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Computer use and work related musculoskeletal disorders: A literature review

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ABSTRACT

Musculoskeletal disorders have been observed and experienced widely at workplaces where the computers are frequently used. Increase in the number of employees working with computer and mouse coincides with an increase of work-related musculoskeletal disorders (WRMSDs) and sick leave, which affects the physical health of workers and pose financial burdens on the companies, governmental and non-governmental organizations. This literature review study begins with the description of the risk factors and followed by the discussion of general characteristics of the musculoskeletal disorders. The economic impact of work-related musculoskeletal disorders was reviewed. This was followed by the discussion of issues related with workplace ergonomics, an extensive review of computer use related upper extremities musculoskeletal disorders, and computer keyboarding with different postures. Finally, the literature review is concluded with a discussion of the effects of interventions.

KEYWORDS

Musculoskeletal disorders;
Work-related;
Computer.

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) in the USA defines a Musculoskeletal Disorder (MSD) as a disorder that affects a part of the body's musculoskeletal system, which includes bones, nerves, tendons, ligaments, joints, cartilage, blood vessels and spinal discs. These are the injuries that result from repeated motions, vibrations and forces placed on human bodies while performing various job actions. The factors that can contribute to musculoskeletal symptoms include heredity, physical condition, previous injury, pregnancy, poor diet, and lifestyle.

Work-related musculoskeletal symptoms occur when there is a mismatch between the physical requirements of the job and the physical capacity of the human body. Musculoskeletal disorders are work-related when the work activities and work conditions significantly contribute to their development, but not necessarily the sole or significant determinant of causation. Work-related musculoskeletal disorders (WRMSDs) describe a wide range of inflammatory and degenerative conditions affecting the muscles, tendons, ligaments, joint, peripheral nerves, and supporting blood vessels. These conditions result in pain and functional impairment and may affect neck, shoulders, elbows, forearms, wrists and hands.

The causes of musculoskeletal disorders in the workplace are diverse and poorly understood. The meaning that working has to an individual may help to explain why certain psychological factors are associated with musculoskeletal discomfort and may eventually provide one way to intervene to reduce MSD.

Musculoskeletal disorders have been observed and experienced widely at workplaces where the computers are frequently used. Increase in the number of employees working with computer and mouse coincides with an increase of work-related musculoskeletal disorders (WRMSDs) and sick leave, which affects the physical health of workers and pose financial burdens on the companies, governmental and non-governmental organizations.

This literature review study begins with the description of the risk factors and types of musculoskeletal disorders, and followed by the discussion of general characteristics of the musculoskeletal disorders. The economic impact of work-related musculoskeletal disorders was reviewed. This was followed by the discussion of issues related with workplace ergonomics, and an extensive review of computer use related upper extremities musculoskeletal disorders. Finally, the literature review is concluded with a discussion of computer keyboarding with different postures and different keyboard designs.

WORK-RELATED MUSCULOSKELETAL DISORDERS (WRMSDS)

Orthopedic Clinics of North America (1996) cited the causes of work-related musculoskeletal symptoms in two categories:

Psychosocial factors

These include monotonous work, time pressure, a high workload, unorganized work-rest schedules, complexity of tasks, career concerns, lack of peer support, a poor relationship between workers and their supervisors, and poor organizational characteristics (climate, culture and communications).

"Psychosocial factors at work are the subjective aspects as perceived by workers and the managers. They often have the same names as the work organization factors, but are different in that they carry 'emotional' value for the worker. Thus, the nature of the supervision can have positive or negative psychosocial effects (emotional stress), while the work organization aspects are just descriptive of how the supervision is accomplished and do not carry emotional value. Psychosocial factors are the individual subjective perceptions of the work organization factors"[18].

Organization of work refers to the way work processes are structured and managed. In general, work organization refers to the way work processes are structured and managed, and it deals with subjects such as the following:

- Scheduling of work (work-rest schedules, hours of work and shift work)
- Job design (complexity of tasks, skill and effort required, and the degree of control of work)
- Interpersonal aspects of work (relationships with supervisors and friends)
- Career concerns (job security and growth opportunities)
- Management style (participatory management and teamwork)
- Organizational characteristics (climate, culture and communications).

Many of these elements are referred to as "psychosocial factors" and have been recognized as risk factors for job stress and psychological strain. Stress is considered as human body's physical and emotional reaction to circumstances or events that cause frightening, irritation, confusion, danger or excitement. Particularly, stress is a change from a person's normal behavior in response to something that causes wear and tear on the body's physical or mental resources.

It is the extensive and intensive stress that causes the disorders in the musculoskeletal system. The causes of the stress arise due to experience the feelings like frustration, anger, irritation, confusion, nervousness, or tension. Not only the frequency of exposure to these emotions, but also the repetition of the motions and activities cause the musculoskeletal disorders or injuries.

Physical factors

These include intense, repeated, or sustained exertions; awkward, non-neutral, and extreme postures;

rapid work pace; repeated and/or prolonged activity; insufficient time for recovery, vibration, and cold temperatures.

Awkward postures

Body postures determine which joints and muscles are used in an activity and the amount of force or stresses that are generated or tolerated. For example, more stress is placed on the spinal discs when lifting, lowering, or handling objects with the back bent or twisted, compared with when the back is straight. Manipulative or other tasks requiring repeated or sustained bending or twisting of the wrists, knees, hips, or shoulders also impose increased stresses on these joints. Activities requiring frequent or prolonged work on wrists and fingers, such as keyboarding, can be particularly stressful.

