ERGONOMICS IN THE WORKPLACE

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ABSTRACT

The goal of ergonomics is to fit the task to the individual, not the individual to the task. Practicing good ergonomics achieves increased productivity, improved health and safety of workers, higher job satisfaction and better compliance with government regulations. The general ergonomics principles that should be applied to the workplace include aiming for dynamic versus static work, optimizing work surface heights, avoiding overload of muscles, avoiding unnatural postures, and training individuals to use the workplace, facility, and equipment properly. This article further discusses several important components of ergonomics including anthropometry, seat design, manual materials handling, and focuses on most common musculoskeletal disorders (MSDs) such as cumulative trauma disorders and lower back injuries.

INTRODUCTION

Ergonomics is defined as the study of the design of a workplace, equipment, machine, tool, product, environment, and system which takes into consideration human being's physical, physiological, biomechanical, and psychological capabilities and optimizes the effectiveness and productivity of work systems while assuring the safety, health, and well being of the workers (Fernandez and Marley, 1998). In general, the goal of ergonomics is to fit the task to the individual, not the individual to the task.

An ergonomist evaluates the demands of a specific task with reference to the capacity of workers to perform the task over a certain time period. When developing a particular job design, the demands of the task would ideally be held within the capacity of a fixed percentage of the working population (so that 75 to 95 per cent of the population is accommodated). When the task demands of an existing job are such that it is beyond the capacity of this predetermined percentage of the population, then the work, procedures, and/or work tools should be redesigned in order to accommodate the predetermined percentage of the working population. If the accommodated percentage is unacceptable (e.g., below 75 per cent) and redesign is not possible, then the final alternative is to place workers so that only those whose capacity exceeds the task demands are allowed to perform the task (Fernandez and Marley, 1998).

The application of ergonomic principles in the workplace can result in the following:
• Increased productivity,
• Improved health and safety of workers;
• Lower workers' compensation claims;
• Compliance with government regulations such as Occupational Safety and Health Administration (OSHA) standards;
• Improved job satisfaction;
• Increased work quality;
• Lower worker turnover;
• Lower lost time at work;
• Improved morale of workers;
• Decreased absenteeism rate

Since the focus of ergonomics is on people, it is often convenient to think of ergonomic-related problems by the type of body system, which is affected. The musculoskeletal system is one example. The physical demands of many jobs make the musculoskeletal system highly vulnerable to a variety of occupational injuries and illnesses. There are two main types of musculoskeletal injury: disorders associated with manual materials handling (MMH) and cumulative trauma disorders (CTDs).

This article discusses key ergonomic issues such as anthropometry, seat design, workplace principles, manual materials handling, and cumulative trauma disorders. These important issues need to be understood and applied if the objective is to reduce work-related injuries, improve productivity, and improve the quality of life of the workers.

ANTHROPOMETRY

Anthropometry may be defined as the measurement (e.g., height, elbow-wrist length, etc.) of human beings. Factors which affect anthropometric measurements include gender, ethnicity, growth and development, secular trend, ageing, social class, and occupation, as well as clothing and personal equipment.

Anthropometric surveys detailing various measurements have been conducted for various populations. (Pheasant, 1986). Currently, the most referenced source book is an international text for the International Labour Office (Jurgens et al., 1990).

This text has compiled a comprehensive anthropometric database. The workforce is different in different parts of the world and diversified; therefore, it is important to design the workplace based on the anthropometry of the users.

Each person's anthropometric measurement is compared to values observed in the general population and expressed as percentiles. Percentile is defined as a set of divisions that produce exactly 100 equal parts in a series of continuous values. (Last, 1988) Thus a person whose height is above the 90^{th} percentile is taller than 90% of all persons in a series. The smallest value of a measurement is usually associated with the 5th percentile female, and the largest value of a measurement is usually associated with the 95th percentile male.

