No stratified or multivariate analyses	Participation 79% (similar in both groups). No information on time of onset of symptoms. Self-reported keystrokes per hour from company records; other exposure data.
Burt, 1990 (30)	Cross-sectional	834 newspaper workers (keyboard-intensive and non-keyboard jobs)	Internal comparisons on job title, work history, hours and practices (questionnaire data)	Symptoms in past year in neck, shoulder, elbow/ forearm, and hand/wrist	Adjusted for age, gender, medical conditions, job dissatisfaction, keyboard use outside work	Participation 81%. Cases restricted to onset since employment on current job; excluded acute injuries. Work sampling sub-study validated time spent typing (r=0.75)

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Camerino, 1995 (32)	Cross-sectional	106 office workers (47 VDU operators, 59 non-VDU workers) and 236 workers in other companies without occupational exposure to prolonged fixed posture, heavy lifting or vibration	VDU use compared to reference group. Index of postural fixity constructed from observations of work organization, body postures, and workstation ergonomics. Questionnaire data on exposure history, mood states, and workplace psychosocial characteristics.	Symptoms of cervical spine disorders from standardized questionnaire, previously validated with clinical examination	Restricted to female subjects. Analyses stratified on age. All groups had similar length of employment in current job and exposure in previous jobs.	Participation 86%
DeMatteo, 1993 (41)	Cross-sectional	228 data entry clerks (VDU use >6 hr/day) and 64 clerical workers (VDU use < 6 hr/day)	Data entry compared with general clerical work. Data also collected by questionnaire on keystroke rate, postures, rest breaks, etc.	UE musculoskeletal symptoms in the past 6 months (yes/no and number of symptoms (0-6); history of UE MS diagnosis	No data on or analysis of gender, age, seniority, or other covariates.	Participation 76%. Multivariate analysis used, but lack of hierarchical model obscures role of "stress" as an intervening variable (see text).
Evans, 1987 (45)	Cross-sectional	3,819 VDU users	Internal comparisons on hr/day at VDU, rest breaks, type of work, workstation ergonomics, general office conditions (all self-reported).	MS symptoms; data shown primarily for neck and shoulder symptoms.	Some analyses stratified on gender. No adjustment for age or other covariates.	Study base and participation rate cannot be defined: the survey was distributed through a magazine, apparently then distributed and collected by management personnel and union representatives in their workplaces.

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Fahrbach, 1990 (46)	Cross-sectional	205 clerical and professional office workers	VDU use: no (4 hr/ day) vs. yes (> 4 hr/day)	Current symptoms in neck, shoulders	Age, psychosocial strain similar between 2 exposure groups; no adjustment for gender	Participation 60%
Faucett, 1994 (47)	Cross-sectional	150 newspaper employees (VDU use 4 hr/week)	Internal comparisons on work hours, postures, organizational factors	Current symptoms (yes/no), and symptom severity, in past week in neck/shoulder/ upper back and hand/arm	Adjusted for gender and age (in unpub-lished data [1)])	Participation 56%; non-respondents generally similar to respondents. Postures observed on subset (n=70); other exposures self-reported.
Ferreira, 1997 (54)	Retro-spective cohort, 2.5 years follow-up	106 VDU operators in interactive tasks (customer service)	Internal comparisons on cases and non-cases for workplace events and conditions	Cases of UE MSD confirmed by 2 physi-cians, causing ≥1 work day loss	Restricted to females, adjusted for age and seniority	Participation rate implied to be 100%
Gobba, 1988 (66)	Cross-sectional	38 female VDU data-acquisition clerks	Good vs. bad workstation in ergonomic terms (over-all evaluation based on 6 of 13 items, other did not differ)	Presence of pain or dis-comforts in total body (not separated)	Restricted to female subjects, otherwise no adjustments made	Not clearly stated (could be 38 of 38).
Green, 1989 (70)	Cross-sectional	514 keyboard operators, including both computer and typewriter users. Random sample of 70 for anthropometric measurements	Internal comparisons on adjustability of workstation components and information received on how to adjust them.	UE MS symptoms on questionnaire (not well defined)	No data on gender, age, or other covariates. No stratified or multivariate analysis.	Participation 51.5% in questionnaire survey.

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Grieco, 1989 (71)	Cross-sectional	29,759 VDU operators in tele-communications (64% male)	Internal comparisons by task type, hours/day at VDU, and years of VDU work	"Frequent" neck and upper extremity pain	Analyses stratified by age and gender. Some analyses excluded subjects with prior exposure to spinal loading.	No information on study base, participation, or data collection methods
Hales, 1992, 1994 (78-79)	Cross-sectional	533 telephone service workers (VDU use 6 hr/day)	Internal comparisons on work hours, practices, postures, organizational factors	Symptoms in past year of neck, shoulder, elbow/ forearm, hand/wrist; PE findings	Adjusted for gender, age, race, medical conditions, recreational activities, use of bifocals	Participation 93%. Cases restricted to onset since employment on current job; excluded acute injuries. Keystrokes/day obtained from computer records (for one job title only).
Heyer, 1990 (81)	Cross-sectional	754 office workers in communications, airline, state agency (93% VDU use 4 hr/day)	Internal comparisons of work hours, task ("data entry" vs. "interactive"), and postures	Symptoms of neck, arm, hand (time period not specified)	Restricted to female subjects; adjusted for age, education, job satisfaction; did not examine all occupational exposures simultaneously	Participation 63%. Most exposures from observation and supervisor interview.
Hocking, 1987 (83)	Surveil-lance	Workforce of Telecom Australia (no enumeration of individuals)	Job title: telephonists, clerical workers, telegraphists.	Reports of "RSI" (not classified by severity or clinical features) from multiple data sources	Only crude analyses; raw data presented by age and gender for telephonists (only). No data on length of employment or other covariates.	Denominator not specified by job group and calendar year. Uniform reporting procedures unlikely. Individual subjects may have contributed multiple reports.