Repetitive motions

If motions are repeated frequently (e.g., every few seconds) and for prolonged periods such as an 8-hour shift, fatigue and muscle-tendon strain can accumulate. Tendons and muscles can often recover from the effects of stretching or forceful exertions if sufficient time is allotted between exertions. Effects of repetitive motions from performing the same work activities are increased when awkward postures and forceful exertions are involved. Repetitive actions as a risk factor can also depend on the body area and specific act being performed.

Duration

Duration refers to the amount of time a person is continually exposed to a risk factor. Job tasks that require use of the same muscles or motions for long durations, such as prolonged typing, increase the likelihood of both localized and general fatigue. In general, the longer the period of continuous work (e.g., tasks requiring sustained muscle contraction), the longer the recovery or rest time required.

Frequency

Frequency refers to how many times a person repeats a given exertion within a given period of time. Of course, the more often the exertion is repeated, the greater the speed of movement of the body part being exerted. Also, recovery time decreases the more frequently an exertion is completed, and as with duration, this increases the likelihood of both localized and general fatigue.

Psychological risk factors

In addition to the above conditions, other aspects of work may not only contribute to physical stress but psychological stress as well. While the human body is, indeed, a mechanism limited in motions by virtue of the biological characteristics of the body, it also contains a thinking, reasoning, feeling brain. Human beings experience pain, joy, sadness, depression, anger, boredom, frustration, fear, outrage, jealousy, love hate, and (even) schizophrenia.

Responses such as anxiety, tension, depression, anger, frustration, fear, fatigue, confusion, helplessness, and lack of vigor arise when the human being exposed to stress.

The nature of WRMSDs

The World Health Organization recognize the conditions that result in pain and functional impairment that affect neck, shoulders, elbows, forearms, wrists, and hands are work-related when the work activities and work conditions significantly contribute to the development of work-related disorders but not as the sole determinant of causation.

Baker et al.[3] thought that the causes of musculoskeletal disorders in the workplace are diverse and poorly understood. Therefore, they conducted an exploratory study to see if there was an association between the meaning of working discomfort and musculoskeletal discomfort and if that association was predictive of the severity of the discomfort. They asked 170 subjects to fill out a survey about the meaning of work, and a questionnaire on musculoskeletal discomfort. They entered seven component composites of the meaning of working (work centrality, obligation, entitlement, comfort, promotion/power, expressive, and social support) into a linear multiple regression model. The results suggested that there was a moderate, significant association between overall musculoskeletal discomfort and promotion/power as well as the control variables age, gender, job satisfaction, average hours worked, and work site. A logistic linear regression found that these composites, along with social support, could accurately identify who was in a none/mild discomfort category or a moderate/severe discomfort category 72% of the time. The overall pattern suggested that females who worked longer hours, valued promotion and power and disliked social support were most likely to develop moderate to severe musculoskeletal discomfort. Their study provided a preliminary exploration of the association between meaning and musculoskeletal disorders (MSDs) in the workplace.

In their review paper[1], stated that biomechanical factors such as repetitive motion, strenuous efforts, extreme joint postures and/or psychosocial factors establishes the key role in work-related musculoskeletal disorders.

Punnet and Wegman[36] indicated that work-related musculoskeletal disorders are highly prevalent in manual intensive occupations such as clerical work, mainly on upper extremities. They listed the job features that cite as risk factors for musculoskeletal disorders as; rapid work pace, repetitive motion patterns, insufficient recovery time, heavy lifting and forceful manual exertions, non-neutral body postures, pressure concentrations, segmental or whole body vibration, and local or whole body exposure to cold. According to them; age, gender, socio-economic status, ethnicity, obesity, smoking, muscle strength and work capacity are psychosocial risk factors).

McBeth and Jones[30] examined the rate of musculoskeletal pain in adolescent and adult populations, with a focus on three commonly reported pain disorders: shoulder pain, low back pain and fibromyalgia/chronic widespread pain. Their results showed that there was a paucity of data on musculoskeletal pain in adolescent populations, pain was common, although the actual rates were unclear. Pain was commonly reported among adult populations, with almost one fifth reporting widespread pain, one third shoulder pain, and up to one half reporting low back pain in a 1-month period. They stated that the prevalence of pain varies within specific population subgroups; group factors (including socioeconomic status, ethnicity and race) and individual factors (smoking, diet, and psychological status) were all associated with the reporting of musculoskeletal pain.

Musculoskeletal conditions (MSC) are common throughout the world and their impact on individuals is diverse and manifold. Knowledge of the determinants for disability and of strategies for prevention and rehabilitation management according to the scientific evidence is critical for reducing the burden of MSC. Weigl et al.[53] reviewed the evidence for common determinants of functioning and disability in patients with MSC. They focused on environmental factors (EF) and personal factors (PF) and have structured them according to the International Classification of Functioning, Disability and Health (ICF) framework. They also discussed prevention strategies, prevention needs to address those EF and PF. Furthermore they described modern principles of rehabilitation and reviewed the evidence for specific rehabilitation interventions.

Economic impact and lost productivity

Musculoskeletal disorders of the low back and upper extremities is an important and costly health problem. Musculoskeletal disorders account for nearly 70 million physician office visits in the US annually and an estimated 130 million total health care encounters including outpatient, hospital, and emergency room visits. In 1999, nearly 1 million people took time away from work to be treated and recover from work-related musculoskeletal pain. Conservative estimates of the economic burden imposed, as measure by compensation costs, lost wages and lost productivity are between $45-54 billion annually (US Commission on Behavioral and Social Sciences and Education, 2000).

