INTRODUCTION

Handling of material manually is the most predominant as well as the most economical mode of activity in all spheres of life in India (Gangopadhyay et al, 2002)\(^4\). We lift, carry, lower, push, and pull, while moving, packing or storing various sorts of objects (Marco et al, 1998; Snook et al, 1978)\(^5,6\). These objects may sometimes be bulky or small, smooth or with sharp edges, of varied shapes and sizes. Handling of these materials occurs occasionally during leisure activities or repeatedly as a part of daily occupation. MMH is a very frequent and common mode of work both in the organized as well as in the unorganized sectors (Gangopadhyay et al, 2003)\(^7\) with more than 70% of the total population of India engaged directly in MMH (Gangopadhyay et al, 2003)\(^8\).

The scientific definition of material handling as given in “Material Handling Handbook” (1958)\(^9\) is the movement and storage of materials at the lowest possible cost through the use of proper methods and equipments. There are mainly two different types of material handling — (i) mechanical and (ii) manual. Sen (1979)\(^10\) remarked that material handling by man utilizes energy from food, which is about 100 to 200 times more expensive than the fuel sources of energy such as diesel, petrol, coal, electricity etc, used by big machines handling materials mechanically. But these machines are highly expensive and the fossil fuels, electricity, oil etc. are gradually becoming a scarcity. Consequently, material handling, practiced extensively throughout India using human labour, cannot be eliminated. Moreover it will remain as a primary mode of work in the years to come.

There are a number of variations in the manner in which a load is being handled. It may be lifted from the floor or from higher or lower level than the floor. Moreover the load that is to be lifted may be fixed or variable at times. The materials can also be carried manually in a number of ways like by hand, overhead, on back or with the help of a yolk on shoulder. It is also known that not all the process of handling materials, of
numerous shapes and sizes, has equal effect on human body. While some handling methods are quite hazardous, there are certain other methods of load handling that turn out to be less strenuous and physiologically economical than others. Moreover a number of factors namely, individual differences, physical condition, sex etc. markedly influence the abilities of individuals to perform such activities (Gangopadhyay et al, 2003)\textsuperscript{7}.

**DIFFERENT MODES OF HANDLING LOAD MANUALLY**

**LIFTING TASKS**

Lifting tasks, of course, make up a large proportion of MMH tasks. Several task-related variables can affect the physiological costs of work, the performance of workers and the acceptability of tasks to workers. The variables are discussed below.

**Height and Range of Lift:** The height and range of lift are very important. Common practice provides for categorizing height of lift as follows: (1) floor to knuckle, (2) knuckle to shoulder, and (3) shoulder to reach (from shoulder to maximum reach above). The evidence indicates very strongly that reaches above the shoulder are most demanding in terms of physiological criteria and are least acceptable to workers (Mital, 1984)\textsuperscript{11}.

Further, Davies (1972)\textsuperscript{12} reported that the energy cost of lifting objects from the floor to about 20 in (51 cm) is about half again as much as lifting the same weight from about 20 to 40 in (51 to 102 cm). This is because of the additional effort of raising and lowering the body. On the basis of Davies analysis, the most efficient lift range is between 40 and 60 in (102 and 152 cm). This suggests that, where feasible, work places should be designed to provide for the primary lifting to be within this range.

**Methods of Lifting from the Floor:** It has been a rather common custom to recommend that lifting from the floor be carried out from a squatting position, with knees and hips bent and the back reasonably straight (sometimes called the straight-back, bent-knee method or "leg lift"). There had been inklings that this tended to minimize back
problems. The “squat” method generally is in contrast with the “stoop” method (or “back lift”), in which the legs tend to be straight, with the back bending forward and doing most of the lifting.

Although there are inklings that the stoop lift may have some advantages over the squat lift, one should be careful of overgeneralizations because of the ubiquitous presence of interacting variables. For example, the load in question can fit between the legs, a squat lift usually places less stress on the back than a stoop lift. In line with this, it is reasonable to suggest that very heavy, small objects should probably be raised with a squat lift.

Trained athletes lift their loads with the powerful muscles of the legs and the buttocks. They rise from the squatting position, holding the upper part of the body erect and tense. Only weights lifted in this manner cannot lead to any injury. In correct straight-back lifting, the pelvis is inclined from the hips and the spine is held rigid on the pelvis in a statically suitable i.e., erect position. The upper part of the body is bent and straightened at the hips by the buttock muscles, with the spinal column acting merely as a support.

**Straight-back Lifting:** In this case the spine is braced from all sides by muscles. It is subjected only to compression as all bending forces are absorbed by the muscles. The compressive stress is distributed favourably over the total surface of the vertebrae and the disc.

**Bent-back Lifting:** In this case the entire spine is bent into an arc. The neutral axis passes through the rear third of the vertebral and disc area. The compression effort is thus distributed unevenly over the front two-thirds of the disc area, while the rear third and the back muscles are subjected to tensile stress.

