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The continuing problem of OOS in the office.

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Abstract

Much work over the last twenty years has identified factors associated with the development of occupational overuse syndrome (OOS). Although management strategies have been developed to assist workers and supervisors to control such factors, recent data indicate that the problem still persists. Further, it is acknowledged that OOS is an international problem, with many sufferers hoping for some “magic cure”. A variety of companies produce a myriad of products for users to help alleviate the risk of OOS.

This paper reviews the recent literature on OOS with a particular focus on the impact of new technology for addressing this problem in the office environment.

Keywords

Office ergonomics, occupational overuse syndrome, prevention

Introduction

Occupational overuse syndrome (OOS) may also be called repetitive strain injury, repetitive motion disorders and cumulative trauma disorders. This terminology has variously been applied to different soft tissue and inflammatory joint conditions, including tendonitis, tenosynovitis, nerve entrapment syndromes (e.g. radial, ulnar, etc.), epicondylitis, muscular sprain and strains, carpal and radial tunnel syndrome, bursitis and rheumatoid and arthritic conditions, particularly when associated with some occupational exposures. The aetiology is usually unclear i.e. symptoms appear gradually and do not relate to a specific causative event(1- 4).

All of these conditions have similar symptoms – pain (often diffuse and burning in nature), tingling, numbness and swelling in the joints and muscles (generally of the hand, arm and forearm). Tenderness and autonomic dysfunction are sometimes present (5). Other symptoms include lack of movement and pain in the shoulder and neck regions. Static muscle loading (maintaining the same posture and position of a joint) has been shown to be a contributing factor, as well as repetitive movements, and exposure to vibration and cold temperatures (3,6).

Fernström and Ericson(7) reported that important contributing risk factors for the development of musculoskeletal diseases associated with office work include working hours, work distribution and pace, repetitive and monotonous tasks and stressful postures such as wrist flexion, extension and/or deviation, and upper arm elevation. Research (6) has shown it is better for workers to have frequent short breaks rather than fewer longer breaks during their working day. Lawrence et al (1995)(8) found that workers who completed repetitive manual tasks were particularly at risk of suffering radial tunnel syndrome.

Work duties within many industries involve repetitive movements. Hand and wrist tasks can be considered repetitive if the basic action is repeated within 30 seconds(6). So, for example, computer mouse usage qualifies as a repetitive task. Many software programs are “mouse driven”, particularly those involving data entry and text or graphics editing tasks.

Erdil, Maurer and Dickerson(1) stated that metabolic, hypertrophic, contractile, and fibre content changes result from an increase in physiological demands in muscles and tendons. Thus, if a group of muscles are worked at a level which does not allow adequate time for tissue recovery (although the task demand is below the threshold level which would result in actual tissue damage), submaximal and cumulative tissue damage may result. The symptoms experienced by a worker in such a situation may be consistent with CTD. If the changes are in an anatomical structure with limited adaptive capabilities (such as the "tight" carpal tunnel compartment), mechanical compression and/or microvascular insufficiency can lead to further injury, for example, to the neural tissues(1).

The amount of time spent completing repetitive tasks over the working day is significant(6) but the body can recover from stressful work tasks if there is enough variation in the tasks and/or "rest" time. Muscle and joint recovery is dependent on blood supply reaching tissues. If blood supply to a group of muscles or a joint is reduced or restricted, for example, due to an increase in the external or internal pressure at the carpal tunnel of the wrist, OOS symptoms may result(6). Workers who are exposed to vibration and use power grips associated with their work are also at risk of developing OOS(6). Muscles repair and recover faster than ligaments, tendons and nerves following stress and injury; however, the amount of time for each person to recover from physical "stress" varies.

The repetitive use of a mouse can result in OOS symptoms, especially if the work is mainly computer and mouse based. This is particularly relevant for editing tasks when the user "scrolls" through screens of data to effect changes, or "drags" and "clicks" the mouse buttons repeatedly. In this case, the small muscles of the hands and fingers complete most of the work, whilst the wrist, elbow, shoulder and neck are held in virtually the same position. This results in "static" muscle loading and may lead to pain, strain and stiffness in the muscles and joints.

More elements of working life are becoming computerised and more people are using VDT and related equipment to complete their work(7, 9). Thus, many more workers are exposed to the potential problems associated with working with this equipment.

The scope of the problem

The “NOHSC Compendium of Workers’ Compensation Statistics, Australia” (10-12) does not list OOS as a separate condition. However, the data for neck, shoulder and hand, fingers and thumb injuries and diseases may be used as an indication of the problem of OOS. Data in the Compendia are prepared from workers’ compensation claim statistics under the various jurisdictions workers’ compensation Acts. The threshold for data to be included in the “NOHSC Compendium of Workers’ Compensation Statistics, Australia” (10-12) is that any reported work-related injury or disability results in an absence from work of five or more days. It is difficult to compare data prior to 1993 with that analysed after 1993 due to changes in various jurisdictions legislation, data collection criteria and data presentation in the Compendia. However, a steady increase in the cost of workers’ compensation injuries is revealed.

Data in 1992-93(10) did not include ACT or Victorian figures (unavailable for inclusion) and did not present average costs of the injuries. Data were not combined for upper limb diseases/injuries in this report.

Workers’ compensation (10-12) claims associated with neck injuries/diseases represented 2.4% of new Australian cases in 1995-96 (compared with 3% in 1992-93 and 2.5% in 1994-95) and upper limb injuries/diseases represented 28.7% of new Australian cases in 1995-96 (compared with 23.3% in 1992-93 and 28.5% in 1994-95). Statistics for the state of Victoria are not included because the threshold for claims changed from five days lost from work to ten days lost from work in 1993. Data for the ACT were not available at the time of preparation of the Compendium, and data from Victoria were not available for inclusion in 1992-93. The data for upper limb injuries/diseases in 1992-93 were derived by combining values for wrist (4%), shoulder (5%) and hand, fingers and thumb (14.3%) injuries/diseases.

In 1992-93(10) the average absence from work ranged from 4.8 working weeks for hands, fingers and thumb injuries/diseases to 9.7 working weeks for shoulder injuries/diseases. In 1994-95(11) the range for the average absence from work was 5.0 working weeks for hands, fingers and thumb injury/disease to 9.6 working weeks for shoulders. In 1995-96(12) this increased to an average absence of 5.4 working weeks for hands, fingers and thumb injury/disease and 10.6 working weeks for shoulder injuries/disease. All these data exclude Victoria and ACT.

The average direct cost per claim for hand, fingers and thumb injuries increased from $A3,258 in 1992-93(10) to $A3,351 in 1994-95(11) and to $A3,536 in 1995-96(12). Average direct costs per claim for shoulder injuries increased from $A6,564in 1992-93(10) and decreased slightly to $A6,488 in 1994-95(11) and increased to $A6,911 in 1995-96.(12) These figures exclude data for Victoria, ACT and WA.

The above data do not include injuries resulting in less than 5 days absence from work, journey injuries, nor those workers covered by workers' compensation outside State, Territory or Commonwealth legislation. Data for self-employed are also not recorded in the NDS. The available statistics consider only the treatment and time lost from work costs – the direct costs - associated with these claims. However, the indirect costs associated with a claim, including staff replacement and training, loss of production, loss of quality whilst new staff learn the required skills and abilities, and claims-related costs, such as administration and legal costs (if the claim is litigated) are difficult to estimate.(1)

The recently released "The 1995 Australian Workplace and Industrial Relations Survey (AWIRS 95): An OHS Perspective"(13) contains data obtained from 19,155 questionnaires distributed in 1896 workplaces. The results of this Employee Survey revealed dislocation, strain and sprain injuries as the most commonly reported work-related injury or illness, with a rate of 43%(13). These data include injuries and illness for which less than five days were lost from work. Only 35% of the respondents received workers' compensation payments for their injuries or illness, possibly because the nature of the injury or illness was considered minor.