In a national household survey across Great Britain in 1995 estimated that 5.4 million working days are lost annually due to time off work because of work-related neck and upper limb musculoskeletal disorders. That makes approximately 1 month's work is lost annually for each individual case in the UK. The Health and Safety Executive (HSE) in Britain estimated that work-related upper limb disorders incurred an approximate cost of £1.25 billion per year.

In Norway, 15% of all reports are considered to be work-related, 40% in Denmark and Finland, and 70% in Sweden[9]. In Italy, 60% of claims for upper limb musculoskeletal disorders were recognized as occupational diseases and so resulted in compensation.

In France, the percentage of recognized and compensated musculoskeletal disorders compared to total number of occupational ill-health diseases steadily increased from 40% (2602 cases) in 1992 to 63% (5856 cases) in the year 1996[1, 20]. Stated that work-related musculoskeletal disorders of the upper limb accounted for over two-thirds of all occupational disorders recognized in France. Moreover, in France the cost of low back pain was estimated at nearly 1.3 billion Euros in 1990[1].

It is believed that direct costs due to compensated work-related musculoskeletal disorders are only a relatively low proportion (30-50%) of the total costs[8, 18]. Estimated that the direct cost of neck pain in the Netherlands for 1996 was $160 million and the indirect cost was $527 million, where the direct cost was approximately 30% of the indirect cost.

Toomingas[51] estimated that about 20-25% of all expenditure for medical care, sick leave and sickness pensions in the Nordic countries in 1991 were related to conditions of the musculoskeletal system (of which 20-80% were work-related). In Sweden, musculoskeletal conditions constituted 15% of all sick-leave days and 18% of all sickness pensions in 1994 (Statistics Sweden, 1997).

Among work related upper extremity disorders, Carpal Tunnel Syndrome (CTS) has the biggest impact in the professional computer users' health and in the industrial related medical and non-medical costs (Fagarasanu and Kumar[16]. CTS affect over 8 million Americans (U.S. Department of Labor, 1999). From the 37,804 cases of work-related CTS reported in 1994, 7897 (21%) were attributed to repetitive typing or key entry data[48]. In the U.S. alone, approximately 260,000 carpal tunnel release operations are performed each year, with 47% of the cases considered to be work related. Almost half of the carpal tunnel cases resulted in 31 days or more of work loss (U.S. National Center for Health Statistics, 2000). The non-medical costs of a CTS case from compensation settlement and disability average $10,000/hand. This sum is increased by the medical cost and indirect costs that raises it to $20,000-$100,000/hand[48]. Up to 36% of all CTS patients require lifelong medical treatment (U.S. Department of Labor, 1999).

Computers and WRMSDs

In 1984, only 25 percent of the population used computers every day in their jobs. By 1993, that number had climbed considerably to an estimated 45 percent and has continued to climb ever since. The Occupational Safety and Health Administration estimates that over 18 million workers must perform extensive keyboarding as part of their jobs.

Later in 1996, more than 647,000 American workers experienced serious injuries due to overexertion or repetitive motion on the job. These work-related musculoskeletal disorders (WRMSDs) account for 34 percent of lost workday injuries. WRMSDs cost employers an estimated $15 to $20 billion in workers' compensation costs in 1995 and $45 to $60 billion more in indirect costs. (Occupational Safety and Health Administration, Feb 1999)

The US Census Bureau reported that, in the USA (1999), half of the employed adults used a computer in their jobs and the trend still continues (http://www.census.gov/population/pop-profile/1999/chap10.pdf). It has been reported that 27% of office workers who work with a computer have discomfort in the neck and shoulder[40].

More than half of the working population (both males and females) in the European Community use computers in their daily work. Increased computer use time for work purposes leads to an increased incidence of work-related musculoskeletal disorders among computer users. High prevalence of health disturbances has been associated with constrained posture, poor ergonomic design of the work place, exclusive use of input devices as well as of stress related factors[15].

Intensive computer use is associated with an increased risk of neck, shoulder, elbow, wrist and hand pain, paresthesias and numbness. Repetition, forceful exertions, awkward positions and localized contact stress are associated with the development of upper limb cumulative trauma in computer users. The repetitive computer use such as typing on the keyboard and dragging the mouse overload neck, shoulder, arm and hand muscles and joints. As they continue to be overworked cumulative trauma happens[34].

Jensen et al.[23] studied associations between duration of computer and mouse use and musculoskeletal symptoms among computer users. They delivered a questionnaire with a 69% participation rate. Logistic regression analyses on full-time working employees showed that working almost the whole working day with a computer was associated with neck symptoms and shoulder symptoms among women and hand symptoms among men. Among respondents spending almost all of their work time on a computer the gender and age-adjusted odds ratio for mouse use more than half of the work time was 1.68 for hand/wrist symptoms. Call center and data entry workers experienced the lowest possibilities for such development at work.

Blatter and Bonger[7] examined the association between work-related upper limb disorders (WRULDs) and duration of computer and mouse use, to investigate differences in these associations between men and women, and examined whether a possible relationship between duration of computer use and WRULDs was explained by physical or psychosocial risk factors. Participants had filled out a questionnaire on job characteristics, job content, physical workload, psychosocial workload and musculoskeletal symptoms. Working with a computer for more than 6 h/day was associated with WRULDs in all body regions. Their analyses showed that the strength of the associations differed between men and women. In men, only moderate associations were seen for computer use of more than 6 h/day. In women, moderate increases were observed for duration of computer use of more than 4 h/day and strongly increased risks for a computer use for more than 6 h/day.