**Frequency of Lifts:** Everyday experience tells us that we can tolerate occasional exertion (as in lifting) much better than frequent exertion. This pattern is confirmed by numerous
investigations. In one study by Mital (1984), for example, women and men with considerable industrial work experience were made to perform various types of lifting tasks. He elicited their estimates of maximum weights they believed they could lift at various frequencies per minute if that rate were continued over a regular 8th workday. By using their estimates, other frequencies were related to that base. The results from two other comparative studies were very similar, thus lending confidence to the data. In addition, however, Mital found consistent patterns of increased heart rate and oxygen consumption associated with increased frequencies of lifting. The oxygen uptake just about doubled between 1 and 12 lifts per minute, for both males and females.

Other factors also can be relevant to lifting tasks, such as the size of the object handled, the availability of handles, the amount of horizontal movement etc. Some indications of the relationships among certain such variables is reflected in the pages of research data from Snook (1978).

In connection with the possible effects of many variables on lifting tasks, some basis of synthesizing the effects of various combinations can be ascertained. One such analysis is provided by Davies (1972). On the basis of a more comprehensive synthesis of data on lifting, NIOSH (1981) has developed a guideline (in the form of a formula) for estimating the “risk” of various combinations of task variables. Underlying this formula are the concepts of MPL (the maximum limit that should be allowed) and action limit (the limit above which some “administrative control” of the task is required). The formula provides for estimating the AL.

Carrying: As with lifting tasks, there are marked differences in the weights people find acceptable, depending on the frequency with which the activity is carried out. According to Snook (1978) apart from individual differences, there are systemic differences between males and females.

Pushing and Pulling: It has been estimated that nearly half of the MMH activities consists of pushing and pulling (Marco et al, 1998; Baril-Gingras and Lortie, 1995;
Kumar et al, 1995)\textsuperscript{5, 15, 16}. Derived from literature, pushing and pulling could be defined as the exertion of a (hand) force of which the direction of the major component of the resultant force is horizontal by someone on another object or person (Marco et al, 1998; Martin and Chaffin, 1972; Baril-Gingras and Lortie, 1995)\textsuperscript{5, 17, 15}. In pushing the (hand) force is directed away from the body and in pulling the (hand) force is directed towards the body.

Additional data on manual handling tasks from Snook deal with acceptable levels of weights in pushing tasks. This represents data for pushing at average shoulder height. Pushing at elbow or knuckle height appears not to influence the levels reported as acceptable.

According to Chaffin (1987)\textsuperscript{18} the risks of health complaints (e.g. LBP) induced by pushing and pulling can arise from two types of hazards. Firstly the musculoskeletal system can become physically overexerted. Secondly pushing and pulling is accompanied by an increased risk of accidents due to slipping or tripping, which can cause injuries to the musculoskeletal system (Grieve, 1983)\textsuperscript{19}. A reasonable number of low back injuries are related with slipping and tripping accidents (Manning, 1988; Clemmer et al, 1991; Garg and Moore, 1992)\textsuperscript{20, 21, 22}. Snook et al (1978)\textsuperscript{6} found that 7\% low back injuries were associated with slipping, tripping and falling. Manning and Shannon (1981)\textsuperscript{23} showed that slipping and tripping led to 33\% of the total lumbo-sacral injuries. Lastly Manning et al (1984)\textsuperscript{24} showed that 13\% of the slipping accidents that result in LBP were associated with pushing and pulling.

In terms of work-related factors, exposure can be expressed with three dimensions: intensity (amplitude and direction), frequency and duration (Winkel and Mathiassen, 1994)\textsuperscript{25}. If one of the dimensions deviates from its optimum value, the risk of MSD increases. Many authors suggested pushing and pulling as an occupational risk factor for LBP (Snook et al, 1978; Frymoyer et al, 1980; NIOSH, 1981; Damkot et al, 1984; Klein et al, 1984; Damlund et al, 1986; Pope, 1989; Kelsey et al, 1990; Clemmer et al, 1991; Riihimaki, 1991; Garg and Moore, 1992; Nadeau, 1996)\textsuperscript{6, 26, 14, 27, 28, 29, 30, 31, 21, 32}.
NIOSH has reported that 20% of the injury claims for LBP are associated with pushing and pulling. Klein et al (1984) found only 9% of worker's compensation claims for back pain strains related to pushing and pulling, whereas overexertion as a general category (including lifting, pushing and pulling) accounted for 72% of all the back strains and 19% of the compensation claims were spent on back injuries. Other epidemiological studies found that 9-18% of the low back injuries were associated with pushing and pulling (Snook et al, 1978; Metzler, 1985; Lee et al, 1991; Garg and Moore, 1992). Thus it can be concluded that pushing and pulling is associated with the occurrence of LBP.

Motamedzade et al (2003) designed a participatory ergonomics model for improving working conditions, quality, and productivity in a medium-sized manufacturing enterprise by making use of a Supportive Expert Team (SET). They showed that application of such a model could be considered as a provider of a more humanized work environment as well as a more efficient and cost-effective approach.