In ergonomic design, one can use anthropometric data in three different ways. The first is designing for a range (the smallest to the largest, usually from the 5th percentile to the 95th percentile), such as the design of adjustable height chairs based on popliteal height. The second is designing for the extremes (the smallest *or* the largest, usually for the 5th percentile or the 95th percentile), such as the design of the doorpost height for the largest person's stature (plus ample clearance) or the design of a shelf for the smallest person's functional reach. The third is designing for an average. This method is only acceptable when one is using the workplace for a very short duration. This method is usually avoided by ergonomists, as it does not accommodate a large segment of the user population. An example is designing work surface heights in a bank for customers' elbow height.

SEATING

The main two objectives of ergonomic seating in the workplace are: (1) to increase individual efficiency and reduce fatigue and (2) to facilitate proper posture.

The advantages of sitting over standing include the following:

- Sitting requires less muscular activity, delaying fatigue. An individual can sit for approximately one hour but stand for approximately only half an hour before fatigue sets in.
- Sitting has more stability, which is needed for precision or fine tasks.
- While sitting, a worker can operate a foot control more easily while maintaining a good posture.

The factors most often emphasized when purchasing or selecting chairs are cost and appearance. The factors that should be considered in the design and selection of chairs include:

(1) Ergonomic factors:

- anthropometry of the users; comfort of the users (not the buyer).

(2) Adjustability factors:

- range of adjustability of the user;
- ease of adjustability (e.g. labeled, color-coded controls).

(3) Economic factors:

- initial cost of the chair;
- maintenance of the chair;
- life of the chair.

(4) Safety factors:

- tipping;
- gliding;
- other.

(5) Other factors:

- swivel mechanism to reduce/eliminate awkward postures of the body;
- armrest (adjustable height and width);
- casters;
- weight.

ERGONOMIC PRINCIPLES IN WORKPLACE DESIGN

Some ergonomics principles that should be applied to the workplace, whether in an industrial or an office environment, include the following:

(1) Aim at dynamic work, avoid static work (work where there is no movement). Static work or static loading of the muscles is inefficient and accelerates fatigue. Static work can occur when the workplace is too high or too low, when holding a weight in one's arms for an extended period, or when there is constant bending of the back to perform a task.
(2) Adjust work surface heights to the size (anthropometry) of the worker and the type of task performed (precision, light assembly, or heavy manual).
(3) Work within 30 per cent of one's maximum voluntary contraction (strength). Avoid overloading of the muscular system.
(4) Place primary controls, devices, and workpieces within the normal working area. Secondary controls should be placed within the maximum working area so as to reduce extended reaches and fatigue.
(5) Strive for best mechanical advantage of the skeletal system.
(6) Work with both hands. Do not use one hand (non-preferred hand) as a biological holding device.
(7) Hands should move in symmetrical and opposite directions.
(8) Use the feet as well as the hands.
(9) Design knowing the capacity of the fingers. Do not overload the fingers.
(10) Use gravity. Do not oppose it to dispose of unbreakable products.
(11) Avoid unnatural posture. Bend the handle of the tool not the wrist.
(12) Permit change of posture. Maintain a proper sitting posture.
(13) Counter-balance tools when possible to reduce the weight and forces.
(14) Accommodate the large individual and give him or her sufficient room.
(15) Use bins with lips for storage and manual retrieval of small parts instead of boxes. Incline containers so as to reduce awkward postures of the body.
(16) Train the individual to use the workplace, facility and equipment properly.

MANUAL MATERIALS HANDLING

The improper manual handling of materials frequently leads to musculoskeletal disorders, most commonly lower back injuries. The seriousness of the lower back injury problem is reflected in the large number of claims under the US Worker's Compensation Act of 1970. The National Safety Council (1978) reported that in the USA 400,000 workers face disabling back injuries every year. Statistics (NIOSH 1981) also show that back injuries resulting from manual materials handling (MMH) activities are a major source of lost time and compensation claims. Morris (1984) estimated that 28 per cent of the US industrial population would experience disabling lower back pain at some time in their lives, with 8 per cent of the total working population being disabled during each year.

The costs associated with treating lower back injury are also substantial. According to Leamon (1994), lower back pain costs Liberty Mutual Insurance Group about US$ 1 billion per year, at an average cost of US$8,321 per incident. Lahey (1984) stated that back injuries alone cost industry an estimated US$14 billion a year.