In their study, Fogleman and Lewis[17] studied the risk factors associated with the self-reported musculoskeletal discomfort in a population of video display terminal (VDT) operators. They collected data via a survey from 292 VDT users, and asked to report on symptoms for six body regions, as well as job requirement information, demographic information, and non-occupational hobbies. They constructed factor analysis to determine descriptive information and logistic regression to estimate the risk. Their results indicated that there is a statistically significant increased risk of discomfort on each of the body regions (head and eyes, neck and upper back, lower back, shoulders, elbows and forearms, and hands and wrists) as the number of hours of keyboard use increases. Moreover, their results showed that improper monitor and keyboard position were significantly associated with head/eye and shoulder/back discomfort, respectively.

Szeto et al.[49] compared the EMG changes and discomforts experienced by a symptomatic and an asymptomatic group of workers when they were challenged by the physical stressors of increased typing speed and increased typing force. They divided the respondents into 2 groups, 21 female office worker in the Case Group, and 20 in the Control Group. The respondents were asked to participate a typing test for 20 minutes in 3 conditions; normal, faster, and harder. The Case group showed trends for higher muscle activities in all three conditions in both upper trapezius and cervical erector spinae muscles. There were greater increases in muscle activities in both groups under “faster” condition, implying that increasing the typing speed was a more difficult demand. They further divided the Case Group into High and Low groups. They realized that it was mainly the High group that showed the greatest changes in terms of muscle activities and discomforts.

Shuval and Donchin[41] examined the relationship between ergonomic risk factors and upper extremity musculoskeletal symptoms in VDT workers, by taking into account individual and work organizational factors, and stress. Their data was derived from a questionnaire responded by 84 workers from computer programmers, managers, administrators, and marketing specialists, while ergonomic data were collected through two direct observations via rapid upper limb assessment (RULA) method. Their results of RULA observations indicated that excessive postural loading with no employee in acceptable postures. Hand/wrist/finger symptoms were related to the RULA arm/wrist score (in a logistic regression model) as well as working with a VDT between 7.1 and 9 hours per day. Neck/shoulder symptoms were related to: gender (female), working more than 10 hours per day, working for more than 2 years in a hi-tech company, and being uncomfortable at the workstation.

Dennerlein and Johnson[14] studied the differences in biomechanical risk factors across different computer tasks: typing text, completing an html-based form with text fields, editing text within a document, sorting and resizing objects in a graphics task and browsing and navigating a series of intranet web pages through participation of 30 touch-typist adults (15 females, and 15 males). Their results indicated that keyboard-intensive tasks were associated with less neutral wrist postures, larger wrist velocities and accelerations and larger dynamic forearm muscle activity. Mouse-intensive tasks (graphics and web page browsing) were associated with less neutral shoulder postures and less variability in forearm muscle activity, larger range of motion and larger velocities and acceleration of the upper arm. Additionally, their results suggested that comparing different types of computer work demonstrates that mouse use is prevalent in most computer tasks and is associated with more constrained and non-neutral postures of the wrist and shoulder compared to keyboard use.

Computer display height and desk design to allow forearm support are two critical design features of workstations for information technology tasks. However there is currently no 3D description of head and neck posture with different computer display heights and no direct comparison to paper based information technology tasks. There is also inconsistent evidence on the effect of forearm support on posture and no evidence on whether these features interact. In their study[46] compared the 3D head, neck and upper limb postures of 18 male and 18 female young adults whilst working with different display and desk design conditions. Their results show that there was no substantial interaction between display height and desk design, and lower display heights increased head and neck flexion with more spinal asymmetry when working with paper. Furthermore the curved desk, designed to provide forearm support, increased scapula elevation or protraction and shoulder flexion / abduction.

Samani et al.[39] evaluated effects of active and passive pauses and investigate the distribution of the trapezius surface electromyographic (SEMG) activity during computer mouse work. Twelve healthy male subjects performed four sessions of computer work for 10 min in one day, with passive (relax) and active (30% maximum voluntary contraction of shoulder elevation) pauses given every 2 min at two different work paces (low/high). Bipolar SEMG from four parts of the trapezius muscle was recorded. The relative rest time was higher for the lower parts compared with the upper of the trapezius ($p < 0.01$). The centroid of exposure variation analysis (EVA) along the time axis was lower during the computer work with active pause compared with passive one ($p < 0.05$). The results of this study revealed (i) lower rest time for the upper parts of trapezius compared with the lower parts, in line with previous clinical findings, (ii) active pauses contributed to a more variable muscle activity pattern during computer work that might have functional implications with respect to work-related musculoskeletal disorders.

Past research on work- related musculoskeletal disorders (WRMSD) has frequently examined the activity of neck–shoulder muscles such as upper trapezius (UT) and cervical erector spinae (CES) during typing tasks. Increased electromyographic activity in these postural stabilising muscles has been consistently found in chronic neck pain patients under different physically stressful conditions[50]. compared muscle activity when female office workers with chronic neck pain ($n = 39$) and asymptomatic controls ($n = 34$) adopted two resting postures: (1) with hands on laps versus; and (2) hands on a keyboard. Their results indicated that resting hands on keyboard elicited significantly increased muscle activity in the right upper trapezius (UT) of subjects with high discomforts ($n = 22$), similar to that observed during actual typing. In contrast, the asymptomatic controls showed no difference in muscle activity between the resting postures. Their results suggested that altered muscle activation patterns were triggered by some anticipatory task demand associated with a task-specific position in some individuals.

Postures

In order to improve the work performance; workplace, working posture, and discomfort are needed to be justified. Liao and Drury[28] demonstrated the interactions between workplace, work duration, discomfort, working posture, as well as performance in a 2 hour typing task. They used three levels of keyboard heights to investigate the effects on working posture, and discomfort (perceived body part discomfort) and performance (typing speed, error rate and error correction rate). Their results showed that the interrelationships among posture-comfort-performance were supported. Moreover, keyboard height had effects on the working posture adopted.