Successful ergonomic design of the workstation depends on proper consideration of several interrelated aspects. The work task, the work posture and the work activities all interact and are influenced by the workstation conditions, including the work environment. Thus, there are many interactions in the relations among person, task conditions and results of the effort.

Figure 1: Interaction between man, task and workstation design
In the past, a substantial effort has been made in determining “safe lifting capacities” for individuals and group of individuals. The assumptions used for these studies were that, there is a relationship between an individual capacity and his or her injury potential. There are three distinct approaches taken for assessing MMH capabilities and for setting recommended workload limits. These are:

i) Biomechanical Approach

ii) Physiological Approach

iii) Psychophysical Approach

**BIOMECHANICAL APPROACH**

Biomechanics views the body as a system of links and connecting joints corresponding to segments of the body such as, upper arm (link), elbow (joint) and forearm (link). Principles of mechanics are used to determine the mechanical stress on the body and muscle forces needed to counteract the stress. Researchers have developed various computerized models to determine the forces acting on the body during MMH activity (Chaffin and Anderson, 1984)\(^\text{37}\). These models estimate both static and dynamic forces in a 2-D or 3-D plane (Chaffin, 1975 and Schultz, 1991)\(^\text{38,39}\). Linear programming has been applied to calculate the forces in “Sum of cubed intensity model” (Crowminshield and Brand, 1981)\(^\text{40}\) and in “Minimum intensity compression model” (Bean et al, 1998)\(^\text{41}\). More recently EMG based model has been put into use by researchers like Marras and Granata (1997)\(^\text{42}\). The most popular static strength prediction model available at present is the “University of Michigan 2D/3D Static Strength Prediction Model” (Ayoub and Wolstad, 1999)\(^\text{43}\). The NIOSH prescribed guidelines are based on biomechanical modeling. The major recommendation is that, strain developed at fifth lumbar (L5) and first sacral (S1) joint, if over 3.4 KN, is a damaging factor (NIOSH, 1981)\(^\text{14}\).
Both the 1981 and 1991 lifting frequencies were based on 3 criteria derived or developed from scientific literature and the combined judgement of experts from the fields of biomechanics, psychophysics and work physiology.

### TABLE 1: CRITERIA USED TO DEVELOP THE LIFTING EQUATIONS

<table>
<thead>
<tr>
<th>DISCIPLINE</th>
<th>DESIGN CRITERIA</th>
<th>CUT-OFF VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomechanical</td>
<td>Maximum Disc Compression force</td>
<td>3.4KN (770lbs)</td>
</tr>
<tr>
<td>Physiological</td>
<td>Maximum Energy Expenditure</td>
<td>22.47Kcal/min</td>
</tr>
<tr>
<td>Psychophysical</td>
<td>Maximum Acceptable Weight</td>
<td>Acceptable to about 99% of male workers and 75% of female workers.</td>
</tr>
</tbody>
</table>

The biomechanical approach has been limited to analyzing infrequent MMH tasks. The goal is to limit task demands to be within the strength capacity and compressive force tolerance of the body by formulation of prediction models (Mc Cormick and Sanders, 1992) and posture analysis method like OWAS.
PHYSIOLOGICAL APPROACH

Although there is limited empirical data to suggest that whole body fatigue increases the risk of musculo-skeletal injuries, repetitive lifting works may exceed an worker's normal energy capacities, causing a premature degree in strength and increasing the chances of injury (Garg and Sexena, 1979)\textsuperscript{45}.

The physiological approach is thus primarily concerned with energy consumption and stress acting on the cardiovascular system. This is best suited to MMH tasks that are done frequently and over some duration of time. During repetitive handling tasks, a person's endurance is the principle factor to be reckoned with and that is mainly limited by the capacity of oxygen transport system. As muscle contracts and relaxes, its enhanced metabolic energy demand requires an increase in the delivery of oxygen and nutrients to the tissue to sustain the activity for long. When a person is engaged in physical work such as MMH, several physiological responses are affected. These include metabolic energy cost, heart rate, blood pressure, blood lactate and ventilation volume (Astrand and Rodahl, 1986)\textsuperscript{46}. Of all these responses, metabolic energy expenditure has been a widely accepted parameter to judge physiological response of the body to MMH. This is because it is directly proportional to the workload at steady state condition [Astrand and Rodahl, 1986; Ayoub and Mital, 1989]\textsuperscript{46, 47}. Several researchers like Chaffin (1975)\textsuperscript{48} and Mital (1983)\textsuperscript{49} have developed prediction models for the energy and cardiac cost responses of individuals engaged in MMH tasks performed in sagittal plane, though not taking into account the effect of task variables and their interactions (Ayoub and Wolstad, 1999)\textsuperscript{43}. Although no such advanced, sophisticated and expensive experiments have been done in India to find physiological stress imposed due to MMH activity, Sen and Gangopadhyay (1985, 1989)\textsuperscript{50, 51} showed by simple experiments that the stress on MMH workers could be very high. They found that handcart pullers perform a very strenuous job, as indicated by their pulse rate reaching 180 beats per min. when a load of about 3000 kg. is imposed on them.
PSYCHOPHYSICAL APPROACH

Psychophysics deals with the relationship between human sensation and its physical stimuli. In 1978, Borg found that the perception of both muscular effort and force obey the psychophysical function where the sensation magnitude grows as a power function of stimulus I. So, the underlying premise of psychophysical approach is that people integrate and combine both biomechanical and physiological stresses in their subjective evaluation of perceived stress.