Yassi (14) et al reported that of all upper limb workers' compensation claims in Manitoba, Canada, in 1991, 382 cases (or 9.3%) were attributed to RSI. Of these, 27.5% were due to tendonitis, and 19.3% were due to carpal tunnel syndrome. Claimants suffered symptoms for an average of eight months prior to lodging claims. Clerical workers as a group had a low incidence of RSI with 13.6% of all upper limb RSI claims. The largest incidence of RSI was found in the meat and poultry industry. The authors stated the average cost for RSI claims was $CA5,569, compared with $CA2,480 for similar non-RSI musculoskeletal claims, and the average lost time from work was 71.4 days for RSI claims, compared with 33.6 days for similar non-RSI musculoskeletal claims. Only 67.3% of RSI claimants returned to the same job, compared with 81% similar non-RSI musculoskeletal claimants.

In June 1998 the World Health Organisation cited a German study (15) of VDU-assisted office work. The survey of 592 self-administered questionnaires across a number of areas (i.e. clerical work, data entry, word processing and programming) included questions relating to job satisfaction, job-related stress, coping styles and health effects. Females tended to occupy the lower-skilled jobs. Almost two thirds of respondents reported some health problems associated with their work, with 49% reporting painful neck and shoulders, 37% back pain, 35% headache and 30% eyestrain. Organisational factors, such as the level of subjectively rated workload, social support by colleagues, individual significance of work and aspects of social gratification, were found to be significant. The study also identified that 14% of the sample subjects stated that they were unable to relax.

Pan and Schleifer(16) stated that 18% of all occupational illnesses in the USA in 1981 were due to ‘cumulative trauma disorders’ and, by 1992, this increased to 61% of all reported occupational illnesses. Although not stated by these authors, this increase may partly be explained by a different attitude to reporting occupational illnesses, and perhaps different diagnostic processes.

Fogelman and Brogmus(17) reviewed workers’ compensation claims data for cumulative trauma disorders of the upper extremities (CTDUE) from the Liberty Mutual Group (USA) between 1986 and 1993, inclusive. They concluded that claims associated with the use of a computer mouse were very small relative to all claims (0.0% in 1986, increasing to 0.04% in 1993), but the comparative incidence increased when compared with computer-related claims (0.0% in 1986 and 6.1% in 1993). The median costs of these claims in 1993 were $170 for computer mouse claims, $314 for computer claims and $372 for CTDUEs, compared with $192 for all claims. However, these authors stated that due to the small number of computer mouse-related CTDUEs, the average and median costs associated with these claims should be viewed with caution. They further concluded that the majority of CTDUE claims were made by female workers, and that the actual number of these claims may be an underestimate of the problem due to the search method used in elucidating the data.

Hales et al (18) reported a cross-sectional study of 533 telecommunications employees who used VDTs in three locations in the USA. Their study included a questionnaire and physical examination of subjects. The authors claimed this was preferable to studies using only questionnaires, which may have doubled the prevalence rates. Twenty-two percent of participants were considered to suffer upper extremity musculoskeletal disorders. Of these, 15% had probable tendon-related disorders, 8% had probable muscle-related disorders (tension neck syndrome and neck trigger points), 4% had probable nerve entrapment syndromes, 3% had joint-related findings and another 3% had ganglion cysts. However, as the criteria for subjects to be included as a case in this study required symptoms to persist for at least one week, or to have occurred for at least once a month, the actual number of persons with problems may have been higher. The authors(18) further reported that of the 22% with symptoms, 12% had hand/wrist symptoms, 9% had neck area symptoms, 7% had elbow area symptoms, and 6% had shoulder symptoms. Psychological factors were found to be more significant for the neck/shoulder region rather than the hand/wrist area. They concluded that no single psychosocial or work organisational factor was the predominant cause of upper extremity musculoskeletal disorders. Therefore, improving a single workplace factor would not result in the substantial reduction of the prevalence of these disorders.

This latter study, in particular, supports the current ergonomics approach of completing both a full task analysis as well as a detailed workplace assessment during workplace evaluations.

Greening and Lynn (5) completed a controlled trial to investigate any relationship between the experience of RSI, hand vibration thresholds and keyboard related tasks. This study involved three groups – office workers who intensively used computer keyboards, patients diagnosed as suffering RSI and a control group of university staff and students who may occasionally have used keyboards. The authors reported that objective testing of office worker subjects who intensively used computer keyboards and suffered from RSI showed signs of minor polyneuropathy of the median, ulnar and radial nerves, with the median nerve being the most affected. In particular, the vibration threshold for the median nerve was significantly raised in both the patient and office-worker groups. Additionally, the patient group recorded raised ulnar nerve vibration thresholds and showed further raised median nerve vibration thresholds following keyboard use, indicating a work-related exacerbation. Results of this study also revealed 82% of the patient group had a changed sensory response at suprathreshold stimulation, suggesting possible changes in the central processing of non-noxious sensory information. Greening and Lynn(5) proposed using vibration threshold studies as an early indicator of workers who may develop RSI.

Background and Recent studies

Computer keyboard

In the past, typists were taught their skill in typing classes, where posture, style, speed and accuracy were valued. Students' techniques and posture were observed and corrected by the trainer as appropriate. The use of typewriters allowed the use of larger muscle groups with some actions such as the carriage return and the associated duties such as the use of carbon paper for multiple copies and other miscellaneous office work offering task variation and work pauses.

Current work practices result in less variation in tasks, and many more workers use a keyboard, regardless of skill levels. Workers untrained in typing and completing keyboard-related tasks may have a "hunt and peck" style of typing, using only a few fingers to press the keys, but larger muscle groups to travel across the keyboard. Touch typists may be self-taught, using either a computer software program, random training or books. Irrespectively, such methods rarely contain enough information on reducing the amount of musculoskeletal strain experienced during task completion, but largely focus on attaining speed and accuracy. Even when there are descriptions of "correct" posture and warnings regarding OOS symptoms, it is difficult for most people to "see" their posture and method of work when they are actually doing the task. Self-awareness of muscle movement is highly variable and often inaccurate.

Ortiz et al(19) stated posture is a contributing risk factor to the development of upper extremity musculoskeletal disorders among VDT users and that there have been few epidemiological studies which adequately address postural measures. Cook and Kothiyal(20) reported that some studies have stated that up 80% of keyboard users experienced some musculoskeletal problems.

In contrast, Bergqvist et al, (21) in their survey of 353 office workers from 1981 to 1987, found musculoskeletal problems were not associated with VDT work in general. However, they found that limited unscheduled rest breaks, combined with data entry work, increased the risk of musculoskeletal discomfort or disorders in the neck and shoulder region. Arm and hand discomfort was increased when the keyboard was too low (generally below elbow position). VDT users who worked more than 20 hours per week were more prone to intensive neck and shoulder discomfort if they had a history of often suffering "stomach reactions" and if their work involved repetitive movements. They also found that prolonged use of VDTs was associated with tension neck syndrome in users who wore bifocal or progressive glasses. Prolonged use of VDTs was also associated with arm or hand region diagnoses if the users had limited rest breaks and no lower arm support at their workstations.

People learning new skills may exert more energy and effort whilst completing the task, and tend to focus their concentration on outcome rather than method. This may result in learners not noticing musculoskeletal pain or strain symptoms in the early stages, and continuing to complete their learning activities despite physical discomfort.

As reported by Radwin and Jeng (22), numerous studies have shown that many typists exert more force with each key press than is necessary to activate the key. It is believed that this exerted force contributes to localised musculoskeletal strain and pain. The amount of force applied to depress keys is determined by a number of factors including workstation design, typing skills, individual and psychosocial factors and the actual keyboard characteristics, particularly the type and timing of key press feedback, whether auditory or tactile.

Radwin and Jeng (22) studied the amount of force applied to keys by measuring the distance and force that keys are depressed to complete a key switch task. The keys used in the test had auditory and visual feedback of successful strikes. The authors defined the different parts of the key travel and key press sequence, with "make point travel" being the key travel necessary to activate the key, and "over travel" being the maximum travel a key can be depressed beyond the make point travel until the key hits bottom. Results showed that when the amount of "over travel" was increased from 0.0 to 3.0 mm, the amount of force exerted decreased substantially (by 24%) and the key-tapping speed increased (by 2%). They also found the key-tapping rate increased (by 2%) when the key travel for activation was reduced (from 4.0 mm to 1.0 mm). Thus, typing became more efficient when the key press distance required to activate a key was decreased and the amount of movement after key activation was increased.

Feuerstein et al (23) also found that 48 typists exerted 4-5 times the amount of force required to operate the keyboard and concluded that using excessive force whilst typing on a computer keyboard may contribute to the severity of upper extremity symptoms.

