CHAPTER 3

CRITICAL MUSCULOSKELETAL DISORDER
RISK FACTORS

3.1 INTRODUCTION

Technological advances, particularly, invention of computers, have revolutionized our way of working. Computer has become an integral part of our life. However, its use is not free from health hazards. Intensive computer work puts stress and strain on muscles, as well as joints, because of continuous and repetitive nature of movements. In Video Display Terminal work, the muscular activity of the neck and shoulders resists the gravity acting on the forward flexed head while the worker views the screen. The bones and joints of the upper limb have to be stabilized by the muscles to enable exact movements of the fingers and hands. If there is no mechanical support for the forearm, the shoulder muscles must hold the weight of the whole upper limb and this further increases muscle tension (Mc Donald 2000). Computer intensive workplaces report a high prevalence and incidence of musculoskeletal disorders among the workers (Bergvist et al 1995, Faucette and Rempel 1994, Punnett and Bergqvist 1997, Tittiranonda et al 1999). Punnett and Bergqvist (1997) in their review of epidemiological studies of VDT work indicated higher risk of neck, shoulder, arm, wrist and hand musculoskeletal illness compared with non-VDU work.
3.2 DEFINITION OF ERGONOMICS

In August 2000, the International Ergonomics Association (IEA) council adopted an official definition of the discipline of ergonomics. This states that ‘ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance’. Those engaged in ergonomics and human engineering have long since recognized that the preferred route for preventing problems and enhancing performance in systems is through a design or redesign process. This may require a consideration of a range of issues. These include the system goals, the task collection, the equipment design, interactions between sets of equipment and groups of people, the work organization and the job design.

3.3 EARLIER MUSCULOSKELETAL DISORDERS MODELS TO VDT WORK

3.3.1 Dose – Response model

Armstrong (1993) presented a conceptual model for the pathogenesis of work-related musculoskeletal disorders. The model contains sets of cascading exposure, dose, capacity and response variables, such that response at one level can act as dose at the next. Response to one or more doses can diminish or increase the capacity for responding to successive doses. The model is used as a framework for discussing the development of work-related muscle, tendon, and nerve disorders. In practice, it demonstrates the relationship between common exposure factors and different responses. The dose-response model includes the factors and processes that result in
work-related neck and upper-limb disorders. Figure 3.1 represents the Dose – Response relationship.

![Figure 3.1 Dose - Response Model](image)

**Exposures and Response variables**

As conceptualized in the model by Armstrong (1993), the characterization of work related musculoskeletal disorders in general and muscle, tendon and nerve disorders, in particular, according to sets of cascading exposure and response variables are discussed below:

**Muscle Disorders**

Exposure-dose: Muscle force, Muscle velocity, frequency and duration
Response: Membrane permeability, Ion flow, Membrane action potentials, Energy turnover (metabolism) muscle enzymes and energy stores, Intramuscular pressure, Ion imbalances, Reduced substrates, Increased metabolites and water, Increase in blood pressure, Heart rate, Cardiac output, Muscle blood flow, Muscle fatigue, Pain, Free radicals, Membrane damage, Z-disc ruptures and Afferent activation.

**Tendon disorders**

Exposure: Muscle force, Muscle length, Muscle velocity, Frequency, Joint position, Compartment and pressure.

Response: Stress, Strain (elastic & viscous), Microruptures, Necrosis, Inflammation, Fibrosis, Adhesions, Swelling and pain.

**Nerve disorders**

Exposure: Muscle force, Muscle length, Muscle velocity, Frequency, Joint position, Compartment and pressure.

Response: Stress, Strain, Ruptures in perineural tissue, Protein leakage in nerve trunks, Edema, Increased pressure, Impaired blood flow, Numbness, tingling, Conduction block, Nerve action potentials.

**3.3.2 Bongers Model**

The Bongers Model (1993) was designed to test the relationship between psychosocial factors at work and the prevalence of MSD. The concepts used in the model includes
i) Psychosocial factors at work directly influence the mechanical load through changes in posture, movement and exerted forces.

ii) Psychosocial factors at work (demands and factors such as job control and social support), together with the personal capacity to cope with such factors, may increase work-related stress.