The psychophysical criterion is based on data defining worker's strength and capacity to perform manual lifting at different frequencies for different durations. The direct use of psychophysical approach in assessing a lifting task requires that subjects adjust the weight of a load to the maximum amount they can sustain without strain or discomfort and without becoming unusually tired [Snooke and Ciriello, 1991].

The maximum load selected is called the "maximum acceptable weight of lift" (MAWL). The maximum-acceptable-weight-of-lift provides an empirical measure that appears to integrate both biomechanical and physiological sources of stress for all high frequency lifting tasks (Karwoski and Ayoub, 1984). Unlike maximum strength measures that define what a person can do on a single attempt, the maximum acceptable measures defines what a person can do repeatedly for an extended period with excessive fatigue, which may lead to lifting-related musculo-skeletal disorders. Psychophysical models have also been constructed to assess MMH (Mc Cormick and Sanders, 1992).

The psychophysical criterion can also be defined indirectly from studies for measuring isometric strength. Although strength is an important determinant of the capacity of the individual to perform an infrequent or occasional lift, "capability appears to be substantially lowered than isometric strength maxima." (Ayoub and Mital, 1989).
ONSET OF WORK RELATED MUSCULO SKELETAL DISORDERS

The clarification of Shilling and Anderson (1986)\textsuperscript{55} is used to frame the discussion of work-relatedness with a disorder:

Category 1: The work exposure is a necessary cause of the disorder (as in occupational diseases such as silicosis or lead poisoning).

Category 2: The work exposure is a contributory causal factor but not a necessary one.

Category 3: The work exposure provokes reaction by a latent weakness or aggravates an existing disease.

Category 4: The work exposes the worker to potential dangers that may increase the likelihood of a disease development (such as alcoholism in liquor industry workers).

WMSDS (Kuorinka and Forcier, 1995)\textsuperscript{56} continue to present a major challenge to workers and their employers in virtually every industry or working sectors. Clearly, WMSDS are the result of the interplay of many different variables. Although workplace ergonomic factors play a role, wider work organization issues, social aspects of work and the health of the workers themselves are important. The current state of knowledge is of a web of factors that are associated with musculoskeletal outcomes. The main occupational factors associated with musculoskeletal conditions at work are:

- Force
- Posture
- Repetition
- Duration

Bernard\textsuperscript{57} reviewed the literature available in 1997 (National Institute of Occupational Safety and Health, 1997)\textsuperscript{58} and found evidences indicating that most of the conditions were associated with one or more of the above factors. He concluded that many of the conditions were caused by the work exposures based on the following criteria:
Armstrong et al (1993)\textsuperscript{59} had developed a model of MSD that emphasizes exposure, dose, capacity and response. In that model exposure refers to work demands such as posture, force and repetition rate that have an effect (the dose) on the internal body parts. Metabolic changes in the muscles, stretching of tendons or ligaments, compression of the particular surfaces of joints are examples of what is meant by a dose. The dose may produce a response such as a change in the shape of a tissue, the death of cells or accumulation of waste products in the tissues. These primary responses can be accompanied by secondary responses such as pain or loss of co-ordination. A response (such as pain) can be a dose that causes another response (example: increased muscular contraction). Capacity refers to the individual worker's ability to cope with the various doses to which his musculoskeletal system is exposed.

An individual's capacity is not fixed. According to the above model it may change over time as the person ages or the development of skill may improve the ability to generate large forces with less effort. Training can increase strength or endurance, whereas the development of scar tissue to replace injured muscle tissue may impair strength or endurance.

Forces produced during various processes of material handling e.g. pulling, pushing, lifting, carrying etc are normally sensed by a person and maintained within the safe mechanical limits of the tissues involved. But in certain condition, these forces produced may be much above the normal tolerance level of the person. This may be caused either due to improper load handling involving awkward postures or due to too much heaviness of the load (Gangopadhyay et al, 2002)\textsuperscript{4}. Whatever may be the reason, improper material handling results in MSD. MSD are the most common self-reported, work-related illness. They are the manifestations of the ergonomic hazards and are the
leading causes of disability among the people during the working years. They represent one of the most commonly reported work related illnesses in industrialized countries (Hodgson et al, 1993; Bernard, 1997; Jones et al, 1998; Buckle and Devereux, 2000; Burnett et al, 2001; Kumar, 2001) . According to Levy and Wegman (2000) occupationally caused or aggravated MSD rank first among the health problems in the frequency with which they affect the quality of life. They nearly affect one half of the nation’s workforce at some time, thereby resulting in time loss from work. Thus based on lost earnings, worker’s compensation payments and medical payments, MSD are more costly than any other single health disorder. Prevention of work-related MSD is one of the most prevalent issues to be addressed in the occupational health and safety research in both industrialized countries and developing countries (Jafry and O’Neil, 2000; Kogi and Kawakami, 1997).