However, and perhaps paradoxically, Pan and Schleifer(16) found that in their study of 43 data entry transcribers lower key press forces were associated with higher right hand discomfort and that slower typing speeds were associated with higher levels of right shoulder discomfort and fatigue. They stated this was in contrast to biomechancial theories suggesting musculoskeletal discomfort is positively associated with key press force and key press rate (speed). These results may have been due to workers altering their keying style in response to increased discomfort and fatigue. The authors concluded that musculoskeletal discomfort was cumulative, peaking at the end of the workday, and that other factors such as psychological stress reactions, posture, task duration and fatigue may be important contributing risks.

Australian Standards provide design guidelines for input devices. In particular, AS3950.1 (24), AS3950.2 (25) and AS3950.3 (26) (1990) list recommendations relating to workstation design and equipment. AS3950.3 (26) relates to keyboard and mouse input devices, and defines the amount of force that should be applied. Many of the Australian Standards relating to workstation design were developed in the late 1970’s. Some of these have been withdrawn(27-29), while others have been superseded with Standards dated 1996(30-37). Evans(38) discusses problems associated with the use of the “older” Standards where technological advances have rendered many recommendations obsolete.

Computer mouse

Cook and Kothiyal (20) found that computer mouse users worked with their shoulders outwardly rotated more often than keyboard users (81% of the time, compared with 65% of the time, respectively). Cooper and Straker (39) found that mouse users experienced higher muscular loading on the anterior deltoid muscle and lower loading on the upper trapezius muscle, compared with keyboard users.

Cook and Kothiyal (20) maintain that computer users tended to use their arm muscles constantly. Typically, there was dynamic use of the small muscles of the hands and forearms, and continuous use of the supporting postural and stabilising muscles in the arm, shoulders, trunk and neck. Computer mouse users tended to have unilateral movements – they flex, abduct and externally rotate the shoulder on one side of the body only. They also stated that musculoskeletal symptoms were increased when computer operators used a mouse beside the numeric keypad attached to the computer keyboard as this increased the reach distance to the mouse from the midline of the body.

Karlqvist and Hagberg (40) reported that mouse users spent long periods of time in strenuous working postures compared with non-mouse users. In a separate study, Karlqvist et al (41) found that mouse technique changed posture and movements compared with non-mouse usage.

One study (42) found that, by increasing the amount of tactile feedback in a computer mouse, the speed and accuracy of use was increased. It could be argued that this would decrease the error rate involved in mouse usage, and decrease accessory movements and muscle fatigue associated with attempting to control the cursor position.

Some people using a computer mouse lean on their arms, or rest their wrist while relying on sideways movements of their wrists and fingers to direct and control the mouse. These types of movements and sustained postures have been shown to increase the risk of musculoskeletal strain and pain. Working in postures with the arms abducted (away from the side of the body) and externally rotated (turned away from the body) has been shown to increase the risk of musculo-skeletal symptoms. Cook and Kothiyal(20) found that mouse users were more likely than keyboard users to have musculoskeletal symptoms possibly due to the distance of the mouse from the centre of the keyboard, and that removal of the numeric keyboard for mouse users is helpful in reducing this reach distance.

Karlqvist(43) found that the standard office VDU workstation designs did not facilitate non-keyboard computer input devices, and the design of the keyboard didn’t assist mouse usage.

This study suggested that workstations should be adjustable to allow work from a seated or standing position, and that the work surface should be positioned so that the arms can be supported. The equipment should be positioned to prevent extreme shoulder external rotation. Another problem associated with the use of the computer mouse in a standard workstation is user hand dominance. Most workstations are designed for right-handed users, forcing left-handed users to place the mouse on their right side. Hoffman et al(44) compared 10 left-handed and 10 right-handed computer mouse users task performance when using a right handed mouse. They concluded that left-handed users were not significantly disadvantaged when forced to use a computer mouse with their right hand, and that they were often equally skilled with their left and right hands. This study also confirmed left-handed users were superior to right-handed users when using their non-preferred hands, possibly relating to their need to develop dexterity skills with their non-dominant hand in daily life.

Fernström and Ericson(7) compared the use of a computer mouse with a Trackpoint device – a small button (or joystick) inserted close to the middle of the keyboard. They found that the use of the Trackpoint was associated with decreased shoulder muscle but increased hand, finger flexion and forearm muscle load, and that use of the computer mouse was preferable to keyboard-only use. They also found handwriting increased the load on the muscles of the forearm.

Burgess-Limerick et al(45) studied the wrist postures adopted by twelve subjects when using a computer mouse and compared this to wrist postures adopted when using a trackball. Wrist flexion/extension and ulnar/radial deviation were measured. Their results showed that users experienced considerable exposure to extreme ulnar deviation (greater than 10°) and some exposure to extreme wrist extension (greater than 30°) when using a computer mouse. They also found there was reduced exposure to extreme ulnar deviation when using a trackball, but this was countered by increased exposure to extreme wrist extension in some of the subjects. These authors concluded that there was so much individual variability in the postures adopted when using these devices that it was difficult to absolutely advise regarding the benefits of these input devices when compared with each other for prolonged use.

Workers should have access to alternative styled input devices. These include foot, head, eye or voice operated mouse units, vertically oriented mouse controls (similar to a “joy stick” design), use of function keys and macros to avoid single handed data and editing input, tracer balls, pen “mouse” and right- and left-handed equipment. Software programs should be designed to allow users alternative key strokes for input. Thus, by changing the method used to complete the task, fatigue and static muscle loading on the same muscle groups can be reduced. It would be helpful if larger organisations could provide a range of input devices for staff to trial before deciding on a particular unit to purchase for individuals. Although some of these devices may be difficult to access, the Internet has a number of sites (46, 47) which describe (and sell) some of these units.

It seems that workers who predominantly use a computer mouse find it easier if the mouse and mouse pad are close to the body – either just to one side, or towards the middle. This is obviously difficult if the full 101 style alphanumeric keyboard is used. However, using a narrower board, e.g. without the numeric keypad fixed to the side of the keyboard, seems a reasonable compromise. It can be difficult to obtain such keyboards, however. An alternative is to temporarily remove the keyboard from the immediate workspace whilst mouse tasks are completed, and to allow mouse users a number of styles of devices, if possible for use with either the left or right hand. It must be noted that accuracy and speed may suffer when attempting to use an alternate input device until competency and skill are learned.

It is important to consider that the times workers are more likely to need alternate devices due to increased work load are often accompanied by an attitude that there is less time to consider and practice the basic ergonomics work principles of pause breaks and task variation.

Ergonomics-styled keyboards

A number of Ergonomics-styled keyboards have been introduced recently. These are becoming more popular with users as an alternative to the standard computer workstation keyboard. The keyboards may be split or divided so the left and right hand keys are separated, and/or may be sloped in some way. Some include a mouse device – usually either a track ball or touch pad. The theory supporting the use of these keyboards is that the fingers, hand and wrist angles change with wrist movements, and that the sloped keyboard reduces the amount of forced rotation and deviation of the fingers and hand with typing tasks.

Most of these keyboards tend to have the keys located in the same position as on the standard "QWERTY" keyboard, named after the first six letters on the third row of keys. This configuration was developed to stop typewriter hammers jamming during typing. An alternative "Dvorak" keyboard (48) is available, which has the keys arranged according to statistical frequency of use in the English language, resulting in almost equal use of left and right fingers, and fewer words needing to be typed with single hand reaches. Various authors(49-51) have discussed and surveyed the use and merits of the different keyboard designs in terms of productivity, physical comfort and risk factors during task performance. Some (52) suggest the use of the split keyboard helps to reduce wrist deviation during typing tasks, and most state that speed and accuracy rates recover fairly quickly after the initial training time. A 1993(48) study comparing the Dvorak and QWERTY keyboards found:

- 70% of typing is completed on the home row of keys in the Dvorak keyboard compared with 31% in QWERTY;
- the Dvorak keyboard has 35% more right hand reaches, 63% more same-row reaches, 45% more alternate-hand reaches, and 37% less finger travel than the QWERTY keyboard.