The occupational risk factors for lower back injuries include the force and amount of weight lifted, the frequency of lifting, the location and size of load, the starting and ending point of lift, the stability of the load, the presences of handles, the twisting forces, the geometry of the workplace, and environmental factors.

In 1981 (and revised in 1991) the National Institute for Occupational Safety and Health (NIOSH) published *Work Practices Guide for Manual Lifting* (NIOSH, 1981 and 1991). This technical report contains guidelines, which were designed to aid in the identification of hazardous MMH situations and to help evaluate these jobs as well as possible solutions when problems are encountered. Guidelines proposed by Mital et al. (1997) and Snook and Ciriello (1991) are industry norms and should also be used to reduce the risk of MMH injuries.

CUMULATIVE TRAUMA DISORDERS

Cumulative trauma disorders (CTDs) are defined as physical injuries, which develop over a period of time as a result of repeated biomechanical or physiological stresses on a specific body part. CTDs is a collective term for syndromes characterized by discomfort, impairment, disability, or persistent pain in joints, muscles, tendons and other soft tissues (Kroemer, 1989). Other terms, which are also used to describe these disorders, include repetitive trauma injuries (RTI), repetitive strain injuries (RSI), musculoskeletal disorders (MSD), and occupational overuse syndrome. Since these injuries develop over relatively long periods of time (months or years), it is difficult to determine how often CTDs occur. CTDs are generally considered to be work-related and tend to be more prevalent among working people than among the general population. There has been a significant increase in the number of CTDs cases reported in the USA from 1981 to 1996 (US Dept. of Labor, 1998). Some of the reasons for this increase could include a change in technology, an ageing workforce, a decrease in the physical capacities of new workers, a lower rate of worker turnover, an increase in awareness and diagnosis, and a change in reporting methods. An increase in the number of CTDs cases means the associated cost has also increased significantly.

Putz-Anderson (1988) summarizes the relevant research on CTDs, describing four main occupational risk factors. These include awkward postures, excessive manual force, high rates of manual repetition, and long task duration (or inadequate rest). In addition to these four factors, static loading may also increase the risk of CTDs (Fernandez and Marley, 1990). Static loading occurs when muscles are required to generate tension without movement. Static work is not very efficient and causes the muscles to fatigue rapidly. Vibration is another factor, which has been implicated in the development of CTDs. Vibration causes constriction of blood vessels in the fingers as well as numbness and swelling of the hand tissues. This leads to a reduction in grip strength. Any job, which involves one or more of these risk factors, will have a high probability of causing CTDs depending on the severity of each factor.

The potential for CTDs' development increases when leisure time activities such as sewing, gardening, and woodworking continue to strain the ligaments and muscles. In addition, as the mean age of the working population increases, strength and flexibility decreases. These are also important factors, which can contribute to the development of CTDs (Chaffin and Anderson, 1991).

Putz-Anderson (1988) outlined three major categories of upper extremity CTDs: tendon disorders, neurovascular disorders, and nerve entrapment disorders.

Tendon Disorders

The tendon is a specialized type of tissue, which connects muscles to bones. Tendons are surrounded by sheaths of fibrous tissue that protect the tissue from friction. The sheath contains a synovial membrane which facilitates gliding of the tendon during mechanical actions. Minor disorders of tendons and their sheaths are very common (Putz-Anderson, 1988).

Tendinitis: Tendinitis is inflammation of the tendon occurring from repeated action of the muscle/ tendon unit. Since tendons have virtually no blood supply, they are incapable of self-repair and damage becomes incremental (Rowe, 1985). The accumulation of minor damage results in a roughened tendon, which may produce friction and irritation of its sheath. Ultimately, the tendon may become so weakened that it ruptures. Without rest or sufficient time for tissue to heal, the tendon may be permanently damaged (Curwin and Stanish, 1984).