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Hoekstra, 1994 (84)	Cross-sectional	108 Social Security Administration "teleservice" representatives	Internal comparisons on work hours, chair and workstation characteristics	Symptoms in past year of neck, shoulder, elbow/ forearm, hand/wrist	Adjusted for age, gender	Participation 95%. Cases restricted to onset since employment on current job; excluded acute injuries. Workstation characteristics observed by investigators; other exposures self-reported.
Hünting, 1981 (87)	Cross-sectional	295 office workers	Job type: 1) data entry at VDU; 2) conversational VDU; 3) typing; and 4) non-keyboard office work	Symptoms in neck, shoulder, arm, hand (recall period not specified); PE findings in shoulder, arm, hand	All groups similar in age; groups #1 and #3 and groups #2 and #4 similar in gender mix.	Participation > 95%. Exposures observed by investigators.
Jeyaratnam, 1989 (89)	Cross-sectional	672 full-time VDU operators in 3 companies; >90% in conversational VDU work	Internal comparisons on hours/day at VDU, years of employment, and demographic variables	Symptoms by NMQ in neck, shoulder, elbow, and hand/wrist	Restricted to female subjects. No stratified or multivariate analyses to adjust for other covariates.	Participation 97%. Authors stated that workstations did not fit local anthropometry, but no data given.
Kamwendo, 1991a (94)	Cross-sectional	420 medical secretaries (43% VDU or typewriter use 5 hr/day)	Internal comparisons on work with office machine 5 vs. <5 hours/day; length of employment	Symptoms by NMQ in neck, shoulder in past year	Restricted to female subjects; controlled for age only in analysis of years employed; did not examine all occupational exposures simultaneously	Participation 96%.

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Kamwendo, 1991b (95)	Cross-sectional	79 medical secretaries with neck/shoulder pain in past year who worked 30 hr/week (subset of Kamwendo 1991a population)	Internal comparisons on primary work station, body postures, daily hours typing, changes from sit to stand, perceived workload	Pain and fatigue of neck, shoulder (3-4 times per day); stress symptoms	Restricted to female subjects; subjects served as own controls in some analyses	Workstations and postures observed by investigators (one 10-minute period); other exposures self-reported. High inter-observer reliability in posture ratings. Validation sub-study on 10 subjects: high correlations between observed, self-reported hours typing and sit/stand changes per day.
Karlqvist, 1996 (101)	Cross-sectional	542 CAD operators (telecommunica-tions laboratory)	Internal comparisons on duration of compu-ter mouse use and non-optimal mouse location	MS symptoms of neck and upper extremities	Adjusted for age and sex but no other covariates.	Participation 67%. Test-retest and intra-method reliability of self-reported expo-sures evaluated in separate group of 100 office workers: high for items kept in analyses.
Kemmlert, 1988 (102)	Cross-sectional	555 office workers using various office machines (large state agency)	Internal comparisons on primary machine used, workstation dimensions and postures.	Neck and shoulder symptoms from NMQ, different periods of recall up to 1 year	No stratified or multivariate analyses.	Participation 99%. Workstation dimensions and postures assessed by observation.

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Knave, 1985 (104)	Cross-sectional	563 office workers (airline, newspaper, post office, insurance)	414 VDU operators (>5 hrs/day) vs 149 referents with no VDU use (similar tasks)	Symptoms (intensity and frequency scores)	Stratified sampling by age, gender where possible; stratified analysis by gender. Examined medical history, smoking, alcohol, education, job satisfaction; did not examine all occupational exposures simultaneously.	Participation 96 %. VDU use determined by investigators; other exposures self-reported
Krapac, 1994 (105)	Cross-sectional	95 office workers (state agency)	56 VDU operators (>5 hr/day; 59% female) vs. 39 non-VDU workers (non-repetitive work, low physical load; 36% female)	Symptoms from questionnaire and MSD diagnoses from medical examinations.	No stratified or multivariate analyses.	Participation rate not stated. Work postures of all subjects recorded by still photography, but no data reported.
Levoska, 1994 (111)	Cross-sectional	232 female office workers (bank, insurance)	Internal comparisons on psychosocial risk factors	Frequency of body symptoms including UE	Age adjusted analyses, all subjects females	Participation 88%
Lim, 1994 (116)	Cross-sectional	129 office workers in various tasks (VDU use average 7 hr/day)	Internal comparisons on psychosocial and physical ergonomic risk factors	UE MSD symptom indices from 2 standardized NIOSH questionnaires	Workforce 87% female. No analysis of age or non-occupational risk factors.	Subject selection procedure and participation rate not described.