Thus stress may either increase musculoskeletal signs in itself or increase the perception of symptoms due to other risk factors. Figure 3.2 provides a structure for the discussion of possible association between psychosocial factors and musculoskeletal disorders.

Figure 3.2 Possible association of psychosocial factors at work with stress and musculoskeletal symptoms
The five psychosocial categories are represented in the model and its factors are given below:

**Category 1-Psychosocial factors at work – Demands and control**

Factor – Monotonous work, Time pressure, High concentration, High responsibilities, High work load, Few opportunities to take breaks, Lack of clarity, Low control and Little autonomy.

**Category 2-Psychosocial factors at work – Social support**

Factors – Poor social support from colleagues, Poor social support from superiors

**Category 3- Individual characteristics**

Factors – Personality type (Neuroticism, Hysteria), Extrovert personality, Psychological dysfunctioning (Depression), Coping styles, Attitude towards own health, Low social class and Low educational level.

**Category 4- Stress symptoms**

Factors – Worry, Tension, Anxiety, Physical stress symptoms, Fatigue or exhaustion, High perceived work stress, Low job satisfaction and Physiological parameters

**Category 5- Physical and behavioral health indicators**

Factors – Poor physical health, Respiratory disease or cough, Stomach trouble, Cardiovascular disease, Head ache, Use of medication and Use of medical services.
3.3.3 Klussman’s Model for MSD

The factors responsible for MSD prevalence among VDT users are represented in Klusman’s Model (2008). The author has grouped the factors into four major categories as shown in Figure 3.3. The four major categories are individual factors, workplace factors, psychosocial factors and features of workstation.

![Figure 3.3 Klussman’s model](image)

3.4 RELATIONSHIP BETWEEN ERGONOMIC RISK FACTORS AND THE PREVALENCE OF MSD

Earlier models of the causation of MSDs characterized worker activity as movements and exerted forces that lead to the generation of internal forces within the body (Armstrong et al 1993). The Bonger’s model discusses the importance of psychosocial factors at work as well as psychosocial personal factors influencing MSD among VDT users. These psychosocial work factors may also influence the biomechanical load and / or the reactions to workplace stress (Bonger’s et al 1993). The working situation derives from the organization of work (work organization factors) and the perceptions or beliefs held by workers regarding the way the work is
organized (Psychosocial work factors). This has led to models and scientific evidence indicating that work organization and psychosocial work factors are associated with the development of work-related MSDs (Carayon et al. 1999, Smith et al. 1996).

There are theoretical reasons to believe the work organization factors can play a role in the report and development of WRMDs (Sauter and Swanson 1996, Smith and Carayon 1996, Carayon et al. 1999). Several models have been proposed for this theoretical relationship (Smith and Carayon 1996, Carayon et al. 1999). One model stipulates that work organization factors that can cause psychological stress may influence or be related to ergonomic stressors, such as force, posture and repetitiveness, which can influence WRMDs. Another model highlights the physiological, psychological and behavioural stress reactions to psychosocial work stressors that can affect WRMDs directly and indirectly. These models are discussed by Smith and Carayon (1996), Carayon et al. 1999 and Sauter and Swanson (1996) to show the theoretical relationship between WRMDs and work organization. There is inadequate research to know precisely what is the role of psychosocial work stressors in WRMDs and whether it is significant. Work organization factors are seen as the objective aspects of how work is organized, supervised and carried out. Psychosocial work factors are the individual subjective perceptions of the work organization factors.


Work organization determines, eg. Work pace, repetitiveness, duration of exposures and recovery time as well as psychosocial dimensions of the work environment such as decision latitude, psychosocial job demands, and social support from supervisors and among co-workers. High psychological work demands typically involve both rapid physical work pace and feelings of time pressure. Highly stereotyped finger motion patterns occur when a manual job both is monotonous and offers little decision autonomy (Punnett and Herbert 2000).

Several epidemiological studies show that intensive computer work and factors related to work organization, as well as physical and psychosocial exposures in computer work, are associated with increased risk of neck and upper extremity disorders (Tittiranonda et al 1999, Ekman et al 2000, Wigaeus Tornqvist et al 2001). Exposures relevant to the occurrence of musculoskeletal disorders include both physical workload and the organization of work in general (Punnett and Herbert 2000).