Many users may request, or may be advised to obtain, access to different styles of keyboards. This may be particularly relevant for workers whose duties involve repetitive and exclusive use of a keyboard. The alternative keyboards are often difficult to obtain and may be more expensive. Many word processing packages apparently can be customised for the Dvorak keyboard, with either stickers attached to the existing keys, or the existing letters from the keyboard may be re-arranged by lifting the tops off the keys. The now superseded Australian Standard AS 2287 – 1979(27) was written with respect to the QWERTY keyboard, and is referred to in AS 3590.3 – 1990(26) as the basis for the arrangement of alphanumeric characters on the keyboard.

Wright and Andre (49) surveyed 424 users in business, educational and government office settings on the use of differently styled ergonomics keyboards. They concluded that over 80% of users felt that their alternative keyboards were preferable to standard keyboards. Some said the alternative keyboard allowed them to continue working when they would otherwise have been unable to or that they would have undergone surgery had it not been for the use of the alternative keyboard. Other users felt that using split, sculpted and adjustable keyboards improved their posture and comfort, and that they experienced less pain associated with their work when using these keyboards(49). This view is supported by Gerard et al(53) who found similar results when investigating the use of alternative keyboards. They reported that users experienced decreased muscular activity in maintaining their resting posture and decreased muscular effort in typing.

However, Fernström et al (54) found that the muscular load on the forearm and finger muscles during keying tasks was not influenced by an “angled” keyboard. Swanson et al(55) reported that there were no significant differences between the use of alternatively styled keyboards and standard keyboards on the user’s experience of musculoskeletal discomfort. They evaluated one standard and four alternative QWERTY keyboards over two days and concluded that the use of the alternative designs had only a minimal impact on productivity, comfort and self-reported fatigue after two days exposure. They also suggested that skilled typists would regain their typing rates and accuracy fairly quickly when using an alternative keyboard.

NIOSH(50) has produced a publication to offer guidance for users when selecting alternative keyboards. These guidelines include compatibility with existing software, work organisation factors and training effect.

Many keyboards have a fixed wrist rest, with the bottom row of keys placed some distance from the front edge of the keyboard. These are usually rounded but may encourage users to lean their wrists on these rests forcing wrist extension to reach the keys. Some researchers suggest that leaning the forearm on a hard or ridged surface (such as the edge of the desk or an ill-shaped wrist rest) may increase the risk of musculoskeletal symptoms as this may reduce the blood flow to the compressed area(3,4). Dickerson and Erdil(56) referred to an ANSI document and mentioned pressure within the carpal tunnel can be increased by wrist extension greater than 15°. They also stated there is little scientific evidence supporting the use of wrist (or palm) rests during keyboard-related tasks and that use of wrist rests during speed typing tasks may inhibit wrist flexion. Wrist rests should therefore be supplied as optional equipment depending on an individual’s preference.

The use of alternative keyboards may not redress the issues confronting all keyboard users – i.e. whether work organisation factors are appropriate for the work tasks, and whether the use of such alternate keyboards will reduce the risk or rate of OOS-type symptoms. Since novice users of different styles of keyboards require a training period, work productivity may suffer as a result of the introduction of such technology.

Notebook and laptop computers with flat panel displays

Many workers are now using notebook or laptop computers for at least some of their work. These computers tend to be lightweight and easily transportable. They require less energy and space, and emit less noise than desktop computers. Notebook and laptop computers generally have fixed keyboards attached to the screens, and must be kept open when operating. The angle of the screen can be altered to some extent during work. Glare and reflection onto the screen are common problems and seem to be related partly to the type of screen used. Users with passive matrix screens are more likely to experience difficulties with lighting, glare and reflection than users with the more expensive active matrix screens. The "mouse" input device may also be unsatisfactory. There are a number of styles of input device, each with its own problems(7). The touch pad can fail after some time, the track ball may be located in an awkward position on the keyboard, and the "Trackpoint" or "Easy Point" button can be very difficult to direct, particularly for users with large fingers.

Many notebooks and laptops have built-in wrist rests, so the actual keys are some distance from the front edge of the keyboard. The design of the keyboards may be smaller than standard keyboards, and the configuration of individual keys may be different. The numerical keyboard is often absent, and there may be fewer "function" keys than on standard keyboards. This may contribute to musculoskeletal symptoms in some users.

Some workers use the notebook or laptop as the main processing unit and plug this into standard monitors and keyboards once in the office. Others use these for "convenience" when working away from the office or to increase their working flexibility, which is particularly important for workers who travel frequently. There has always been an ergonomics compromise in the use of notebook computers because of the difficulty of having the keyboard at the correct height for typing and the monitor in a comfortable position for visual range and acuity, whilst accommodating the key features of transportability and durability.

In general, notebook or laptop users must decide whether they wish to optimise the workstation for their hands and typing tasks, or their visual comfort. This may result in a predisposition for OOS-type symptoms in their hands, wrists, shoulders, neck and back, or eye strain, unless the notebook is used with supplementary equipment.

Saito (57) et al studied the working posture of computer users, comparing the same task completed by ten subjects on both a notebook computer and a desktop computer. These authors found that the characteristic features of notebook users were work postures involving short viewing distance from the screen, and forward inclination of the head associated with the viewing angle of the screen. Neck muscle EMG readings were higher for the notebook computer user than for the desktop computer user, due to the forward inclination of the head. The authors claim that the shorter viewing distance and increased angle increased the risk of visual disturbances such as transient myopia, visual fatigue and changes in accommodative response. They found that the average viewing distance for the notebooks was shorter than the resting point of accommodation and vergence for the eyes. They found fewer changes in the head angle with notebook use, which they believed may have be attributed to the smaller screen size, allowing more coverage of the screen by eye movement alone, rather than eye and head movements combined. This may be helpful in reducing some muscle strain, but may increase the risk of static muscle loading and the associated musculoskeletal strain and pain symptoms.

Saito et al (57) concluded that the visual and musculoskeletal workloads caused by poor posture associated with use of the notebook computer were greater than with a desk top computer. However, because the screen on a notebook is lower than the desktop computer, there is a physiological advantage associated with the resultant downward gaze.

The results of this study were supported by Straker et al(58) who found statistically significant postural differences in users when comparing use of a laptop and desktop computer. These authors reported users had increased neck flexion and head tilt when using the laptop computer. Neck protraction was increased but this increase was not significant. There were no significant differences in the users' trunk, shoulder, elbow, wrist, scapula and neck retraction angles when using laptop computers. Seventy-five percent of the subjects of this study reported visual fatigue after 20 minutes use of the laptop, which the authors attribute to postural changes and eye fatigue. They concluded laptop computer use tends to increase the users' neck and shoulder stress, contributing to greater physical discomfort, and that prolonged use of a laptop computer has the potential for increasing musculoskeletal disorders. Thus, prolonged use of the laptop computer should be avoided, and the use of this type of equipment should be limited to short periods.

It is difficult to determine the level of usage of notebook computers. Villanueva et al(59) state that 3 million notebook computers were marketed in Japan in 1997 alone, representing 40% of the total computer output for that year. In their study of 10 computer users, a comparison of posture and comfort across four computers (3 notebooks and one desktop) found significant differences between the use of notebook computers and desktop computers. Specifically, the smaller the screen on the notebook computer the closer the user sat to it (shorter viewing distance), the greater the degree of backward tilting of the screen, and the lower the monitor height. Users had greater viewing and neck flexion angles, more constrained postures and greater forward inclination of the trunk when using the smallest notebook computer. The authors also noted that the desk edge was used "more effectively" as a forearm rest when the smaller notebooks were used. They also noted greater inward rotation of the shoulders whilst using the smaller notebooks rather than the desktop computer. They found that the greatest number of test subjects complained mostly of musculoskeletal discomfort in the neck, shoulder, elbow and wrist areas and complained of eye discomfort when using the smallest notebook. They concluded that visual discomfort associated with the use of this type of computer was likely to be due to problems relating to the type of screen i.e. the luminance, contrast and screen uniformity, glare and reflection, and height above the work surface, which contributed to the lower viewing angle. (59)

Taken together, the above studies suggest that, where possible, it is preferable for users to attach standard keyboards, mouse type input devices and/or monitors when working with notebook computers. This should allow needs for both visual and physical comfort to be addressed, thus decreasing the risk of musculoskeletal and visual discomfort associated with the use of this type of equipment.