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Linton, 1989 (117)	Cross-sectional	420 secretaries at large medical center (75% VDU or typewriter use >2 hr/day)	Internal comparisons on psychosocial work environment (work content, psychological job demands, social support)	Neck and shoulder MS symptoms from NMQ	All subjects female. No adjustment for age or other covariates.	Participation 96%. Exposures self-reported.
Marcus, 1996 (125)	Cross-sectional	416 office workers in 3 companies (333 current VDU users, 34 former users, 46 never users)	Internal comparisons on hr/week and years of VDU use, and on psychosocial work environment (JCQ)	Neck/shoulder and arm/hand symptoms at least once per week or at least moderate intensity in past year	Subjects all female and 40 years old or younger. Examined demographics, medical history, caffeine alcohol and tobacco consumption.	Participation 70%; no difference in age or job title between participants and non-participants
Murata, 1996 (133)	Cross-sectional	27 VDU operators and 19 non-VDU users	VDU use; yes/no	Sensory nerve conduction velocities in right median nerve, CTS symptoms	Restricted to young females, with no history of injury etc. Lemgth of employment and skin temperature	Participation rate implied to be 100%
Nathan, 1988 (137)	Cross-sectional	159 office workers ("Classes I and II") from 471 employees in 4 industries	Employment class, by amount of resistance and repetition rate: keyboard use <4 hrs/day (Class I, low repetition) vs keyboard use >4 hrs/day (Class II, high repetition)	Median nerve conduction velocity (NCV)	NCV values standardized for age; no other factors analyzed	Subjects randomly selected, but no data on participation rate among recruited individuals. Criteria not presented for exposure classes. Not stated whether job evaluations blinded to NCV results.

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Nishiyama, 1984 (138)	Cross- sectional	437 VDU users in newspaper industry vs. 122 keyboard (non-VDU) workers	VDU use vs. other keyboard use	Stiffness or dullness in neck, shoulder, arm and fingers	No control for covariates, VDU users younger than other keyboard users	No details of selection, response rate not stated
Ong, 1981, 1984 (141-142)	Cross-sectional	103 office workers (3 different workplaces)	Data entry VDU use (36), conversational VDU use (26), no VDU use (41)	MS symptoms in neck, shoulder, arm, hand	Restricted to female subjects under 40 years old. No adjustment for other covariates.	Subject selection procedure and participation rate not described. Workplaces observed by investigators: poor ergonomic conditions at all 3 sites.
Onishi, 1982 (144)	Cross-sectional; Pre- vs post-shift and week comparisons	250 office workers	Type of office machines (6 types, all used full-time)	Localized fatigue before, during and after work, 5 days/week. Shoulder tenderness threshold measured in 41 workers.	Restricted to female subjects; groups all similar mean ages; subjects served as own controls in cross-shift and -week comparisons	Subject selection procedure and participation rate not described
Oxenburgh, 1987 (146)	Case-referent sampling from cross-sectional survey	156 office workers using keyboards (46 cases, 110 non-cases)	Internal comparisons on workstation characteristics and hours of keyboard use	"Repetition strain injury" diagnosed by in-house medical personnel	Restricted to female subjects; examined age, length of employment, job performance rating	Participation rate 100%. Some workstation characteristics observed by investigator; other exposures self-reported
Pickett, 1991 (150)	Cross-sectional	78 data entry clerks	Internal comparisons on office site, workstation characteristics, length of employment	"Chronic work-related" symptoms of neck, shoulder, arm, wrist, hand	Restricted to female subjects; adjusted only for mental stress at work	Participation 99%. Exposures observed by investigators (one occasion per operator), except mental stress self-reported

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Rossignol, 1987 (163)	Cross-sectional	1,545 clerical workers (banking, communications, computers, hospitals, utilities, state agencies)	Internal comparisons on hours per day at VDU	Symptoms of neck, shoulder, arm, wrist, hand/fingers	Adjusted for age, smoking, industry type, use of corrective lenses, VDU training, medical and injury history; 85% of subjects were female	Participation between 94 and 99% for different sites. No association of upper respiratory symptoms with VDU use (argues against information bias)
Rubino, 1989 (165)	Not stated (cross-sectional?)	22,243 VDU users (>1 hr/day) and 9,327 non-users (<1 hr/day)	Internal comparisons on hr/day at VDU and exposure scores for workstation ergonomics, lighting, visual screen, noise, and microclimate	MS symptoms of neck, upper limbs, lower limbs, and "limb hyperesthesia" combined into one factor	No adjustment for gender, age or other covariates.	No information on study base, subject selection procedure, or participation, or on any data collection methods. Exposures apparently self-reported (?).
Ryan, 1988 (166)	Cross-sectional (case-referent sampling)	143 VDU data entry operators (state agency)	Internal comparisons on physical environment, postures, workstation dimensions, work organization, psychosocial strain	Current symptoms (frequency) of shoulder/neck and lower arm, with PE findings	Examined age, gender, height, weight, marital and parental status, handedness, length of employment; did not examine all occupational exposures simultaneously	Participation 99%. Postures and workstation dimensions observed by investigators (one occasion per operator); other exposures self-reported
Sauter, 1983, 1984 (168-169)	Cross-sectional	333 office workers, average VDU use >5 hr/day (5 job groups, state agency)	Internal comparisons on physical and psychosocial work environment	MS symptoms of the "upper torso" and "limbs/extremities"	Adjusted for age and marital status and examined alcohol, tobacco and socioeconomic variables in analyses of entire study group. Only crude analyses of observed physical exposures.	Participation 90%. Objective workstation dimensions and postural data observed for about 25% of VDU users, only. Other exposures self-reported.