Individual factors, prolonged awkward postures, poor workstation design and psycho-social environment can lead to development of symptoms of musculoskeletal discomfort (MSD). If these symptoms are ignored and if no preventive measures are taken, MSD such as myalgia, myofascial syndromes, nerve entrapment syndromes, tendonitis, epicondilities and tenosynovitis can develop.

3.5 GENERAL VDT STANDARDS

When people think of workplace safety hazards, chances are there that the computers don’t pop into their heads immediately as a threat to health
and safety. However, spending long periods in front of the computer, whether you’re surfing the Internet, playing games, or working, can begin to take a toll on the body. Some of the ways using a computer often affects the body includes strained eyes and headaches, back and neck problems, carpal tunnel syndrome, and poor posture, which leads to other problems.

One of the best ways to keep the computer from damaging the health is through computer ergonomics. Computer ergonomics consists of placing the computer, desk, chair, and other components of the workstation in certain ways in order to best minimize the risks of those who are on their computer a lot. An ideal check list for testing ideal computer ergonomics is given in Appendix III.

The following are the ideal computer ergonomics for those who are on their computer a lot:

3.5.1 Workstation

The workstation typically consists of desk or the table on which the computer and other things are kept. The desk should be high or low enough that we don’t have to hunch over or reach up uncomfortably to reach the keyboard or other things on the desk. In addition, it should have enough space for legs to fit underneath without having to turn to avoid knocking into drawers or other parts of the desk. The workstation should also have adequate space for keeping phone, papers, documents, and other things without crowding. A typical workstation is shown in Figure 3.4.

3.5.2 Keyboard/Mouse Height

The height of the keyboard and mouse should allow the user to sit with shoulders relaxed, elbows bent, and forearms, wrists, and hands
approximately parallel to the floor. The keyboard angle should be adjusted to promote a neutral/flat position of the wrists. This may be achieved in a number or combination of ways, such as:

- a bi-level table easily adjustable for screen and keyboard height.

- a lower or higher table that promotes a straight wrist while keying (i.e., a table height approximately two inches below the user's elbow).

- a height-adjustable keyboard tray that can be attached to existing desk or table and provides both the appropriate keyboard/mouse height and adequate leg room for the user.

- a mouse tray.

- a chair that is height-adjustable (may need to provide footrest).

- a keyboard that is detachable from the monitor and adjustable for angle.
3.5.3 Screen Height

The top of the display screen should be approximately at, but no higher than, eye level; lower and possibly closer for bi-focal wearers. The user should not have to assume awkward neck postures to view the screen or hard-copy documents. Retrofitting options include the following:

- Bi-level table adjustable for screen and keyboard height.
- Base monitor by putting it on top of hard disk drive, boxes, or books.
- Lower monitor by removing it from the hard disk drive or other platform.
- Adjustable monitor arm.
3.5.4 Firm Posture Support

Chairs should firmly support a comfortable posture, providing support to the lower-back region and avoiding pressure on the back of the thighs. Retrofitting may include a number or combination of options such as:

- Chair adjustable for height and tilt of seat pan and backrest. VDT users should be able to adjust chairs from seated position without use of tools.

- Armrests, if provided, should be height adjustable or removable to avoid interfering with natural movement of the arms.

- Lumbar-support cushion if chair does not provide adequate lower back support.

- Seat cushion or seat wedge.

- Footrest if VDT user's feet do not rest firmly and comfortably on the floor.

3.5.5 Wrist Support

Wrist rests may be helpful in promoting a neutral/flat position of the wrists. Retrofitting options include:

- Padded, movable wrist rest, same height as keyboard home row.

- A cushioned mouse pad.
3.5.6 Accessories

Workstation accessories can prevent awkward neck positions. Accessories that should be provided if needed include:

- Document holders adjustable to screen height for users who type from hard copy documents.
- Lightweight telephone headsets for users assigned to continuous telephone work in conjunction with VDT use.