Babski-Reeves et al.[2] studied the effects of monitor height and chair type on low back and neck muscle activity, perceived level of discomfort, and posture shifts. They investigated if chairs at opposing ends of their price spectrum differ in physiological benefits. Their findings indicated that the interaction of monitor height and chair type significantly affects the loads placed on the human body. Task demands also played an important role in the loads placed on the body, posture fixity, and level of discomfort reported. Therefore, they stated that the location of VDT equipment and chair selection should be based on task demands to minimize static loading and discomfort.

Laptop computers were introduced into the workplace for reasons of portability. However laptop computer screens and keyboards are joined, and therefore they are cannot be adjusted separately in terms of screen height and distance, and keyboard height and distance. Straker et al.[44] studied the postural implications of using a laptop computer. Their results showed that there were significantly greater neck flexion and head tilt with laptop use. Trunk, shoulder, elbow, wrist, and scapula did not show any statistical differences. Additionally, the average discomfort experienced after using the laptop for 20 minutes was not significantly greater.

Straker and Mekhora[45] investigated the effects of monitor placement in a group of normal subjects. Ten male and ten female subjects within the working age range volunteered to perform a computing task for 20 min in two different VDU monitor placement conditions; high monitor position (HMP) and a low monitor position (LMP). Postural angles (gaze, head, neck, and trunk), normalized electromyography (upper trapezius and cervical and thoracic erector spinae), discomfort (upper body), and individual preference for monitor placement were determined. Their results indicated that the gaze, head, neck, and trunk angles in the LMP were significantly greater (more flexed) than those in the HMP. There was a trend for lower levels of electromyographic (EMG) activity for trapezius in the HMP. There were significantly lower levels of EMG activity for cervical and thoracic erector spinae in HMP. The results of their study suggested that subjects may use a less flexed head, neck and trunk posture and less cervical and erector spinae muscle activity when working with a HMP.

Notebook computers users reported more constrained posture and higher neck muscle activities than those of desktop computers. Jonai et al.[24] investigated the effects of liquid crystal display (LCD) tilt angle of a notebook computer on posture, muscle activities and somatic complaints in 10 subjects. They found that at the tilt angle of 100^0, the subjects were noted to have relatively less neck flexion. Also, the static neck extensor muscle activity was observed to be the lowest at this tilt angle. Their results strongly suggested that the ergonomic features and problems attributable to notebook computers are distinct from the desktop computers.

There has been substantial research carried out to evaluate the effects of working on a VDT, keyboard and input device using desktop PCs. In response to discomfort, poor posture and restricted movement due to the inability to separate the keyboard and VDT in laptop PCs, "laptopstations" have been introduced to the market. Berkhout et al.[6] studied the effect of using laptopstation and a laptop PC and how this difference in work setup affected the mechanical load on the neck, and productivity. Their results indicated that there was a significant ($p<0.005$) difference with the use of the laptopstation resulting in decreased torque, less perceived strain at the neck and a higher productivity score. Additionally, their results confirm the importance of adjustable work tools that recognize anthropometric differences and biomechanics to meet the needs of individual customers during continuous VDT work.

Cook and Burgess-Limerick[11] examined the effect of three different postures during keyboard use: forearm support, wrist support and floating (no support, used as a reference condition), in order to understand the effect of forearm support on wrist posture. Electromyography was used to monitor neck, shoulder and forearm muscle activity. Their findings indicate that typing with upper extremity support in conjunction with a wrist may be preferable to the floating posture.

Supporting the forearm on the work surface during keyboard operation may increase comfort, decrease muscular load of the neck and shoulders, and decrease the time spent in ulnar deviation. Cook and Burgess-Limerick[11] investigated the musculoskeletal discomfort effects of using forearm support in intensive computer users in a call center. A controlled study was conducted on 59 subjects; group 1 with forearm support, group 2 with "floating" posture. Their results showed that there were significantly fewer reports of discomfort in the neck and back, although the difference between the groups was not statistically significant. Therefore, their findings indicate that forearm support may be preferable to the "floating" posture for computer workstation setup.

Musculoskeletal problems reported by school children using computers have often been linked to bad posture. In their study, Robbins et al.[37] investigated whether posture education affects the reported prevalence of musculoskeletal symptoms amongst secondary school children using computers. They designed a prospective blinded randomized controlled trial. The participants in their study were seventy-one school children aged 11–12 years divided into intervention (n = 37) and control (n = 34) groups. They assessed both groups received posture training delivered by teachers at the school and on their knowledge of correct posture. Then they gave a follow-up lesson 1 week later during which the intervention group also received automated posture warnings and tips on their personal computers. They noted the prevalence and severity of musculoskeletal symptoms were measured at the start of the study and at the start and end of the follow-up lesson and any differences between the two groups found over the course of the 60 min follow-up lesson. Their results indicated that by the end of the follow-up lesson, the mean visual analogue pain scale representation of the degree of discomfort due to the musculoskeletal problems fell significantly from 1.53 to 0.39 for the intervention group, while that for the control group only fell from 1.23 to 1.13 (non-significant). Furthermore, their overall incidence of musculoskeletal problems in the intervention group showed a greater trend towards reduction, falling significantly from 32.4% to 5.4% compared with the control group, which fell from 29.4% to 20.59% (non-significant).

Psychosocial factors

Work-related musculoskeletal disorders (WRMSD) have a multifactorial etiology that includes not only physical stressors but also psychosocial risk factors, such as job strain, social support at work, and job dissatisfaction. Once an injury has occurred, psychosocial factors, such as depression and maladaptive pain responses, are pivotal in the transition from acute to chronic pain and the development of disability[33].