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Sauter, 1991 (170)	Cross-sectional	539 VDU data entry operators (2 state govt. agencies)	Internal comparisons on work history (n=539); postures, workstation dimensions (n=40)	Symptoms (grouped by factor analysis into left and right arms, trunk, and leg symptoms)	Adjusted for age, height, weight, body mass index, use of corrective lenses	Participation 91 % of full study group. 539 data entry workers then chosen for study. Exposures observed by investigators (one occasion per operator) only for 40 subjects
SHARP, 1993 (174)	Cross-sectional (last survey in follow-up study)	34 billing clerks (state workers' compensation agency) in 1993, after completion of multiple interventions	Internal comparisons on work history, hours, workstation characteristics	Symptoms in past year and PE findings of neck, shoulder, elbow/ forearm, hand/wrist; median nerve conduction velocity (NCV)	Adjusted for age, gender, obesity, use of corrective lenses, smoking, hobbies, job satisfaction, general health status	Participation 83%. Excluded subjects with acute injuries or systemic diseases. Work activities and postures observed by investigators (1 entire work day for 20 subjects in 1993).
Smith, 1981 (183)	Cross-sectional	412 clerical & professional office workers (newspaper, insurance)	254 VDU operators vs. 158 non-VDU users	Symptoms in past year	Examined age, gender, ethnicity, education, marital status, length of employment	Participation 50% in VDU users and 38% in non-VDU users; subject selection procedure unclear. Subjects may have been aware of study hypothesis.
Smith, 1984 (180)	Cross-sectional	283 newspaper workers (union members); 71% VDU users	Internal comparisons on VDU use, workstation ergonomics, screen characteristics, work organization and psychosocial variables.	Pain and stiffness "during usual work activities" in arms, hands, and legs combined into one factor.	Examined age, gender, education, lighting, and psychosocial variables in analysis of ergonomic factors.	Participation 48% of target population. Participants had similar age and length of employment to non-participants but had more education and VDU use.

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Smith, 1992 (182)	Cross-sectional	762 telecommunication workers	Presence of electronic monitoring	Pain and other symptoms in different body locations, including UE	Population mostly female. No other adjustments for age or gender performed. Crude percentages reported	Participation 26%
Starr, 1982 (189)	Cross-sectional	250 directory assistance operators	145 full-time VDU operators vs. 105 non-VDU workers	Symptoms on work days in past month	Analyses unadjusted. Age-matched subset, but no matched analysis.	Participation lower among VDU users (76%) than paper users (95%). Workers blinded to specific hypothesis. Questionnaires collected by managers.
Starr, 1985 (188)	Cross-sectional	100 full-time VDU operators (substudy of Starr 1982 population)	Internal comparisons on postures	Symptoms on work days in past month	Same as above	Posture measures observed by investigators (one occasion per operator)
Starr, 1984 (187)	Cross-sectional	359 telephone company service representatives	211 VDU operators vs 148 non-VDU workers; internal comparisons on task and workstation characteristics, job satisfaction, job security	Symptoms on work days in past month	Gender examined. Age-matched subset (only) but no matched analysis.	Participation 90%. VDU use, task and workstation characteristics determined by management; job satisfaction and security self-reported. Workers blinded to specific hypothesis. Questionnaires collected by managers.

(for notes, see end of the table)

APPENDIX I (continued)

Study, author, year	Study design	Study population	Primary basis of comparison	Outcome variable(s)	Covariates	Comments
Stellman, 1985 (191)	Cross-sectional	1,830 full-time non-managerial office workers (public agencies)	Internal comparisons (5-item score of job characteristics)	Symptoms in upper extremity and back (scored by frequency)	Analyses unadjusted	Participation 86%. Respiratory symptoms not associated with ergonomic stressors (argues against information bias).
Stellman, 1987 (190)	Cross-sectional	1,032 female clerical workers (subset of Stellman 1985 population)	5 groups (clerk, part- & all-day typist, part- & all-day VDU user)	Symptoms in upper extremity and back (scored by frequency)	Restricted to female subjects; group mean ages similar	Respiratory symptoms not associated with ergonomic stressors (argues against information bias).
Van der Heiden, 1984 (197)	Cross-sectional	69 CAD operators at 38 workstations.	Comparison of prevalences with those in Hünting et al. (87).	Symptoms in neck, shoulder, arm, hand (recall period not specified)	No information or control of covariates	Participation rate not stated.