Work-related musculo-skeletal injuries generally inflict the muscles, ligaments, tendons, soft tissues or nerves and occur when there are excessive stresses on humans’ musculo-skeletal system (Kroemer et al, 1989) . MSD can be triggered or aggravated by repetitive movements and or physical strain. It has been established that awkward working postures can lead to transient fatigue, pain and eventually musculo skeletal impairment (Van Wely, 1970 and Westgaard et al, 1986) . The report of work related musculo skeletal pain refers to discomfort and pain in the muscles and joints that are caused or made worse by work (WHO, 1992; Griffiths, 1994; Bernard, 1997; Jones et al, 1998) . MSDs were often the consequences of wrong postural configuration used during manual material handling (Kavis and Kothiyal, 1996) . A study revealed that many Korean workers were exposed to repetitive manual tasks or prolonged poor working postures, which were closely related to symptoms of MSDs (Chung et al, 2005) . From an ergonomic point of view the main concern is that work activity imposes stress that cause long term damage to body muscles, tendons and nerves, leading to discomfort, pain, injury and reduced performance.

Hageberg (1995) made a detailed review of the literature of MSD. It has been shown that occupational exposure is fully associated with MSD and that involve high
relative risks. In 1994 a study was made in Stockholm to find out relation between workload and MSD. They found that in heavy work there is greater prevalence of MSD and vice versa. In office workers the risk of prevalence of MSD was low. Linton et al (1998) reported that the 1-year prevalence of MSD involving low back and neck in 35 to 45 year-old Swedish residents was 66.3%. In addition, 8% of those with MSD reported their sick leave as lasting 15 days or longer. Epidemiological studies reveal that MSD may arise due to the involvement of one or more factors, such as repetitive motion, forceful motion, mechanical stress, static posture and even due to local vibrations. All these factors produce stress to the nerves and their corresponding muscles resulting compression of nerve, stretching and/ or sliding of muscle tendon, chronic fibrous reaction in tendon to fibrous nodule formation of tendon, inflammatory reactions of tendons (compression of the microstructure of tendons leading to the ischaemia of tendon) — which ultimately results in the development of MSD.

Thus the mechanism of WMSDS is thought to be repeated micro trauma at the cellular level. Repair capacity is hampered owing to a lack of rest during the day and repeated daily exposure (Pitner et al, 1985).

A musculoskeletal injury includes sprain, strain and inflammation that may be caused or aggravated by work (Ergonomic risk control programme- 2003). The three common causes of such injuries are overexertion, muscle strain and repetitive strain. The risks of injury also directly related to the number and speed of movements and the amount of force exerted with each movement. A task with high repetition but low force and good posture may not be a problem, but a task with high repetition and poor postures may result in a significant number of complaints or injuries (Ergonomic risk control programme- 2003). Huang and Feuerstein (2004) suggested that job redesign and interventions that address a worker's work style when faced with increased work demands may help reduce the likelihood of musculoskeletal symptoms and/or their intensity.
A person working with an extreme or awkward posture will have to use more force to accomplish the same amount of work when compared to using a neutral posture (Randal, 1997). Posture and the location and weight of a load affect the moment of force required in the lumbar region, which in turn affects muscle loading and compressive forces on the internal vertebral disc (Chaffin and Anderson, 1984; McGill and Norman, 1985). The amount and quality of forward-bent work postures and the techniques of MMH influence compressive forces on the vertebral discs and the EMG of erector spinae muscles (Chaffin and Anderson, 1984; Leskinen, 1993). However, working in a stooped posture results in a higher heart rate, metabolic load and rating of discomfort and fatigue (Morrissey, 1987). Mital (1986) has shown that the ability to produce maximal forces depends considerably on the work posture used.

Handling of heavy loads is one of the highly physically demanding occupations. While performing various manual tasks for extended periods of time, the workers adopt different awkward postures. These awkward postures associated with shoulders and arms for prolonged periods may lead to the development of chronic MSD of the upper limbs (Wells et al, 1994).

Haslegrave (1994) presented a simple task posture model describing the relationships between the various factors that influence working postures as an aid to workplace design. An analysis was also made of the factors involved in the exertion of force, including physiological, environmental, personal and task factors, in order to give a better understanding of the influences of task and workplace on strength capability.