Large Screen Computer Technology

Many industries, such as telecommunications and insurance/finance sector companies, are introducing large computer monitors for more efficient data handling. These monitors are too large (too deep and often at the incorrect height) to fit standard workstations. Some monitors measure 480mm in depth compared with 360mm deep for older monitors. As many desks used for computer work are 600 mm deep (rather than the preferred and recommended 900 mm)(24, 60), the available desk space is taken by the monitor. The keyboard (often 170 mm deep) is either placed directly in front of the monitor (with some overhang on narrower desks) or to one side, forcing the user to adopt a twisted posture at their work. Additionally, these monitors are often placed in existing workstations in the same configuration as the smaller, older units (i.e. on top of the computer processing unit on top of the desk), rather than more appropriately on the desk top. This results in the top edge of the monitor being above the user's eye level, and much closer to their eyes than suggested for visual comfort. An alternative system is to place the CPU on the floor, preferably in tower, or mini-tower configuration. Easy access to the floppy disk drives of the computer system should be ensured, if necessary.

Workers may be at risk of occupational overuse injuries, musculoskeletal strain and eye strain and fatigue whilst completing their work. Insufficient desk space has been associated with tension neck syndrome and neck/shoulder discomforts (61). Berqvist et al (61) identified that the lack of adjustability of equipment (height and placement) was associated with shoulder and neck problems as well as hand and arm problems.

Villanueva et al (62) assessed EMG readings associated with the working posture adopted by ten desk top computer users whilst completing mouse-driven tasks in a computer game. They adjusted the monitor height to three levels, measured from the floor to the middle of the screen i.e. 800mm, 1000mm and 1200mm, whilst keeping other variables such as desk and chair heights constant. They found increased monitor height was significantly associated with a more backward-leaning trunk posture and a more erect neck posture. They also stated it was likely that there would be a reduced biomechanical load on the muscles of the neck with the more upright posture. Further, these authors suggested that it was likely that undesirable positions of the upper back and trunk may increase the muscular load on the shoulder. Thus, improving the posture with the height of the video monitor may decrease the risk of musculoskeletal problems associated with computer work.

Some authors have reported that reclining postures reduce the amount of biomechanical load on the muscles of the back and the vertebral discs at L5/S1 (the fifth lumbar vertebra and the first sacral vertebra) (63, 64) and at L3 when using a backrest(63). This posture may be more relevant for seating when travelling or relaxing as it may increase the reach distance for desk work. An alternative posture for office work involves tilting the seat pan forwards to reduce hip flexion; however, this may result in increased flexion of the upper thoracic and cervical spines when working at written tasks. In this case, it is sensible to tilt the desktop forwards about 5° to decrease the amount of upper torso and neck flexion whilst preventing items rolling from the desk (64). Straker et al(58) mentioned that whilst there was continuing debate regarding the most preferable sitting posture, there tends to be consensus regarding the need for minimal shoulder and neck flexion.

Large screen technology may compound the problem of eyestrain associated with VDT use, due to the lack of space on standard office workstations for this equipment. Users tend to sit closer than visually comfortable in order to reach the keyboard on a “too narrow” desk. The height of these screens may also be difficult to adjust, as standard monitor arms may not be wide enough to support the larger monitors.

Eye Strain

Office workers have complained of eyestrain associated with the use of VDT’s for many years. Many factors contribute to this, including natural aging of the lens of the eye, and the fact that the ciliary muscles around the eye may “freeze” with constant focus on the computer screen (65). Lie and Watten(66) found that VDT users experienced negative changes in ciliary and vergence muscle capacity, when compared with non-VDT users. Bergqvist and Knave (67) found use of VDTs was associated with increased occurrence of eye discomfort symptoms. The increasing number of people working with VDTs combined with an aging workforce may contribute to the problem of more workers suffering eyestrain, particularly as visual acuity deteriorates with age.

Ideal ergonomics workstation design and layout is based on the relationship between the individual users' personal anthropometry and characteristics (such as age and the type of glasses worn) and work factors such as the type of VDT equipment, the design of the office work area and work organisation. The amount of ventilation and lighting has also been shown to be a significant factor (52). Wallin et al(68) found the use of "computer glasses" whilst working with VDTs was associated with reduced VDT-related ocular symptoms.

The critical elements in designing a computer workstation for visual comfort are the height of the monitor (the viewing angle) and the distance of the monitor from the user (69). Jaschinski et al (69) studied a total of 22 computer users at a telephone assistance office. All users wore telephone headsets and used identical equipment with fully adjustable workstations with height and viewing distance controls. Data typed by the study subjects appeared on the bottom line of the monitor, and information provided by the database and relayed to clients appeared in the upper part of the monitor. None of the subjects wore near-vision glasses and all were under 45 years of age.

This study revealed that operators experienced more eyestrain if they viewed the monitor in a more horizontal plane, rather than with lowered gaze. The authors (69) mentioned that, physiologically, near vision tends to be achieved by looking lower than the horizontal plane, and distance vision tends to be viewed in the horizontal plane. They argue that the human visual system may have been adapted to these conditions. The study found eyestrain was influenced by the relationship between viewing distance and viewing angle, rather than visual acuity and character size. Results also showed the higher the screen height, the greater the amount of eyestrain users experienced. This was particularly significant when the screen was closer to the eye. Jaschinski et al (69) concluded that in order to avoid eyestrain, a high and near screen should not be used.

However, they also identified that these less than ideal conditions often exist in office workstations, particularly if the monitor is placed on top of the computer processing unit. They found that subjects who worked at a viewing distance closer than their personal preference experienced greater eyestrain and visual discomfort. The range for viewing distances was 600 mm to 1000mm and a vertical angle of inclination ranged between horizontal and -16° (downwards). It must be noted that this study described one type of task only, and did not include duties involving reference to hard copy or other materials whilst typing.

Kumar (70) cites a study which found that musculoskeletal problems associated with computer use increased if the user wore bifocal glasses whilst working at the computer. Kumar (70) studied ten desk top computer users who wore bifocal glasses to determine the most appropriate monitor height. The top portion of the glasses was blacked out so users could only view the screen from the lower section of their glasses. EMG readings of the left and right trapezius muscles and the left and right sternomastoid muscles were recorded for all subjects as well as subjective discomfort ratings against three workstation designs. These workstations were a monitor sunken into the desk and inclined to an angle of 35°, a monitor on the desktop and horizontal to the desk, and a monitor placed on top of the computer processing unit on the desk and horizontal to the desk. It should be noted that if the monitor was raised above the desktop, users would have to lift their heads and extend their necks to view the monitor out of the lower section of their glasses as the top section was covered.

The results of this study show that users experienced the lowest amount of muscular tension when using the workstation with the sunken monitor. Both the subjective comfort levels and the EMG recordings were the most favourable for this workstation design. The sunken monitor also allowed the smallest angular visual span between the keyboard and monitor, which was deemed helpful to users who were not touch typists as they did not have to continuously move their head and neck to view either the keyboard or the monitor(70).

Burgess-Limerick, Plooy and Ankrum(71) investigated the optimal monitor height in relation to tracking tasks involving a mouse controlled cursor in twelve subjects aged 19-49 years. They found changes in monitor height resulted in changes in the head inclination angle and in the gaze angle (relative to the head). They also found users preferred to have the monitor at a “low” height, and concluded that there were too many variables to be able to advise an optimal monitor height. These researchers mentioned that the head and neck unit was basically unstable, particularly in the upright position, and that individuals may use considerable muscular effort to support the cervical spine and maintain an upright posture. They stated that reduced time to develop isometric fatigue was associated with the maintenance of static positions involving neck flexion greater than 30°.

In another study, Burgess-Limerick et al(72) investigated twelve subjects aged 21-30 years completing word processing tasks with the computer monitor at a “low” height and at “eye level”. Results of this study showed that the lower monitor height increased the amount of head flexion relative to the neck in the subjects, but did not change the position of the neck relative to the trunk. The authors concluded that postures adopted by computer users may be an attempt to compromise between visual discomfort (due to higher gaze angles than individually preferred) and physical discomfort from maintaining postures with lower cervical flexion and upper cervical and atlanto-occipital extension. They suggested monitors should be placed in work stations so the user had the “top of the monitor” lower than eye height.