Abbreviations: CAD=computer-assisted design; CTS=carpal tunnel syndrome; hr=hour(s); MS=musculoskeletal; MSD=musculoskeletal disorders; NCV=nerve conduction velocity; NIOSH=(US) National Institute for Occupational Safety and Health; NMQ=Nordic Musculoskeletal Questionnaire; PE=physical examination; RSI=repetition strain injury; UE=upper extremity; VDU=visual display unit

[1)] Personal communication (J. Faucett, Dec. 1994 and Nov. 1995)

APPENDIX II. Epidemiological studies not included in the review.

Study reference	Reason(s) for exclusion
Coray *et al*., 1989 (36)	Outcome was “Health Complaints Index,” combining musculoskeletal symptoms, visual problems, and head/back problems. No results were presented for upper extremity musculoskeletal disorders, specifically.
Duncan and Ferguson, 1974 (42)	Subjects were keyboard operators in telegraphy, not VDU users
English *et al*., 1995 (44)	Subjects included “secretaries,” but no information was given as to which type(s) of office machines were used, if any; it cannot be determined whether they used VDUs, typewriters, or neither.
Ferguson, 1971 (50)	Subjects were keyboard operators in telegraphy, not VDU users.
Ferguson, 1974 (51)	Subjects were keyboard operators in telegraphy, not VDU users.
Hünting *et al*. 1980 (86)	Subjects were accounting-machine keyboard operators, not VDU users.
Maeda *et al*., 1980 (122)	Subjects were accounting-machine keyboard operators, not VDU users.
Maeda *et al*., 1982 (123)	Subjects were accounting-machine keyboard operators, not VDU users.
Malchaire *et al*., 1996 (124)	About 35% of the subjects definitely or likely used computer keyboards, but data were not presented for them separately or in any way that would permit determination of the risk associated with VDU operation.
Prezant *et al*., 1987 (151)	Workers were asked to self-attribute musculoskeletal symptoms to specific ergonomic stressors, other associations were not analyzed.
Schreuer *et al*., 1995 (172)	Subjects used typewriters, not VDU keyboards.
Westlander *et al*., 1995 (204)	Musculoskeletal effects not ascertained, due to failure of intervention studies.

For references., see the main reference list. A few of these studies are briefly referred to in the text.

APPENDIX III. Methodological strength of studies

A summary of methodological strengths and weaknesses of etiological studies [1)] on upper extremity musculoskeletal disorders and ergonomic, work organisational and psychological stressors in occupational VDU/keyboard operation is presented in Tables A and B. See Appendix I for further details on each study design, population, and data collection procedures.

For references, see the main reference list.

Table A: Methodologically stronger studies: No evidence of likely major selection or information bias; adequate control of potential confounding by gender, at minimum, preferably age and other covariates. [2)]

Study, (first) author, year	Comments
Aronsson, 1992 (10)	Participation 89%. Adjusted for gender, age, smoking, several work organization characteristics.□
Bergqvist, 1992 (18), Bergqvist, 1995a (19), Bergqvist, 1995b (20), Bergqvist, 1995c (15)	Participation 91% at baseline; 66% follow-up of cohort after 6 years. Analyzed effect of loss to follow-up. VDU use determined by investigators; postures and work stations observed. Adjusted for age, gender, company type, use of eyeglasses, smoking, young children at home, change in job title or tasks from baseline to follow-up; physical and psychosocial exposures analyzed simultaneously.□
Bernard, 1993, 1994 (21-22)	Participation 92%. Cases restricted to onset since employment on current job; excluded non-occupational acute injuries. Carpal tunnel syndrome symptoms and self-reported time typing evaluated by physical examinations and observational sub-study. Adjusted for gender, age, race, height, medical conditions, hours typing outside work; physical and psychosocial exposures analyzed simultaneously.□
Burt, 1990 (30)	Participation 81%. Cases restricted to onset since employment on current job; excluded acute injuries. Self-reported time spent typing evaluated by work sampling sub-study. Adjusted for age, gender, medical conditions, job dissatisfaction, keyboard use outside work
Camerino, 1995 (32)	1995□Participation 86%. Symptoms of cervical spine disorders previously validated by clinical examination. Observations of work organization, body postures, and workstation ergonomics. Control of gender, age, length of employment in current job and exposure in previous jobs.□
Faucett, 1994 (47)	Participation 56%; non-respondents generally similar to respondents. Postures observed on subset (70 of 150 subjects). Examined gender, age; physical and psychosocial exposures analyzed simultaneously.□
Ferreira, 1997 (54)	Outcome ascertained by physical examination/diagnosis. Control of gender by restriction, adjusted for age and seniority.