Devereux and his colleagues (2002) summarized that workers highly exposed to both physical and psychosocial workplace risk factors were more likely to report symptoms of musculoskeletal disorders (MSDs) than workers highly exposed to one or the other. Thus the fact that has to be emphasized is that WMSD may result in sick leave,
loss of productivity, job dissatisfaction and the reduction of time for leisure activities (Croft et al, 2001 and Van der Windt et al, 2000)\textsuperscript{88,89}.

**Muscle Pain:** In general, human muscle has excellent endurance capacity for loads less than 15\% of the muscle's maximum voluntary contraction (Putz-Anderson, 1988)\textsuperscript{90}. Above this threshold, rest periods are needed to avoid acute or chronic problems. The problems at the tissue level may include damage such as a muscle fibre Z-line rupture, ragged type 1 (red) muscle fibres, decreased intracellular ATP and reduced local blood flow (Hales, 1994)\textsuperscript{91}.

Exertional Compartment Syndromes normally occur in the lower limbs with dull aching in a given muscular compartment and increased pressure in the muscle. The pain is triggered by activity. Muscle is known to increase in volume by up to 20\% during exercise (Pitner et al, 1985)\textsuperscript{77} and it is thought that the accompanying pressure increase is sufficient to degrade blood flow through the muscle. The pain subsides after cessation of the activity.

**Tendon Pain:** Pain arising from inflammation of tendons ("tendonitis") is known to be work-related when it occurs in the hands and wrists (National Institute of Safety and Health, 1997)\textsuperscript{58}. There is evidence that force, posture and repetition are all associated with the disorder and the evidence is even stronger when the workers are exposed to these stressors in combination.

Frequent mechanical loading can cause tendonitis or inflammation of the cartilage surrounding a joint. Reduced mobility, pain and weakness may result (Chaffin, 1987)\textsuperscript{18}. Sudden large forces may cause tendons to separate from bones.

**Bones and Joints:** Repeated heavy loading is essential for the proper formation and maintenance of bone. Under repeated loading, particularly of the lower extremities, stress
fractures can occur. Stress fractures like many WMSDS are a process rather than an event (Pitner et al, 1985)⁷⁷.

There is plenty of evidence that joint diseases are more common in some occupations related to load carrying, lifting and pulling than others (Kuorinka and Forcier, 1995)⁵⁶.

**Neuritis:** Repeated or prolonged exertion can cause damage to the nerves supplying a muscle or passing through it. This can cause sensations of numbness or tingling (pin and needles) in areas of the body supplied by the nerve. In case of nerves, overexertion can cause increased pressure in a muscle due to edema or scar tissue formation.

Impaired nerve function, destruction of fibres or damage resulting in reduced nerve conduction velocity may cause muscle weakness. All these problems are more likely to occur if the joints are held in an awkward posture (at the extremes of the ranges of movement) since this ‘pre-loads’ tendons and ligaments and thereby stretch muscle and nerves (Bridger et al, 1994)⁹².

**DISORDERS OF THE NECK**

Ariens et al (2000)⁹³ reviewed literature on the work-relatedness of neck pain. Relationships were found between neck pain and neck flexion, arm force, arm position, deviation of sitting, twisting or bending of the trunk, hand-arm vibration and work place design.

According to Kapandji (1974)⁹⁴, degeneration of the cervical spine, sometimes known as cervical spondylosis, can have serious consequences. Compression of the spinal cord at the level of the cervical spine can take place, resulting in weakness and wasting of the upper limbs. This may then spread to the lower limbs.
Static flexion of the spine increases the moment arm of the head according to the spine of the angle of flexion. This enhances the load on soft tissues in the cervical region and the posterior neck muscles are placed under increased static load in order to maintain the forward-flexed head in equilibrium with gravity. According to De wall et al (1991)\textsuperscript{95} the enhanced static load on these muscles may cause pressure ischaemia and starve the muscle tissues of fuel and oxygen. Pain in the neck and shoulders may result causing muscle spasm.

\section*{DISORDERS OF THE SHOULDERS}

Punnett et al (2000)\textsuperscript{96} found an increased risk of shoulder disorder when the shoulder was abducted or flexed for more than 90 degrees and concluded that there is evidence for a positive association between high repetitive work and shoulder problems and between repeated or static shoulder postures. There is evidence that shoulder problems aggravate with the duration of employment and with the length of the workday.

\section*{DISORDERS OF THE LOWER LIMBS}

The main occupational cause of lower limb injury (excluding falls) appears to be walking while carrying heavy loads and jobs that require excessive use of the knees (Kirkesor and Eenberg, 1996)\textsuperscript{97}. Knee disorders, including osteoarthritis and bursitis are associated with squatting and with heavy physical work (Kirkesor and Eenberg, 1996)\textsuperscript{97}.
LOW BACK PAIN - A PREDOMINANT MUSCULO SKELETAL DISORDER

Pain in the neck, shoulder and low back are the most common MSD associated with manual load handling, with low back disorder representing the most significant non-lethal medical condition (Marras, 2000). MMH tasks have been associated with the majority of low back injuries (Snook et al, 1978; Bigos et al, 1986). LBD represents the most common and most costly MSD experienced in workplace. Up to 80% of the adults will be eventually experiencing back pain at some time during their life and 4.5% of the population has an acute low back pain episode every year (Plante et al, 1997). Surveillance studies have shown that those who handle materials are at much greater risk of LBD than those who work in occupations that do not require lifting (Anderson, 1997).