It is important to consider all elements of the work duties when formulating workstation design and use. Copy typing requires different equipment to typing from a dictaphone, and thus the workstation design considerations vary. It is also important to consider users’ health status. For example, a history of arthritis or spondylitis in the cervical or thoracic spine may influence posture and therefore visual and musculoskeletal comfort.

Training programs

Whilst preventive programs are an important element in reducing the risk of OOS, it is important to determine the appropriate type of program, and to monitor the implementation of these programs. One study (73) found that using a self-administered training program as the only source of intervention did increase the users’ awareness of work-related problems, but that the amount of work-related physical symptoms also increased due to the difficulty workers experienced in implementing appropriate solutions.

Many businesses use tuition software programs to teach the user skills associated with the use of the program, or competence in other tasks such as typing. Quealy and Langan-Fox (74) addressed issues relating to the content and style of computer-assisted instruction programs. Workers’ attitudes to their computer work and the type and amount of computer training received has been shown to contribute to health problems including respiratory, cardiovascular, musculoskeletal and eye strain symptoms and self-rated depression, particularly in users with type-A personalities (75).

It is important that users take adequate rest pauses when using these programs. It is especially important when the program has a timed assessment component, such as touch-typing. In this case, users often continue to type despite discomfort, as they believe breaks during the assessment part of the program will have a detrimental effect on their typing rate. Many programs do not contain adequate warnings about overuse strain or easily accessible points of exit. Other problems associated with the use of these programs in the workplace include the users' frustration with their own lack of skill in using these applications. Explanations for some training examples and situations encountered in the use of these applications may also be a problem for self-directed learning, such as may be found in statistical package training programs. Another problem for managers and supervisors may be the inappropriate use of the programs in work time, so worker's productivity decreases.

Any customised training program should address these issues. In particular, there should be easily accessible exit points so that users can "escape" loops, and performance assessments should not be compromised by users pausing or exiting the test earlier than planned.

Speech Recognition Programs

Speech recognition programs (software applications which allow users to "talk" to the computer) are now being used as an alternative to manual input of data and text in some situations, in particular for users with disabilities e.g. paralysis, spinal cord injuries, visual impairment and OOS. There are different types of programs available: full dictation applications allow users to dictate text which is typed by the software program (76) and navigation systems allow users to state simple commands (e.g. "open file.") to direct the software program (77). The user would still type and complete manual data entry in navigation systems.

Users may find such relatively new technology to be wanting at this stage, although it is very promising. There is usually a need for more powerful hardware and greater memory to allow these programs to be used efficiently.

It is important for potential users to determine their needs, and ascertain whether the current abilities of speech recognition programs are appropriate. Issues to be carefully considered include all parameters of the work to be completed, all applications simultaneously in use, all shared applications in a networked environment and any resident memory needs. This is vital to determine the hardware and memory power required, and any potential for incompatibility with existing software. Some problems currently associated with the use of speech recognition programs include:

- the cost of the software may be excessive, and the need for powerful hardware to run the programs may result in further expense being incurred to upgrade systems;
- error correction procedures may be awkward and slow, therefore the system may be frustrating(78) for users;
- some programs require the user to speak very slowly, making them tedious to use;
- the programs may only recognise the voice and pronunciation of one user. Many workstations are shared, and people's voices may change (e.g. with a head cold, or when tired etc.)
- they may be incompatible with other applications or the program driver (DOS, Windows, NT or OS2 etc.) and thus cause user problems; and
- there may be interference for other workers (and the software) when used in open office configurations.

Miscellaneous OOS issues

Some studies (79-81) have identified other more general risk factors that may contribute to the development of OOS. These results include:

- a weight gain of about 6 lbs. (2 _ kg) increased the risk of OOS by 8%;
- having a previous musculo-skeletal condition was positively correlated with the development of OOS;
- poor autonomy at work, and work tasks involving repetitive bending of the hand or wrist were associated with the development of a work-related disability; and
- being exposed to vibration and low temperatures, localized mechanical stress, highly dynamic movements, repetitive, sustained and forceful exertions and/or working in awkward postures.

Discussion

Of the thirty-nine published studies on physical responses to work environments reviewed in this paper, ten involved sample sizes of up to 10 subjects, although one study considered 10 subjects who acted as their own controls for each of five test conditions. Thirteen of the reviewed papers reported studies of 12-25 subjects, three reported studies of 36-43 subjects and three reported studies of 57-79 subjects. The remaining ten papers reviewed involved sample sizes of more than 150 subjects, with four being questionnaires alone and the remaining six involving questionnaires and medical and/or workplace investigations.

This illustrates the difficulty in completing "real world" studies in existing workplaces with large sample sizes, partly due to problems of gaining access to workplaces and subject compliance. It may therefore be difficult to find statistically significant results and to generalise the results of these studies across larger user populations. However, the results of the studies are useful as they indicate factors to be considered in implementing ergonomics interventions.

The difficulty in completing large studies combined with rapidly changing technology and work practices suggests that ergonomics guidelines should regularly be reviewed in regard to these changes. New technology is being introduced at a rapid rate, as businesses re-organise the manner in which work is completed with the aim of increasing productivity and decreasing costs. There is an increasing reliance on computerisation for many tasks, but opportunities for task variation that allow workers to use different joints and muscle groups are limited. This increases the amount of anatomical and physiological stress and strain on the musculo-skeletal system by introducing repetitive tasks and removing alternative work-related tasks that can act as pause breaks.

There are many factors that should be considered in addressing this issue:

- work processes and procedures continue to involve components of repetitive tasks;
- work organisation impacts on workers' autonomy and productivity, making it difficult for workers to take pause breaks when necessary to decrease musculo-skeletal strain and pain;
- changes in technology occur at a rapid rate;
- businesses implement new technology in workplaces designed for existing technology;

- ergonomics associated with workstation and task design must be considered; and
- many workers are working longer and taking fewer breaks in an attempt to maintain their employers' market competitiveness and their job security.

Workplaces should have an appropriate policy regarding work breaks. Åborg et al (1998)(82) performed a study of office workers in which work factors and task performance were analysed. They concluded that many of the breaks in work tasks due to interruptions were not long enough nor dissimilar enough to normal work tasks to achieve good muscular rest. They stated that work organisation factors should promote task variation so employees can achieve adequate physical and mental breaks.

Advice regarding job design (ergonomics) and work organisation factors has been available for some time. It is suggested that work design should allow an increase in recovery time and frequent small breaks rather than one occasional long break. (6)

Åborg et al (82) concluded that work duties and physical work load should be distributed throughout the working day, allowing a range of activities to be integrated as part of normal task organisation and structure. This would provide maximum benefit to the workers by reducing the risk of overuse symptoms and increase task performance.

Conclusion

It should be considered that most of the above reviewed articles do not mention the musculoskeletal health of the subjects. Most study subjects are "real world" workers and should therefore be representative of the general working population complete with the full range of abilities and disabilities. However, there are many musculoskeletal conditions which may impact on an individual's ability to complete tasks, and to be able to use the full range of any available adjustable furniture. For example, workers suffering osetoarthritic changes in their neck may be forced to place a computer and monitor in a particular configuration irrespective of their preferred gaze angle and visual acuity. Similarly, those with some visual deficits may compromise their musculoskeletal comfort in order to maximise their visual acuity. Working with non-work-related soft tissue injuries may contribute to performance compromises which in turn may contribute to the development of work-related musculoskeletal injuries.

The basic ergonomics paradigm of detailed task appraisal and assessment of the worker in their work environment, including work organisation factors, anthropometry, task demands and work rates, and physical workstation design and equipment, is the most appropriate method for ergonomics evaluations. It is important to consider all aspects of the worker in their work environment, including health status and physical limitations regardless of whether these are work-related, in order to provide the best advice possible, with the aim of achieving durable results.

However, suggesting that a particular design will suit all users is fraught with problems. There appear to be few measures that suit all users, so the best approach is to design for adjustability. If it is absolutely necessary to provide fixed conditions, it may be prudent to design around the most frequently completed task, with the understanding that this too may change with time.