Hudiburg, Pashaj, and Wolfe[21] reported that preliminary studies have focused more on the outcomes of human-computer interactions and less on the personal characteristics of the computer users. Costa and McCrae[12] extended the dimensions of personality traits of Eysenck and Eysenck to five broad traits: Neuroticism, Extraversion, Openness to Experience, Agreeableness and Conscientiousness. In order to evaluate the computer use and knowledge of the participants, a research questionnaire was constructed with three scales: the Computer Hassles Scale, SCL-90, and the Big Five Inventory. The Computer Hassles Scale was significantly correlated with somatization or anxiety rating. The Big Five personality traits yielded only a few significant correlations with computer users' stress and stress outcomes. Only Openness was significantly correlated with the Computer Hassles Score. Only Neuroticism was significantly correlated with the somatization or anxiety ratings.

MIT has a continued interest on human-machine interaction. During interaction with computers, humans encounter unpleasant side effects, which lead to strong, negative emotional states. Frustration, confusion, anger, anxiety can affect not only the interaction itself, but also productivity, learning, social relationships, and overall well-being. A design was conducted by Klein[26] at MIT to study frustration in human subjects by using social, emotional content feedback strategies to help to relieve their emotional state. The results show that social, emotional content interaction with a computer, users experiencing frustration can help to relieve this negative state.

Suh[47] indicated that, with the introduction of computer-based technology to the office work environment, the concern for adverse mental and physical health outcomes of office workers became a primary issue in job stress research. Complaints of visual discomfort, muscular aches, and psychological disturbances aroused by unhealthy working conditions with the increased dependency on technology. Preliminary researches have studied the linkage between work factors to musculoskeletal discomfort and stress. It was suggested that these factors are combined in a system to create stressinducing situations, which result in musculoskeletal disorders. A research was constructed to test the conceptual model of risk perception in the work organization. The model assumes that individual's perception of work-related risk has a significant impact on the outcome of stress. A tool for measuring risk perception, with its degree of contribution to musculoskeletal discomfort and stress explored the primary tasks in the study.

Carayon et al.[10] proposed several pathways for a theoretical relationship between job stress and WRMSDs. These pathways highlight the physiological, psychological, and behavioral reactions to stress that can affect WRMSDs directly and indirectly. Their model stipulates that psychosocial work factors (e.g. work pressure, lack of control), which can cause stress, might also influence or be related to ergonomic factors such as force, repetition, and posture that have been identified as risk factors for WRMSDs.

Peper et al.[35] reviewed the ergonomic and psychosocial factors that affect musculoskeletal disorders at the workstation. Thus, they constructed three different methods, where the participants were asked to work on a computer. First was a model of a physiological assessment protocol that incorporated surface-electromyography (SEMG) monitoring while working on a computer. The participants had ergonomic chairs, document holders and foot supports, and obtained an ergonomically comfortable position. They used a typing test, where a word appears directly above an edit box, and the participants were asked to type that given word. SEMG was monitored from four muscle locations. The results showed that there was a significant difference in right forearm extensor-flexor muscle tension and in right upper trapezius muscle tension between type tasks and rest. Also, there was a significant increase in respiration rate from resting to type tasks. Second was a study that showed that participants lack of awareness of their muscle tension as compared to the actual SEMG levels. This time, the keyboard was placed on a tray that could be moved forward or backward and locked into position. The moveable keyboard tray was marked with five positions at 4.5 cm intervals. The participants were monitored during sequential non-typing and typing tasks. Participants rated shoulder, forearm, trapezius and deltoid muscle tensions significantly higher during typing than during non-typing. Their final study illustrated how an intervention program can reduce repetitive strain injury symptoms, decrease respiration rate, and lower SEMG activity. This time, the participants performed the following sequence in two phases, without training and with training: sitting quietly with hands in lap, hand resting on mouse, tracking task (using the mouse), a correcting task (using again the mouse), hand resting on the mouse, and hands resting on lap. The intervention study demonstrated that, the participants could learn to lower trapezius SEMG activity and respiration rate and reduce symptoms of repetitive strain injury.

Sprigg et al.[42] discussed that the demands of the modern office are thought to contribute to the development of musculoskeletal disorders. According to them, for upper body and lower back disorders, these effects were hypothesized to be mediated by psychological strain. They made a study of 936 employees from 22 call centers which supports this hypothesis. Using logistic regression and structural equation modeling, they found that the relationship of workload to upper body and lower back musculoskeletal disorders was largely accounted for by job-related strain. This mediating effect was less evident for arm disorders. On the other hand, they showed that job autonomy had neither a direct nor a moderating effect on any musculoskeletal disorder.

Physical factors

Coury et al.[13] investigated the influence of gender on work-related musculoskeletal disorders in repetitive task. They compared WRMSDs symptoms for female and male workers doing the same repetitive industrial tasks. Logistic regression analysis indicated that symptoms were primarily influenced by the work done. Symptoms were secondarily influenced by gender, job tenure, and age. When compared within the same age group or in the same job tenure, they found that, there was no significant difference in symptoms between male and female workers. Thus, according to them, when confronting poor working conditions, replacements of female workers by male workers is a worthless strategy to control WRMSDs.