(for notes, see the end of the table)

Table A (continued)

Study, (first) author, year	Comments
Hales, 1992, 1994 (78-79)	Participation 93%. Cases restricted to onset since employment on current job; excluded acute injuries. Physical examination of subjects. Keystroke rates obtained from computer records for one job group. Adjusted for gender, age, race, medical conditions, recreational activities, use of bifocals; physical and psychosocial exposures analyzed simultaneously.□
Hoekstra, 1994 (84)	Participation 95%. Cases restricted to onset since employment on current job; excluded acute injuries. Workstation characteristics observed by investigators. Adjusted for age, gender, length of employment; physical and psychosocial exposures analyzed simultaneously.□
Hünting, 1981 (87)	Participation > 95%. Physical examination of subjects. Exposures observed by investigators. Control of age. Similar gender mix in VDU data entry and typing, and in conversational VDU and non-keyboard office work (other comparisons may be confounded by gender).□
Jeyaratnam, 1989 (89)	Participation 97%. Control of gender but not age or other covariates; did not examine all occupational exposures simultaneously.
Kamwendo, 1991a (94), Linton, 1989 (117)	Participation 96%. Control of gender, and of age only in analysis of years employed; did not examine all occupational exposures simultaneously.□
Kamwendo, 1991b (95)	Participation 96%. Workstations and postures observed by investigators for 10 minutes. Self-reported hours typing and sit/stand changes per day evaluated by observation. Control of gender; some within-subject analyses controlled for other covariates.□
Knave, 1985 (104)	Participation 96%. VDU use determined by investigators. Control of gender, medical history, smoking, alcohol, education, job satisfaction; did not analyze all occupational exposures simultaneously.
Levoska, 1994 (111)	Participation 88%. Job satisfaction score by questionnaire. Control of gender (all females), and age by adjustments.
Marcus, 1996 (125)	Participation 70%; no difference in age or job title between participants and non-participants. Examined former VDU users. Control of age, gender, medical history, caffeine alcohol and tobacco consumption
Murata, 1996 (133)	Participation rate (implied to be) 100%. Outcome ascertained by physical examination/diagnosis. Control of age and gender by restriction.

(for notes, see the end of the table)

Table A (continued).

Study, (first) author, year	Comments
Oxenburgh, 1987 (146)	Participation rate 100%. "Repetition strain injury" reported to and diagnosed by in-house medical personnel. Control of gender, age, length of employment, job performance rating.□
Pickett, 1991 (150)	Participation 99%. Workstations observed by investigators. Control of gender; adjusted for mental stress at work.□
Rossignol, 1987 (163)	Participation 94-99%. Workforce 85% female. Adjusted for age, smoking, industry type, use of corrective lenses, VDU training, medical and injury history.□
Ryan, 1988 (166)	Participation 99%. Postures and workstation dimensions observed by investigators. Examined age, gender, height, weight, marital and parental status, handedness, length of employment; did not analyze all occupational exposures simultaneously□
Sauter, 1983, 1984 (168-169)	Participation 90%. Workforce almost all female. Workstation dimensions and postural data observed for about 25% of VDU users. Adjusted for age, marital status; examined alcohol, tobacco and socioeconomic variables in entire study group; only crude analyses of physical exposures. □
Sauter, 1991 (170)	Participation 91%. Workforce almost all female. Workstations and postures observed by investigators for 40 subjects. Adjusted for age, height, weight, body mass index, use of corrective lenses.□
SHARP, 1993 (174)	Participation 83%. Excluded subjects with acute injuries or systemic diseases. Work activities and postures observed by investigators for 20 of 34 subjects. Adjusted for age, gender, obesity, use of corrective lenses, smoking, hobbies, job satisfaction, general health status.□
Stellman, 1987 (190)	Participation 83%. Restricted to female subjects; group mean ages similar.□

1) Articles are listed together as a single study if they refer to the same population, differing only in the specific data analyzed or the type of statistical analysis carried out, and share the same strengths and weakness.

2) Control refers either to restriction of study subjects (eg., only women studied) or statistical adjustment.

Table B. Methodologically weaker studies: Potential selection or information bias; no control of potential confounding by gender, at minimum. [1)]

Study, (first) author, year	Comments
Bergqvist, 1989 (16)	Participation 75%. No control of gender, age, seniority, or other covariates.
Bozi Ferraz, 1995 (26)	Participation 79% (similar in both groups). No information on time of onset of symptoms. No control of gender, age, seniority, or other covariates.□
DeMatteo, 1993 (41)	Participation 76%. No control of gender, age, seniority, or other covariates.□
Evans, 1987 (45)	Study base and participation rate cannot be defined; high potential for selection bias. Some analyses stratified on gender; no adjustment for age or other covariates.□
Fahrbach, 1990 (46)	Participation 60%. Comparable age, psychosocial strain, but no control of gender.
Gobba, 1988 (66)	No information on subject selection or participation. Small study (n=38). Control of gender but not age or other covariates
Green, 1989 (70)	Participation 51.5% in questionnaire survey. No control of gender, age, or other covariates.□
Grieco, 1989 (71)	No information on study base, participation, or data collection methods. Control of age and gender but no other covariates; some analyses excluded previously exposed subjects.□
Heyer, 1990 (81)	Participation 63%. Most exposures from observation and supervisor interview. Restricted to female subjects; adjusted for age, education, job satisfaction; did not examine all occupational exposures simultaneously. □
Hocking, 1987 (83)	Denominators not well-defined. Uniform reporting procedures unlikely. Individual subjects may have contributed multiple reports. Only crude analyses. □
Karlqvist, 1996 (101)	Participation 67%. Self-reported exposures validated by observations. Adjusted for age and gender only.□
Kemmlert, 1988 (102)	Participation 99%. Workstation dimensions and postures assessed by observation. No control of gender, age, or other covariates.□
Krapac, 1994 (105)	Participation not stated. Gender associated with VDU work; no control of gender, age, or other covariates.
Lim, 1994 (116)	Subject selection procedure and participation rate not described. Workforce 87% female. No control of age or non-occupational risk factors; physical and psychosocial exposures analyzed simultaneously.
Nathan, 1988 (137)	No data on participation rate. Median nerve conduction velocity (NCV) measured; not stated whether job evaluations were blinded to NCV results. Control of age but not gender or other covariates.□