Low back problems are common among MMH workers and appear to be associated with the amount of postures requiring back flexion, carrying and lifting of heavy loads and exposure to whole body vibration (Pentinnen, 1987). Postures particularly severe flexion or lateral twist and bending have been found to be significantly related to LBP (Punnett et al, 1991; Gangopadhyay et al, 2004). Although the causes of LBD are complex, substantial scientific evidence identifies some work activities and awkward postures as significant contributors to the problem.

Shahnavaz et al (1991) reported a large scale of investigation involving 2373 workers to determine the type and extent of MSD occurring in selected work places in China and Thailand. A range of common MSD was found. LBP was the prevalent problem in both countries with 55.4% workers affected in China and 74.8% affected in Thailand. They further found that symptoms of MSD in both countries were influenced by factors such as working conditions, operator age and type of task performance. A similar study was conducted by Xiao et al (2004) in a machinery manufacturing plant.
in China to investigate MSD and related risk factors. They found that LBP was prevalent in almost 64% cases and lifting repetitiveness and work age contributed to the occurrence of LBP.

The relation between low-back injury and workplace ergonomics is supported by the findings of epidemiological surveys. Low back pain remains the most prevalent and costly work-related injury (Liberty Mutual Research Centre Research Report, 1996)\textsuperscript{107}. Hoogendoorn et al. (2000)\textsuperscript{108} found an increased risk of low back pain in workers who lifted a 25 Kg load more than 15 times per day. Magora (1972)\textsuperscript{109} found that low back symptoms were more common in workers who regularly lifted weights of 3 kg or more than those who sometimes lifted such weights. Study conducted by Ijzelnberg and his colleagues (2004)\textsuperscript{110} reported that work-related physical and psychosocial factors largely determine the occurrence of low-back pain and upper-extremity complaints.

Studies of Bernard (1997)\textsuperscript{57} and Hoogendoorn et al (1999)\textsuperscript{111} showed that the risk factors contributing to LBD were: i) heavy physical work; ii) lifting and forceful movements; iii) bending and twisting; iv) whole body vibration and v) static work posture. Canadian statistics showed that following common cold, LBP was the leading cause of absenteeism in industry. Although genetic and morphological factors contribute to LBP and a very little can be done to manipulate this factor. The physiological, psychophysical and mechanical factors for LBP can be utilized in a fruitful way for designing a better manual material handling system. This better designing can reduce the health related disorders associated with material handling, usually of the musculo skeletal system and can improve the efficiency of the work system.

During manual handling tasks, the weight of the load being lifted is transferred to the spinal column in the form of compression and shear forces. The compression and shear are greater when the load is lifted quickly because higher forces are needed to accelerate the mass from rest, according to Newton’s laws of motion.
The abdominal and thoracic muscles play a major role in stabilizing the spine when a weight is lifted according to Morris et al. (1961)\textsuperscript{112}. In relaxed standing, these muscles exhibit little activity. When a person leans forward to lift a weight, a moment of flexion is placed on the spine. The heavier the weight, the greater is the flexion strain. Aspden (1989)\textsuperscript{113} suggested that intra-abdominal pressure compresses the curved surface of the lumbar lordosis, causing it to stiffen. According to Gallagher and Hamrick (1991)\textsuperscript{114} the genital muscle can generate an extensor moment about 5-7 times greater than the lumbar erector spinae, which is why trying to "lift with back" is both inefficient and hazardous.

A catastrophic injury such as a disc prolapse is not simply caused by a sudden event such as lifting a heavy weight. It is usually the end product of years of degeneration of the disc and surrounding structure. This process of degeneration may ultimately result in herniation of an intervertebral disc (Vernon, 1989)\textsuperscript{115}.

Symmetric lifting wherein the load is held with both hands in front of the body is by far the most common method of handling a heavy load, since it equalizes the stresses bilaterally on the musculoskeletal system. However there are situations wherein moderate loads are lifted asymmetrically. An asymmetric lift where a person brings up a load along the side of the body, not only causes a lateral bending moment on the lumbar column but, because of lordosis of the column, it produces a rotation of each vertebra on its adjacent vertebra. One laboratory study by Farfan et al. (1970)\textsuperscript{116} indicates that disc degeneration most often involves the annulus fibrosus, which is the structure that provides 40%-50% of the torsional resistance to twisting of the lumbar vertebrae. Lower back is the most susceptible part of the musculoskeletal system from injury standpoint. The mostly reported types of back injuries are strains and sprains, dislocation of the lumbar disc, fracture, joint (mostly L4/L5 and L5/S1; occasionally shoulder and hip joints) inflammation, laceration of the muscle tissue, contusion and nerve (sciatic) involvement. The prevalence of resulting back pain has been of concern to medical and research community for quite sometime (Chaffin and Park, 1973; Anderson, 1981; Stubbs et al, 1983; Pope et al, 1984)\textsuperscript{117, 118, 119, 120}. Repeated occurrence of back pain leads
to decrease in muscular strength, spinal flexibility and eventually, activity limitation. A majority of these episodes occur during the working ages between 20-55 years, with the first medical episode most often reported between the ages of 20-30 years (Hult, 1954). It has been also recognized that the low back pain is recurrent in nature, with episode occurring most often every 3 months to 3 years (Hult, 1954; Rowe, 1983).