Tendinitis is most likely to occur in areas where the tendon is restricted anatomically, such as in bony channels and tunnels (Curwin and Stanish, 1984). Examples would be the thumb tendons in the radial groove at the wrist or in joint-supporting tendons of the rotator cuff of the shoulder.

Tenosynovitis: Tenosynovitis is fairly common in finger and wrist tendons or in other areas where the tendon excursion within the synovial sheath is long (usually two or more inches). In such situations, repetitive motion (gliding) of the tendon within the sheath may overwhelm the lubricating ability of the sheath. This will ultimately result in an inflammatory reaction within the tendon sheath (Rowe, 1985).

Bursitis: Bursae are anti-friction devices found throughout the body where bony prominences are close to the skin surface or where tendons and ligaments may rub against the prominences (Rowe, 1985). In the presence of friction, the bursae will oversecrete lubricating fluids and bursal sacs will become enlarged and distended. If friction persists, the walls of the sac will thicken and become inflamed.

Ganglionic cyst: Caused by the swelling of a tendon sheath with synovial fluid, a ganglionic cyst is common and is generally related to wrist usage (Birnbaum, 1986). Though rarely causing symptoms of nerve compression, such a cyst can often be painful and is usually treated by aspiration or by surgical removal if the ganglion recurs.

Neurovascular disorders

Neurovascular disorders are those CTDs which involve both the nerve and the adjacent blood vessels.

Thoracic outlet syndrome: Probably the most common form of neurovascular disorder is the thoracic outlet syndrome (Putz-Anderson, 1988). Thoracic outlet syndrome is a general term for compression of the nerves and blood vessels as they pass through the neurovascular bundle between the neck and shoulder.

Also known as cervicobrachial disorder, thoracic outlet syndrome is generally thought to result from heavy workloads combined with repetitive straining or unnatural static positioning of the arms (Sallstrom and Schmidt, 1985). Typical symptoms of thoracic outlet syndrome include numbness and tingling in the fingers and hand, as well as a sensation of the arm "going to sleep". The blood pulse at the wrist may also become weakened.

Vibration syndrome: Sometimes referred to as vibration-induced white finger disease, Raynaud's syndrome, or traumatic vasospastic disease, vibration syndrome is characterized by episodes of blanching (whiteness or paleness), coldness and pain of the fingers due to closure of the digital arteries (Putz-Anderson, 1988). This condition is caused by the transmission or vibration (varying in acceleration, power, or frequency) from a tool to the hand. It is believed to be in part a vascular disturbance due to changes in the blood vessel walls and in part a nervous disturbance caused by reflex contraction of the smooth muscles of the blood vessels. (Taylor, 1974)

Nerve entrapment disorders

Nerve entrapment disorders occur when repeated or sustained work activities expose the nerves to pressure from hard, sharp edges of the work surface, tools, or internal structures such as bones, ligaments, and tendons. The most common nerve entrapment disorders is the carpal tunnel syndrome (CTS). CTS is generally attributed to insult, usually compression, of the median nerve within the wrist. Compression of the median nerve is, in turn, associated with repeated or sustained activities of the fingers and hands, often combined with the application of force, as well as pressure from hard work surfaces and sharp edges on hand tools. Under normal conditions, there is smooth movement of the nerve and tendons accompanying movements of the wrist. However, compression of the nerve will result from flexion and extension movements when the boundaries of the tunnel are compromised or when structures of the tunnel become enlarged. Although the innervation pattern varies slightly in every individual, the primary areas affected by the median nerve include most of the palmar side of the hand, the thumb, and all of the fingers except the ulnar side of the ring and small fingers.

Initial complaints of CTS include sensations of pain, numbness, and tingling in one or both of the hands at night. The symptoms of CTS may progress until attacks of pain and/or tingling are experienced during the day. At this point, individuals may complain of a general clumsiness or an inability to grasp and hold objects. A significant reduction in work-related measures, particularly grip strength, range of motion, and performance time has been demonstrated.