(for notes, see the end of the table)

Table B (continued)

Study, (first) author, year	Comments
Nishiyama, 1984 (138)	Subject selection procedure and participation rate not described. No control of age, gender or other covariates.
Ong, 1981, 1984 (141-142)	Subject selection procedure and participation rate not described. Workplaces observed by investigators. Control of age, gender, but no other covariates.□
Onishi, 1982 (144)	Subject selection procedure and participation rate not described. Shoulder tenderness threshold measured in 41 of 250 workers. Control of age and gender; within-subject analyses controlled for other covariates.□
Rubino, 1989 (165)	No information on study base, subject selection procedure, or participation, or on any data collection methods. No adjustment for gender, age or other covariates.
Smith, 1981 (183)	Participation 50% in VDU users and 38% in non-VDU users; subject selection procedure unclear. Subjects may have been aware of study hypothesis. Examined age, gender, ethnicity, education, marital status, length of employment.
Smith, 1984 (180)	Participation 48% of target population. Participants had similar age, length of employment to non-participants but differed in education and VDU use. Examined age, gender, education, lighting; physical and psychosocial exposures analyzed simultaneously.□
Smith, 1992 (182)	Participation 26%. No control of age, gender, or other covariates.□
Starr, 1982, 1985 (188-189)	Participation lower among VDU users (76%) than paper users (95%). Questionnaires collected by managers. Posture measures observed by investigators for 100 of 250 subjects. Analyses unadjusted. Age-matched subset, but no matched analysis.□
Starr, 1984 (187)	Participation 90%. VDU use, task and workstation characteristics collected by management; questionnaires collected by managers. Gender examined. Age-matched subset but no matched analysis.□
Stellman, 1985 (191)	Participation 86%. Analyses unadjusted for any covariates.□
Van der Heiden, 1984 (197)	Participation rate not stated. No adjustment for any covariates.

[1)] Control refers either to restriction of study subjects (eg., only women studied) or statistical adjustment.

1996

22 M Josephson. Musculoskeletal Symptoms, Physical Exertion and Psychological Job Strain among Nursing Personnel.

23 G Nordström, B Järvholm, B Högstedt, J-O Levin, J Wahlström, C Östman, C Bergendahl och B Linder. Asfaltarbete: Exponering och genotoxisk påverkan.

24 P Lundberg (Ed). Vetenskapligt underlag för hygieniska gränsvärden 17.

25 P Lundberg (Ed). Scientific Basis for Swedish Occupational Standards XVII.

26 G Hedberg, L Wikström-Frisén, U Janlert, K A Jacobsson och M Marklund. Utvärdering av ett interventionsprogram mot insjuknande i hjärt-kärlsjukdom bland yrkesförare.

27 U Tiikkainen, K Louhelainen and H Nordman. The Nordic Expert Group for Criteria Documentation of Health Risks from Chemicals. 120. Flour Dust.

28 M Luotamo and V Riihimäki. DECOS and NEG Basis for an Occupational Standard. Tetrachloroethane.

29 N F Petersson, G Björing, S E Mathiassen och J Winkel. Bedömning av muskelbelastning utifrån produktionstekniska elementartidsystem.

30 V Skaug. The Nordic Expert Group for Criteria Documentation of Health Risks from Chemicals. 121. Refractory Ceramic Fibres.

1997

1 A Kjellberg, K Holmberg, U Landström, M Tesarz och T Bech-Kristensen. Lågfrekvent buller: En prövning av sambandet mellan några tekniska utvärderingsmått och upplevd störning.

2 K Kemmlert. On the Identification and Prevention of Ergonomic Risk Factors, with Special Regard to Reported Occupational Injuries of the Musculo-skeletal System.

3 F Chen. Thermal Responses of the Hand to Convective and Contact Cold – with and without Gloves.

4 L Gonäs and A Spånt. Trends and Prospects for Women's Employment in the 1990s. Submitted to the European Commission Network of Experts on the Situation of Women in the Labour Market.

5 L Barregård, L Ehrenström, K Marcus och L-E Sandén.
I. Vibrationsskador hos bilmekaniker.
B Meding, L Barregård och K Marcus.
II. Handeksem hos bilmekaniker.