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References:

1 Erdil, M., Maurer, K. F., and Dickerson, O. B. 1997 *"The burden of cumulative trauma disorders"* Chap. 1 in *"Cumulative trauma disorders. Prevention, evaluation and treatment."* Erdil, M and Dickerson, O. B. (eds.) Van Nostrand Reinhold, NY pp 1- 22

2 Cherniack, M. G. 1997 *"Nonacute musculoskeletal disorders: then and now"* Chapter 2 in *"Cumulative trauma disorders. Prevention, evaluation and treatment."* Erdil, M and Dickerson, O. B. (eds.) Van Nostrand Reinhold, NY pp 23-58

3 Kiser, D. M., and Rodgers, S. H. 1986 *"Repetitive Work"* Chapter 13 (Contributing authors). "Part IV. Patterns of Work" in Eastman Kodak Ergonomics Group Health and Environment Laboratories *"Ergonomic Design for People at Work. Volume 2"* van Nostrand Reinhold Company New York pp244-258

4 Stevenson, M. 1993 *"Notes on the Principles of Ergonomics"* Ergonomics Unit Worksafe Australia, Chapters 2 and 6

5 Greening, J., and Lynn, B., 1998 *"Vibration sense in the upper limb in patients with repetitive strain injury and a group of at-risk office workers."* Int Arch Occup Environ Health 71: 29-34

6 Konz, S. 1995 *"Cumulative trauma"* Chapter 16, in "Work design: industrial ergonomics". 4th edition. Publishing Horizons, Inc. Arizona pp 221-244

7 Fernström, E. and Ericson, M. O. 1997 *"Computer mouse or Trackpoint – effects on muscular load and operator experience."* Applied Ergonomics vol. 28, no. 5/6 pp 347-354

8 Lawrence, T, Mobbs, P., Fortems, Y., Stanley, J. K., 1995 *"Radial tunnel syndrome. A retrospective review of 30 decompressions of the radial nerve [see comments].* J Hand Surg [Br], 20 (4): 454-9

9 Kontogiannis, T and Embrey, D. 1997 *"A user-centred design approach for introducing computer-based process information systems"* Applied Ergonomics vol. 28, no. 2 pp 109-119

10 Worksafe Australia, Statistics Unit, 1995*"Compendium of workers' compensation statistics, Australia, 1992-93"* Australian Government Publishing Service, Canberra, August pp16-22

11 NOHSC, National and Workplace Statistics and Epidemiology Unit, 1996 *"Compendium of workers' compensation statistics, Australia, 1994-95"* Australian Government Publishing Service, Canberra, December pp24-25, 101

12 NOHSC, Statistics Unit, Performance Measurement Branch 1998 *"Compendium of workers' compensation statistics, Australia, 1995-96"* Australian Government Publishing Service, Canberra, May pp 61-63

13 Mitchell, R., and Mandryk, J. 1998 *“The 1995 Australian Workplace and Industrial Relations Survey (AWIRS 95): An OHS Perspective”* NOHSC, May, Commonwealth of Australia p 38, 45

14 Yassi, A., Sprout, J., and Tate, R. 1996 *“Upper limb repetitive strain injuries in Manitoba”*. American Journal of Industrial Medicine. 30: 461-472

15 Junghanns, Ertel, Ullsperger Anforderungsbewältigung und Gesundheit bei computergesützter Büroarbeit, 1998 *“Coping and Health in VDU-assisted office work”* in WHO Collaborating Centres in Occupational Health Newsletter, June. Vol 3, no 2 (WHO Geneva) p9

16 Pan, C. S. and Schleifer, L. M. 1996 *“An exploratory study of the relationship between biomechanical factors and right-arm musculoskeletal discomfort and fatigue in a VDT data-entry task.”* Applied Ergonomics vol. 27, no 3, pp 195-200

17 Fogelman, M. and Brogmus, G. 1995. *“Computer mouse use and cumulative trauma disorders of the upper extremities.”* Ergonomics, vol 38 no 12 pp 2465-2475

18 Hales, T. R., Sauter, S. L., Peterson, M. R., Fine, L. J., Putz-Anderson, V., Schleifer, L. R., Ochs, T. T., and Bernard, B. P. 1994. *“Musculoskeletal disorders among visual display terminal users in a telecommunications company.”* Ergonomics, vol 37 no 10 pp 1603-1621

19 Ortiz, D. J., Marcus, M., Gerr, F., Jones, W. and Cohen, S. 1997 *“Measurement variability in upper extremity posture among VDT users”* Applied Ergonomics vol. 28, no 2, pp 139-143

20 Cook, C. J. and Kothiyal, K., 1998 *“Influence of mouse position on muscular activity in the neck, shoulder and arm in computer users.”* Applied Ergonomics, vol 29, no. 6 pp 439-43.

21 Bergqvist, U., Wolgast, E., Nilsson, B., and Voss, M. 1995 *“The influence of VDT work on musculokeletal disorders.”* Ergonomics, 38: 754-762

22 Radwin, R. G. and Jeng, One-Jang, 1997 *“Activation force and travel effects on overexertion in repetitive key tapping.”* Human Factors, 39(1) 130-140

23 Feuerstein, M., Armstrong, T., Hickey, P., and Lincoln, A. 1997 *“Computer keyboard force and upper extremity symptoms.”* J Occup Environ Med vol 39, pp 1144-53

24 Standards Australia, 1990 Australian Standard AS 3950.1 – 1990 *“Screen-based workstations, Part 1: Visual Display Units”* Sydney.

25 Standards Australia, 1990 Australian Standard AS 3950.2 – 1990 *“Screen-based workstations, Part 2: Workstation Furniture”* Sydney.

26 Standards Australia, 1990 Australian Standard AS 3950.3 – 1990 *“Screen-based workstations, Part 3: Input Devices”*. Sydney.

27 Standards Australia, 1979 Australian Standard AS 2287 – 1979 *“Layout of typebar typewriter keyboards – QWERTY”*. Sydney. **Withdrawn 1996**

28 Standards Australia, 1979 Australian Standard AS 2250 – 1979 *“Office Machines and Data Processing Equipment. Keyboard Layouts for Numeric Application”*. Sydney. **Withdrawn 1996**

29 Standards Australia, 1980 Australian Standard AS 2386 – 1980 *“Office Machines and Data Processing Equipment. Principles Governing the Positioning of Control Keys on Keyboards.”* Sydney. **Withdrawn 1996**

30 Standards Australia, 1996 Australian Standard AS 4395.1 - 1996 *“Information Technology – Keyboard Layouts for Text and Office Systems. Part 1 – General Principles;”* Standards Australia, Sydney.

31 Standards Australia, 1996 AS 4395.2 – 1996 *“Information Technology – Keyboard Layouts for Text and Office Systems .Part 2 – Alphanumeric”;* Standards Australia, Sydney.

32 Standards Australia, 1996 AS 4395.3 – 1996 *“Information Technology – Keyboard Layouts for Text and Office Systems. Part 3 – Complimentary Layouts of the Alphanumeric Zone of the Alphanumeric Section;”* Standards Australia, Sydney.

33 Standards Australia, 1996 AS 4395.4 – 1996 *“Information Technology – Keyboard Layouts for Text and Office Systems. Part 4 – Numeric;”* Standards Australia, Sydney.

34 Standards Australia, 1996 AS 4395.5 – 1996 *“Information Technology – Keyboard Layouts for Text and Office Systems. Part 5 – Editing;”* Standards Australia, Sydney.

35 Standards Australia, 1996 AS 4395.6 – 1996 *“Information Technology – Keyboard Layouts for Text and Office Systems. Part 6 – Function;”* Standards Australia, Sydney.

36 Standards Australia, 1996 AS 4395.7 – 1996 *“Information Technology – Keyboard Layouts for Text and Office Systems. Part 7 – Symbols;”* Standards Australia, Sydney.

37 Standards Australia, 1996 AS 4395.8 – 1996 *“Information Technology – Keyboard Layouts for Text and Office Systems. Part 8 – Allocation of Letters to Keys of Numeric Keypad”* Standards Australia, Sydney.

38 Evans, O. M., 1998 *“VDT standards – locked in time as the world passes them by?”* in “Implementing Change: the role of standards” Proceedings of the 34th annual conference of the ESA Inc, Melbourne, Oct 5-7, 1998.