The exact incidence rate of CTS in industry is unknown; however, many industries now claim that CTS is among their most disabling and costly medical problem (Bleeker, 1984). The average cost of a CTS case has been reported to be approximately US$3,500, while for the more severe cases, compensation and disability claims may range from US$30,000 to US$60,000 (Hiltz, 1985). Fernandez et al. (1990) stated that the average cost for CTS cases in a mid-western manufacturing facility ranged from US$15,000 to US$18,000.

There are a number of risk factors, which have been associated with the development of CTS. As described by Turner and Buckle (1987), these risk factors can be divided into three broad categories:

(1) occupational risk factors;
(2) systemic conditions;
(3) non-occupational risk factors.

The occupational risk factors most frequently associated with CTS include force, repetitiveness, and posture (Putz-Anderson, 1988). When a job requires high levels of force and repetition, more muscle effort is required. This increases the need for increased rest periods or recovery time. Without sufficient recovery time, cumulative injuries are likely to occur. The amount of time required to perform a task is also thought to be an important variable in the development of CTS (Putz-Anderson, 1988, and Silverstein et al. 1986)

Systemic conditions may account for about 20-30 per cent of the total number of CTS cases, some of these conditions include the following:

- *Acromegaly* - This is an endocrine disorder where ongoing pituitary over-activity appears to be related to the appearance of CTS.
- *Amyloidosis* - Deposits of amyloid have been found in the carpal tunnel of patients with this disorder.
- *Diabetes mellitus* - It has been reported that approximately 5-16 per cent of certain groups of CTS patients appear to be diabetics.
- *Hyperpamthyroidism* - primary and secondary (resulting from renal dysfunction) hyperparathyroidism have been associated with the development of CTS.
- *Hypothyroidism and myoedema* - This is an endocrine disorder which has been associated with CTS.
- *Renal failure* - Altered hemodynamics resulting from dialysis procedures may be related to CTS development.
- *Rheumatoid arthritis* - It has been reported that approximately 7-11 per cent of CTS patients suffer from this disorder.

Some of the non-occupational risk factors which appear to be associated with the development of CTS are:

- *Family history* - One type of bilateral CTS has been reported to be an inheritable disorder transmitted by an autosomal dominant gene.
- *Gender* - Female CTS sufferers tend to outnumber male sufferers by two to ten.
- *Gynecological surgery* - A hysterectomy with bilateral ophorectomy and the use of vibratory hand-held tools has been associated with CTS.
- *Menopause* - Women of menopausal age are at an increased risk for developing CTS.

• *Pregnancy* - (*this was never mentioned)* Some pregnant women report experiencing symptoms consistent with those for CTS.
• *Premenstrual syndrome* (PMS) – Women with PMS who experience water retention, weight gain, and/or bloatedness also report symptoms of CTS.
• *Medication* - Some drug preparations (e.g. oral contraceptives) appear to precipitate episodes of CTS
• *Pyogenic infections* - episodes of CTS secondary to pyogenic (pus-producing) infections of the forearm and hand have been reported.
• *Acute trauma* - Approximately 5-6 per cent of several groups of CTS sufferers had previously fractured their affected wrist.
• *Vitamin B6 deficiency* - this may be associated with development of CTS.

CONCLUDING REMARKS

Recognizing the importance of ergonomics in occupational health and safety, OSHA proposed its ergonomics standard (see www.osha-slc.gov/ergonomics-standard/) in late 1999. If finalized, the standard will affect a wide-ranging sector of American business and industry, from heavy manufacturing to office settings. The proposed standard identifies six elements for a full ergonomics program: management leadership and employee participation, hazard information and reporting, job hazard analysis and control, training, MSD management and program evaluation. OSHA intends that ergonomics programs be job-based, i.e., cover just the specific job where the risk of developing an MSD exists and jobs like it that expose other workers to the same hazard.

Recent developments in the regulatory arena clearly show that understanding of ergonomics and applying good ergonomic practices is key to successful management of human resources. Many companies are realizing that making ergonomic changes *before* major problems occur (proactive ergonomics) is more cost effective than simply responding to work-related injuries (reactive ergonomics). Ergonomics is no longer just a buzzword; it now encompasses every aspect of our lives both at work and at home.

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