3.5.7 Lighting

Overhead lights, windows, or other light sources may contribute to visual discomfort. It is generally recommended that room lighting for use of VDTs with dark background screens be lowered to about half of normal office lighting. External sources of light (windows, overhead lights, etc.) should not be in the visual field of the VDT user, nor should their reflections be visible on the screen. To eliminate the bright sources one of the following ways can be followed.

- Use of blinds or curtains over windows when necessary.
- Positioning the monitor screen at right angle to window.
- Turning off some overhead lights; use of task lighting, if needed.
- Removing every other fluorescent bulb, if necessary.
- Positioning monitors to avoid direct light in user's eyes.
3.5.8 Screen Reflections

Reflections on the screen can reduce the text visibility by decreasing screen contrast. By turning off the computer, visualize the bright reflections on the screen. To eliminate these reflections any one of the following methods can be used.

- Positioning the monitor to avoid direct light on user's screen.
- Use of blinds or curtains over windows when necessary.
- Positioning screen between banks of overhead lights.
- Positioning the monitor screen at right angle to window.
- Making cardboard glare hood for top of monitor.
- Use of glare screen (glass preferred).

3.6 FACTORS CONSIDERED IN THE PROPOSED MODEL

The proposed model contains items including socio demographic factors (e.g. age, gender, physical activity, smoking habits), musculoskeletal symptoms (e.g. prevalence, disability), items about viewing (e.g. use of corrective lenses or glasses), kind and extent of VDT work (e.g. daily proportion of typing, data entry, monitoring job rotation), general working conditions (e.g. time pressure, shift work, working posture) and psychosocial factors (e.g. job satisfaction, cognitive demands, influence of work). The studied outcome “generally reduced productivity” was measured by the items under prevention to job due to MSD prevalence.

The model was constructed with variables related to working conditions like working hours, work content, physical exposure and psychosocial exposures and items about comfort of work environment. The
musculoskeletal symptoms are referred to the pain in the neck, upper back, lower back, shoulder, elbow, wrist and hand. The various items included in the present study are discussed in detail below:

**Body mass index**

Body mass index (BMI) is categorized into Normal Weight, Over weight and Obesity.

**Physical activity**

Physical activity is categorized into doing physical activity and not doing physical activity.

**Smoking**

Smoking is categorized into current smoker and non smoker.

**Keyboard**

Risk factors associated with computer use include physical ergonomic factors such as keyboard, chair and monitor heights, working postures and organizational factors such as duration of computer use per day and psychosocial factors such as stress. Discomfort of the upper extremities has been associated with the use of input devices such as the keyboard and mouse. In a recent prospective epidemiological study of computer users, Marcus et al (2002) reported use of the keyboard placed more than 12cm from the edge of the desk was associated with a lower risk of hand-arm symptoms. Keyboard height was adjusted so that the participants forearms were approximately parallel to the ground.
Arm Support

Working without arm support has been proposed as one of the causal factors of neck and shoulder and arm hand diagnoses (Maeda 1977, Bergqvist et al 1995). Despite this, the traditional floating “posture in which a neutral wrist posture is maintained without supporting the arms is still widely used. Aaras et al (2001) reported a significant decrease in neck, shoulder and back discomfort in a group of computer users who were able to support their whole forearm and hand on a concave workstation. In a laboratory study, forearm support using a conventional desk was also found to result in significantly less ulnar deviation, less time spent in an extreme wrist posture and fewer reports of discomfort. Supporting the forearm on the work surface may decrease discomfort, decrease harmful wrist posture for keyboard and mouse users. Armrests were adjusted to form a 90° angle at the elbow.

Document Holder

Dynamic and sit / stand chairs will lead to more variation in posture and comfort. The use of document holders, a correct placement of the screen and adjustable chair will reduce the neck load.

Work Environment

Important factors for designing the lighting systems and the workplace, as well as procedure for optometric corrections of VDU workers are given by Aaras et al (2000).