6 J-O Levin (red). Principer och metoder för provtagning och analys av ämnen på listan över hygieniska gränsvärden.

7 A Kjellberg, P Muhr och B Sköldström. Trötthet efter arbete i buller – en registerstudie och tre fältstudier.

8 L Laflamme och E Menckel. Elevskador i ett arbetsmiljöperspektiv. Vad kan vi lära av kommunbaserade skolstudier?

9 L Karlqvist. Assessment of physical work load at visual display unit workstations. Ergonomic applications and gender aspects.

10 M Döös. Den kvalificerande erfarenheten. Lärande vid störningar i automatiserad produktion.

11 H Stouten. DECOS and SCG Basis for an Occupational Standard. Isopropyl acetate.

12 R-M Högström, M Tesarz, T Lindh, F Gamberale och A Kjellberg. Buller – exponering och hälsoeffekter inom kraftindustrin.

13 G Lidén, L Kenny, D Mark och C Chalmers. Provtagningseffektivitet för den svenska metoden för mätning av totaldamm.

14 B Lindell. DECOS and NEG Basis for an Occupational Standard. Platinum.

15 A Iregren, B Sjögren, M Andersson, W Frech, M Hagman, L Johansson och A Wennberg. Exponering för aluminium i smältverk. Effekter på nervsystemet.

16 L Punnett and U Bergqvist. National Institute for Working Life – Ergonomic Expert Committee Document No 1. Visual Display Unit Work and Upper Extremity Musculoskeletal Disorders. A Review of Epidemiological Findings.

17 M Sundström. Arbetsskadeförsäkringen – bedömningen i domstol av belastningsskador hos kontorister och sjuksköterskor.

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Most articles published in Arbete och Hälsa are original scientific work, but literature surveys are sometimes published as well. The usual language is Swedish. Doctoral theses, however, are usually written in English.

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A brief foreword may be presented on page 3, explaining how and why the work was done. The foreword should also contain the acknowledgements of persons who participated in the work but who are not mentioned as authors. The foreword is signed by the project leader or the division manager. Page 4 should contain the table of contents, unless the manuscript is extremely short.

Summary

Summaries in Swedish and English are placed after the text, preceding the reference list. A summary should be no more than 100 words long. It should begin with complete reference information (see below for format). The texts should be followed by no more than 10 key words, in both Swedish and English.

References

The references are placed after the summaries. They are arranged alphabetically and numbered consecutively. They are referred to in the text by a number in parentheses. Unpublished information is not taken up in the reference list, only in the text: Petterson (unpublished, 1975).

When a work by more than two authors is referred to in the text, only the first name is given: Petterson et al. All the authors are given in the reference list. In other respects, the references should follow the Vancouver system.

Abbreviations for periodicals are those given in the Index Medicus.

For articles that are not written in English, German, French or one of the Nordic languages, the English translation of the title is usually given, with a note on the original language.

Examples:

a. Articel

1. Axelssson NO, Sundell L. Mining, lung cancer and smoking. *Scand J Work Environ Health* 1978;4:42–52.

2. Borg G. Psychophysical scaling with applications in physical work and the perception of exertion. *Scand J Work Environ Health* 1990;16, Suppl. 1: 55-58.

3. Bergkvist M, Hedberg G, Rahm M. Utvärdering av test för bedömning av styrka, rörlighet och koordination. *Arbete och Hälsa* 1992;5.

b. Chapter in book

1. Birmingham DJ. Occupational dermatoses. In: Clayton GD, Clayton FE, eds. *Patty's industrial hygiene and toxicology Vol.1*. 3rd ed. New York: John Wiley, 1978: 203–235.

c. Book

1. Griffin MJ. *Handbook of human vibration*. London: Academic, 1990.

2. Klaassen CD, Amdur MO, Doull J, eds. *Casarett and Doull's toxicology*. 3rd ed. New York: Macmillan, 1986.

d. Report

1. Landström U, Törnros J, Nilsson L, Morén B, Söderberg L. *Samband mellan vakenhetsmått och prestationsmått erhållna vid körsimulatorstudie avseende effekter av buller och temperatur*. Arbetsmiljöinstitutet, 1988 (Undersökningsrappport 1988:27).

e. Articles written in langueges other than English, French, German or one of the Nordic languages

1. Pramatarov A, Balev L. Menstrual anomalies and the influence of motor vehicle vibrations on the conductors from the city transport. *Akushersto Ginekol* 1969;8:31-37 (in Russian, English abstract).

f. Article in conference proceedings

1. Mathiassen SE, Winkel J, Parenmark G, Malmkvist AK. Effects of rest pauses and work pace on shoulder-neck fatigue in assembly work. *Work and Health Conference*. Copenhagen 22–25 February 1993: 62–63 (Abstract).

2. van Dijk F, Souman A, deVries F. Industrial noise, annoyance and blood pressure. In: Rossi G, ed. *Proceedings of the Fourth International Congress on Noise as a Public Health Problem*. Milano: Centro Ricerche e Studi Amplifon, 1983: 615-627.

Figures and tables

Figures are placed in the text and numbered in order of appearance. The figure text is below the figure. The tables are placed in the text and numbered in order of appearance. The table text is placed above the table. Tables are normally placed at the top or bottom of a page, or immediately above a subhead.