Karlqvist et al.[25] studied the prevalence of musculoskeletal symptoms among male and female VDU operators, and the associations between work-related physical and psychosocial exposures and neck and upper limb symptoms by gender. They collected data on physical and psychosocial exposures and musculoskeletal symptoms by questionnaires. Their results showed that 19% of women (n=785) and 12% of men (n=498) did more than 3 hours of continued computer work without breaks of more than 10 minutes at least twice a week. Men experienced high job strain twice as women. Additionally, a higher proportion of women than men reported symptoms more at least 3 days the preceding month from the upper body. Their results also indicated that duration of computer work was associated with symptoms among both men and women. Only among men, duration of work with a non-keyboard computer input device was associated with symptoms. Only among women, job strain was associated with the symptoms. Time pressure was found to be associated with higher prevalence of symptoms among women. Women experienced higher prevalence of symptoms than men in all body regions and they were more often exposed to physical and psychosocial conditions.

Balcý and Aghazadeh[4] introduced the consideration of proper work-rest schedule to help to reduce the musculoskeletal disorders for VDT operators. Their study compared work-rest schedules (60 min work/10 min rest, 30 min work/5 min rest, 15 min work/ micro-breaks) for VDT operators considering data entry and mental arithmetic tasks. Ten participants were chosen among male college students and the methodology of the study included a discomfort questionnaire and performance measures. Their results indicated that the 15/micro-breaks schedule resulted in significantly lower discomfort in the neck, lower back, and chest than the other schedules. The 30/5 schedule followed by 15/ micro-break schedule were found to have the lowest eyestrain and blurred vision. In addition, discomfort in the elbow and arm was found to be lowest with the 15/ micro-breaks schedule for the mental arithmetic task. The 15/micro-break schedule resulted in the highest speed, accuracy, and performance for both of the tasks. Moreover, their results showed that the data entry task resulted in significantly increased speed, accuracy, and performance, and lower shoulder and chest discomfort than the mental arithmetic task.

Village et al.[52] worked on high injury rates in Intermediate Care (IC) facilities and the unclear factors related to these injuries. Their objectives of this exploratory sub-study, which was part of a large multi-faceted study in 8 IC facilities were to: (1) evaluate EMG measured over a full-shift in the back and shoulders of 32 care aides (CAs) as an indicator of peak and cumulative workload (n=4×8 facilities); investigate the relationship between EMG measures and injury indicators; and explore the relationship between EMG measures and other workload measurements. They converted lumbar EMG predicted cumulative spinal compression and ranged in CAs from 11.7 to 22.8 MN s with a mean of 16.4 MN s. Their results indicated that the average compression was significantly different during different periods of the day (p<0.001) with highest compression during pre-breakfast when CAs assist most with activities of daily living. Significant differences were found in average compression between low and high injury facilities for 3 of 5 periods of the day (p<0.010). Peak compressions exceeding 3400 N occurred for very little of the workday (e.g. 11.25 s during the 75 min period pre-breakfast). In their study the peak neck/shoulder muscle activity was low (99% APDF ranged from 8.33% to 28% MVC). They also indicated that peak and cumulative spinal compression were significantly correlated with lost-time and musculoskeletal injury rates as well as with total tasks observed in the CAs (p<0.01), perceived exertion was only correlated with peak compressions (p<0.01). Also they stated facilities with low injury rates provided significantly more CAs (p<0.01) to meet resident needs, and subsequently CAs performed fewer tasks, resulting in less peak and cumulative spinal loading over the day.

Menegaldo et al.[32] showed a new method to estimate the muscle forces in musculoskeletal systems based on the inverse dynamics of a multi-body system associated optimal control. Their redundant actuator problem was solved by minimizing a time-integral cost function, augmented with a torque-tracking error function, and muscle dynamics is considered through differential constraints. Their method was compared to a previously implemented human posture control problem, solved using a Forward Dynamics Optimal Control approach and to classical static optimization, with two different objective functions. Their new method provided very similar muscle force patterns when compared to the forward dynamics solution, but the computational cost was much smaller and the numerical robustness was higher. Their results achieved suggested that this method was more accurate for the muscle force predictions when compared to static optimization, and can be used as a numerically 'cheap' alternative to the forward dynamics and optimal control in some applications.

Helland et al.[19] investigated the effect of moving from single occupancy offices to a landscape environment. Thirty-four Visual Display Unit (VDU) operators reported significantly worsened condition of lighting and glare in addition to increased visual discomfort. Their results showed that for visual discomfort, the difference with 95% confidence interval was 10.7 (1.9–19.5) Visual Analog Scale (VAS) as group mean value. They indicated that the operators were glared from high luminance from the windows, when the Venetian blinds were not properly used. Moreover, according to their results glare was significantly correlated with visual discomfort, r_s=0.35 and both illuminance and luminance in the work area, and contrast reduction on the VDU screen were in line with recommendations from CIE for VDU work. Through a regression analysis, they showed that the visual discomfort explained 53% of the variance in the neck and shoulder pain. They found a marked drop in eye blink rate during VDU work when this was compared to "easy conversation" (VDU work, mean=9.7 blinks per minute; "easy conversation," mean=21.4 blinks per minute) for 12 randomly selected operators from the 34 participants. In their study, participants reported many of the organizational and psychosocial conditions and work factors worse when landscape office was compared to single occupancy office. It was indicated that these factors may have influenced the musculoskeletal pain. However, the pain level was still low at 6 years and not significantly different when compared with the start of the study period, except for a small but significant increase in shoulder pain. In their study, visual discomfort was clearly associated with pain in the neck and shoulder area.