Monitor Height

Monitor Height is defined by the viewing angle created between the users sitting eye height and top half of the monitor screen. Optimal monitor height placement continues to be debated as monitor placement represents a
comprise between the visual and musculoskeletal systems. Psihogios et al (2001) reviewed the literature and specified the monitor height can be classified as high or low monitor placements. Results from the studies they reviewed indicated that high monitor placements have been reported to allow for better viewing angles, less neck flexion and extensions, wider range of neck mobility, lower muscle loads in the shoulder and upper back region and decreased reports of discomfort (Kumar 1994) while low monitor heights are reported to promote decreased muscle loads in the neck, improved neck postures, better overall working postures, and decreased reports of discomfort (Villanueva et al 1996). Psihogios et al 2001 have identified discomfort associated with low monitor heights. Therefore, while general recommendations can be made on “optimal” monitor heights; there are significant gaps in the literature and sufficient inconsistencies in the literature to question the appropriateness of these recommendations.

Psychosocial Aspect

Many researchers have documented that psychosocial factors influence the musculoskeletal pain. Psychosocial factors have been reported to have a significant effect on reported musculoskeletal symptoms (Stock 1991, Hales et al 1994, Gerr et al 1996, Buckle 1997).

Posture

Neutral posture is defined as the back being upright (i.e. head, shoulders and tailbone in a straight line). Posture shifts consisted of deviations from neutral and were classified according to the direction (move forward, move back, move side, move up and other) and body part (neck, back, other [feet, shoulders, etc]). Although there is variety in the preferred postures among different keyboard users, research suggests that each individual’s neck, shoulder and arm postures relatively stable and unchanging during
Keyboarding, wrist and hand postures also tend to be asymmetrical, with the left wrist having greater ulnar deviation than the right (Grandjean et al. 1983).

**Musculoskeletal Pain**

Musculoskeletal pain is not a clear event in time that happens at one time-point, for example as death due to cancer or a first time stroke. The pain comes and goes and this could be called recurrent pain. The pain could also be long lasting, even of the intensity sometimes varies, and this could be called persistent pain. In the present study, the course of pain could have either of these qualities. The term ‘ongoing pain’ is here defined as pain that was present during one year or part of that year. That is, ongoing pain could be either recurrent or persistent pain. Developing pain is here defined as when responders had no pain or only experienced pain periods lasting less than 7 days. The MSD prevalence testing questions were constructed in which the human body is divided into nine anatomical regions. These regions were selected on the basis of the criteria that the regions where symptoms tend to accumulate.

Back pain has been identified as the most prevalent and costly work-related musculoskeletal disorder (WRMSD). It is estimated that approximately 75% of all workers in industrial countries are employed in sedentary jobs with about 35% of these persons reporting back pain. Although neck pain accounts for a much smaller percentage of WMSDs than back pain, it has been frequently studied, especially for sedentary job tasks associated with significant amounts of computer usage. Numerous studies of VDT workstations have investigated the impact of chair design parameters and VDT equipment positioning on back pain and neck pain respectively. Studies have evaluated the influence of numerous chair parameters on the development of back pain, including seat type, seat height, back rest type, back rest angle (Grandjean et al. 1983), lumbar support and presence of
armrests. These studies have identified the effects of these parameters and adjustability features on physiological responses (such as muscle activity and subjective discomfort ratings and user perceptions). An outcome of this body of work was the development and identification of minimum ergonomics chair design parameters.

Studies among more general groups have indicated that work-related physical factors (heavy load, awkward positions, repetitive movements) and psychosocial factors (demands, control, mental stress) as well as several individual risk factors (age, gender, obesity, smoking, physical activity) are important in the understanding of neck, shoulder pain (Miranda et al. 2001, Viikari Juntara E et al. 2001)

Work related musculoskeletal disorders progress in stages from mild to severe.

- Early stage: Aching and tiredness of the affected limb occur during the work shift but disappear at night and during days of work and there is no reduction of work performance.
- Intermediate stage: Aching and tiredness occur early in the work shift and persist at night. There is reduced capacity for repetitive work.
- Late stage: Aching, fatigue and weakness persist at rest. There is also inability to sleep and to perform light duties.

Not everyone goes through these stages in the same way. In fact, it may be difficult to say exactly when one stage ends and the next begins. The first pain is a signal that the muscles and tendons should rest and recover otherwise, an injury can become longstanding and sometimes, irreversible. The earlier the people recognize symptoms, the quicker they should respond to them.