39 Cooper A. and Straker, L., 1998 *“Mouse versus keyboard use: A comparison of shoulder muscle load.”* Industrial Ergonomics Vol. 22: 351-357

40 Karlqvist, L. and Hagberg, M., 1994 *“Variation in upper limb posture and movement during work processing with and without mouse use.”* Ergonomics, vol. 37: 1261-1267

41 Karlqvist, L et al, 1998 *“Computer mouse position as a determinant of posture, muscular load and perceived exertion”* Scan J Work Environ Health vol. 24: 62-73

42 Akamatsu, M., MacKenzie, I. S., Hasbroucq, T., 1995 *"A comparison of tactile, auditory, and visual feedback in a pointing task using a mouse-type device."* Ergonomics, vol 38. No.4, 816-27

43 Karlqvist, L. 1998 *"A process for the development, specification and evaluation of VDU work tables."* Applied Ergonomics, vol 29, no. 6 pp 423-32.

44 Hoffmann, E. R., Chang, W. Y., and Yim, K. Y 1997 *"Computer mouse operation: is the left-handed user disadvantaged?"* Applied Ergonomics, vol 28, no.4 pp 245-248

45 Burgess-Limerick, R., Shemmell, J., Scadden, R. and Plooy, A. (In Press.) *"Wrist posture during computer pointing device use."* Clinical Biomechanics.

46 Porter, Lake *"Alternative Mouse Systems."* Glossary of Adaptive Technologies: Mouse Alternatives. http://www.utoronto.ca/atrc/tech/altmousesr.html (dated 25/6/98)

47 NoHandsMouse. http://www.footmouse.com/picture.html (25/6/98)

48 Ingram, S. 1998, Dvorak International's FAQ http://www.cse.ogi.edu/~dylan/dvorak/DvorakIntl.html (25/6/98) p2.

49 Wright, K S and Andre, A D 1998 *"Alternative keyboards: A user survey"* Ergonomics Australia, June: 17-22

50 Blosser, Fred 1998 *"NIOSH suggests considerations for alternative keyboard use."* NIOSH (DHHS) Update Publication No 97-148, http://www.cdc.gov/niosh (22/6/98)

51 Wright, K S and Wallach D S 1998 *"Alternative keyboards and accessories"* Typing Injury FAQ, http://www.tifaq.com/keyboards (22/6/98)

52 Hedge, A and Powers, JR 1995 *"Wrist postures while keyboarding: effects of a negative slope keyboard system and full motion forearm supports."* Ergonomics vol. 38: 508-517

53 Gerard, M et al, 1994. *"An ergonomic evaluation of the Kinesis Ergonomic Computer Keyboard."* Ergonomics, 37: 1661-1668

54 Fernström, E., Ericson, M. O., and Malker, H. 1994 *"Electromyographic activity during typewriter and keyboard use."* Ergonomics, 37: 477-484

55 Swanson, N. G., Galinsky, T. L., Cole, L. L., Pan, C. S. and Sauter, S. L. 1997 *"The impact of keyboard design on comfort and productivity in a text-entry task"* Applied Ergonomics Vol 28. No. 1 pp 9-16

56 Dickerson, O. B. and Erdil, M. 199 *"Video display workstations and cumulative trauma disorders"* Chap.10 in *"Cumulative trauma disorders. Prevention, evaluation and treatment."* Erdil, M and Dickerson, O. B. (eds.) Van Nostrand Reinhold, NY pp251-269

57 Saito, S., Miyao, M., Kondo, T., Sakakibara, H., and Toyoshima, H. 1997. *"Ergonomic evaluation of working posture of VDT operation using personal computer with flat panel display."* Industrial Health, 35, pp 264-270.

58 Straker, L., Jones, K. J., and Miller, J. 1997 *"A comparison of the postures assumed when using laptop computers and desktop computers"* Applied Ergonomics Vol 28. No. 4 pp 263-268

59 Villanueva, M. B. G., Jonai, H., and Saito, S. 1998 *"Ergonomic aspects of portable personal computers with flat panel displays (PC-FPDs): Evaluation of posture, muscle activities, discomfort and performance."* Industrial Health. 36 pp 282-289

60 Worksafe Australia, 1991 "*Ergonomic Principles and Checklists for the Selection of Office Furniture and Equipment.*" Australian Government Printer

61 Berqvist, et al, 1995. *"Muscluloskeletal disorders among visual display terminal workers: individual, ergonomic, and work organizational factors"* Ergonomics, 38: 763-776

62 Villanueva, M. B. G., Jonai, H., Sotoyama, M., Hisanaga, N., Takeuchi, Y. and Saito, S. 1997 *"Sitting posture and neck and shoulder muscle activities at different screen height settings of the visual display terminal."* Industrial Health. 35 pp 330-336

63 Kiser, D. M. and Rodgers, S. H. 1986 *"Biomechanical analyses of work"*. Chapter 7, "Part III Evaluation of Job Demands" in Eastman Kodak Ergonomics Group Health and Environment Laboratories *"Ergonomic Design for People at Work. Volume 2"* van Nostrand Reinhold Company New York pp 122-158

64 Stevenson, M. 1993 *"Notes on the Principles of Ergonomics"* Ergonomics Unit Worksafe Australia, Chapter 7

65 Brunila, M., 1997 *"Seeing red with VDUs"* Work Health Safety 1997 p24-26

66 Lie, I. And Watten, RG, 1994 *"VDT work, oculomotor strain, and subjective complaints: an experimental and clinical study"* Ergonomics, Vol. 37 p1419-1433

67 Bergqvist, UOV, and Knave, BG, 1994 *"Eye discomfort and work with visual display terminals"* Scandinavian Journal of Work, Environment and Health, Vol. 20, p27-33

68 Wallin, JA, Zhu, Z, et al, 1994. *"A preliminary study of the effects of computer glasses on reported VDT user symptoms: a field study*". Journal of Safety Reasearch, Vol. 25, p67-76

69 Jaschinski, W., Heuer, H., and Kylian, H. 1998 *"Preferred position of visual displays relative to the eyes: a field study of visual strain and individual differences."* Ergonomics, vol 41, pp 1034-1049

70 Kumar, S. 1994 *"A computer desk for bifocal lens wearers, with special emphasis on selected telecommunication tasks."* Ergonomics, vol 37. Pp 1669-1678

71 Burgess-Limerick, R., Plooy, A., and Ankrum, D. 1998 *"The effect of imposed and self-selected computer monitor height on posture and gaze angle."* Clinical Biomechanics, 13, 584-592

72 Burgess-Limerick, R., Plooy, A., Fraser, K., and Ankrum, D. R. 1998 *"The influence of computer monitor height on head and neck posture."* International Journal of Industrial Ergonomics, 23, 171-179

73 Coury, H. J. C. G. 1998 *"Self-administered preventive programme for sedentary workers: reducing musculoskeletal symptoms or increasing awareness?"* Applied Ergonomics, vol 29, no. 6 pp 415-21

74 Quealy, J. and Langan-Fox, J. 1998 *"Attributes of delivery media in computer-assisted instruction."* Ergonomics, 41: 257-279

75 Watanabe, S. et al, 1993. *"Relationships between health status and working conditions and personalities among VDT workers."* Environmental Research, 61: 258-265

76 Price, K. 1998. *"Utilizing the power of voice recognition."* Previous Reviews, University of Missouri-Columbia http://www.missouri.edu/~ccact/prodrev/voicerec.html (29/9/98)

77 Kaitlin 1996. *"Voice recognition."* Kaitlin's Guide: alternate input. http://www.rit.edu/~easi/resource/kaitlininput5.html (29/9/98)

78 Noyes, JM and Frankish, CR, 1994 *"Errors and error correction in automatic speech recognition systems"* Ergonomics, vol. 37, p1943-1957

79 Nordstrom, D. L., et al, 1997 *"Risk factors for carpal tunnel syndrome in a general population."* Occup Environ Med, 54(10): 734-40

80 Blanc, P. D., et al, 1996 *"Self-reported carpal tunnel syndrome: predictors of work disability from the National Health Interview Survey Occupational Health Supplement"* Am J Ind Med, 30(3): 362-8

81 Latko, W. A., et al, 1997 *"Development and evaluation of an observational method for assessing repetition in hand tasks."* Am Ind Hyg Assoc J 58(4): 278-85

82 Åborg, C., Fernström, E., and Ericson, M. O., 1998 *"Work content and satisfaction before and after a reorganisation of data entry work."* Applied Ergonomics, vol 29, no. 6 pp 473-80.