Psychological factors

Steingrímsdóttir et al.[43] studied the relationship between musculoskeletal or psychological complaints and muscular responses to standardized cognitive and motor tasks. Their design examined (i) whether complaint severity predicts muscular responses during standardized tasks and (ii) whether the muscular responses predict changes in complaint severity over one year. They recorded musculoskeletal and psychological complaints by monthly reports for four months preceding and 12 months succeeding a work session in the laboratory; complaint-severity indices were computed from complaint-severity scores (intensity score × duration score). They also recorded surface electromyography (EMG) bilaterally from the upper trapezius, middle deltoid, and forearm extensor muscles in 45 post-office workers (30 women) during two identical task series. Between the series, they performed exhausting submaximal muscle contractions (25% of peak torque). In their adjusted regression models, no relations between musculoskeletal complaints during the previous four months and muscle activity during the task series were found. However, in their study psychological complaints in the last four months predicted higher muscle activity levels and a steeper rise in muscle activity in the muscles not engaged in motor task performance. Their results also showed that sleep disturbance was the strongest individual predictor of increased muscle responses. In contrast, they predicted psychological complaints the last four months lower EMG levels in the task-engaged muscle during the complex-choice-reaction-time tasks. Moreover, they stated that none of the muscle-activity responses to the standardized tasks predicted changes in severity of musculoskeletal or psychological complaints over the subsequent one-year period.

Effect of interventions

It was shown that there was a US $17.8 return on investment for every dollar invested in an ergonomics intervention strategy. As a result of the redesign of an assembly line process, the worker compensation costs for work-related musculoskeletal disorders were reduced from $94,000 to $12,000 in a telecommunications organization. Between 1990 and 1994, ergonomics intervention saved $1.48 million in worker compensation costs for the same organization[21].

Mekhora et al.[31] investigated the long-term effects of ergonomic intervention on neck and shoulder discomfort among computer users who have symptoms of tension neck syndrome, using simple materials and protocols. They conducted two pre-tests to determine subjects' level of discomfort before the planned intervention commenced. Discomfort evaluations (head, neck, shoulders, arms, and back) were conducted eight times within 6 months for both groups. The same patterns of decrease in the levels of discomfort of all body parts were present in both groups. They observed substantial variation in the level of discomfort over time for each body part in each subject after the intervention. However, the mean levels of discomfort ratings before and after receiving intervention were significantly different. They concluded that ergonomic intervention can help reduce the discomfort level of subjects with tension neck syndrome.

Lewis et al.[27] assessed the effectiveness of an office ergonomics training program for VDT users in their study. They examined the worker compensation costs and injury rates for the VDT related musculoskeletal disorders before and after implementation of training at two company locations. The average cost per claim was considerably reduced from $15,141 in the pre-intervention period to $1,553 in the post-intervention period. The average injury rate also reduced in the post (6.94 per 1000 employees) versus pre-intervention period (16.8 per 1000 employees).

Baldwin[5] analyzed the problem of chronic disability associated with musculoskeletal disorders from an economic perspective, focusing on the small fraction cases with extraordinarily high costs. She reviewed the evidence on the costs of musculoskeletal disorders in general, and back pain in particular, identifying the sources of disproportionately high costs. Then, focusing on work-related back cases, she reviews the empirical evidence on workplace characteristics and economic incentives associated with long term disability and large productivity losses.

Lin and Chan[29] studied the effect of ergonomic workstation design on musculoskeletal risk factors (MRFs) and musculoskeletal symptoms (MSSs) reduction among female semiconductor fabrication room (fab) worker. They conducted a prospective study to follow up 40 female fab workers over 3 months after intervention. The intervention program focused on reducing shoulder loadings for 20 female fab workers by redesigning nine workstations. They made simultaneous comparisons for the other 20 female fab workers using original workstations. They used one customized observation checklist and Nordic musculoskeletal questionnaire to evaluate workers' MRFs and MSSs, respectively. They found that one month after intervention, MRFs of awkward shoulder postures and repetitive motions and MSSs in shoulders for the intervention group were significantly lower than those for the control group. The lowering effects persisted for 3 months on awkward shoulder postures but lasted for only 1 month on repetitive motions and shoulder symptoms after intervention.

Robertson et al.[38] undertook a large-scale field intervention study to examine the effects of office ergonomics training coupled with a highly adjustable chair on office workers' knowledge and musculoskeletal risks. They assigned office workers to one of three study groups: a group receiving the training and adjustable chair (*n*=96), a training-only group (*n*=63), and a control group (*n*=57). They created office ergonomics training program using an instructional systems design model and they administered a pre/post-training knowledge test to all those who attended the training. They observed body postures and workstation set-ups before and after the intervention. Their results indicated that perceived control over the physical work environment was higher for both intervention groups as compared to workers in the control group. Also, they observed a significant increase in overall ergonomic knowledge for the intervention groups. Their both intervention groups exhibited higher level behavioral translation and had lower musculoskeletal risk than the control group.

CONCLUSION

Musculoskeletal disorders have been observed and experienced widely at workplaces where the computers are frequently used. Increase in the number of employees working with computer and mouse coincides with an increase of work-related musculoskeletal disorders (WRMSDs) and sick leave, which affects the physical health of workers and pose financial burdens on the companies, governmental and non-governmental organizations.

There are extensive and detailed studies on the WRMSDs in the literature. However, none of the studies in the literature provides a comprehensive description, causes of the WRMSDs, and throughout investigation of the previous researches. This chapter fills the gap in the literature by providing the researchers proper guidelines, and in-depth description of the previous studies in the area.

The literature on WRMSDs due to computer use has focused on the gender differences, physical and psychological aspects of the user and no study yet considered a comprehensive review of these disorders. This study presents the idea of understanding the nature of WRMSDs due to computer use from a broad angle, provides a very useful resource for the researchers who work on this field, and fills an important gap in the literature.

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