The most common types of LBP have been classified as lumbar insufficiency, lumbago and sciatica (Hult, 1954). Lumbar insufficiency is defined as fatigue, stiffness or pain in the low back. These symptoms, frequently described as a “tight band across the small back”, are often provoked by certain forms of exertion – specially work in a bent forward position. Lumbago (or nonspecific LBP) is a more intense pain in the low back that usually incapacitates the workers, particularly those with an active or physically demanding jobs. Sciatica is the pain that radiates into either leg, usually down the posterior or lateral aspect of the thigh and lower leg (Snook et al, 2000).

Postures sustained for long periods have also been associated with LBP. For example, a high incidence of LBP has been shown in workers who sit and stand for prolonged periods, whereas, a much lower incidence of LBP has been shown in workers who can vary their posture repeatedly after short durations (Magora, 1972). Stooped, restricted, kneeling, and other awkward postures adopted during manual material handling have frequently been associated with LBP onset (Splittoesser et al, 2007). Ghesta (1982) studied the low back stress during loading and lifting. Low back is stressed maximally during the lifting act, specially the lower lumbar segments of the spinal column and their associated muscles and ligaments are highly stressed.

Chaffin (1969) and Garg et al (1982) explained the biomechanical criterion of LBP, in which L5 to S1 vertebrate segments are considered as the greatest site of lumbar stress during lifting activity. Although three types of stress vectors are transmitted during lifting to the L5 to S1 joint surrounding musculoskeletal tissue, disc compression is believed to be largely responsible for vertebral end plate fracture, disc herniation and resulting nerve root irritation (Chaffin and Anderson, 1984). Herrin et al. (1986)
concluded that the biomechanical criterion of maximal back compression appears to be a good predictor not only of risk low back incidents but also of over-exertion injuries in general.

**PHYSIOLOGICAL EFFECTS OF MMH**

Astrand and Rodahl (1970)\(^{130}\) stated that when a young adult male is working and using 50% of his maximum aerobic capacity, his HR is likely to be about 130 b/m. A reasonable estimate of the permissible weight of load required to be carried manually can therefore be made from the data presented on this basis. The permissible weight of load is around 30 kg. For manual carriage can also be obtained from the recovery patterns of pulse rates of the subjects taken just before each minute of the continuous five minutes of observation. The average pulse rate measured one minute after cessation of carrying a 30 kg. load was found to be only 98 b/m and well under the limit of 110 b/m proposed by Brouha. The corresponding pulse rates of the subjects carrying 40 kg. or 50 kg. weights exceed this value. The average recovery pulse rate after one minute was 112 b/m, slightly above Brouha's limit. The recovery pulse rate after five minutes was also still considerably elevated than the resting values.

Heart rate has been used to demonstrate the effect of work on cardiac performance since early 1900's (Bower, 1904)\(^{131}\). It has been shown later by various investigators (Brouha et al, 1961; Brouha and Maxfield, 1962)\(^{132, 133}\) that the rate of oxygen consumption is not necessarily a reliable indicator of the physiological strain induced by work, whereas heart rate reflects the degree of strain.

Manual tasks performed in working environments can be characterized by various combination of dynamic and static muscular effort. This is particularly true in daily life activities in load carrying and lifting. Over the years, ergonomists and occupational safety
and health professionals have extensively utilized the measurement of heart rate (Sanchez et al, 1979; Mass et al, 1989) and systolic blood pressure (Asfour et al, 1986) to determine the physical effort involved in different types of manual work.

Based on the measurements of HR, it was proved that cardiovascular responses to load carriage were substantial in homeostatic balance (steady state). Gamberale et al (1987) also concluded that a rise in workload resulted in a linear increase in both exertion and heart rate. The highest attainable heart rate during performance of heavy muscular work depends upon age and state of training. At the age of 20 years, the maximal heart rate is about 200 b/m, which is reduced to 155 b/m at the age of 70 years. So it is clear that heart rate decreases with advancement in age (Rasch and Wilson, 1968).

Astrand and Rodahl (1986) proposed the following table wherein the category of work and the corresponding heart rate have been shown.

<table>
<thead>
<tr>
<th>Category of work</th>
<th>Heart rate (beats/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light work</td>
<td>Up to 90</td>
</tr>
<tr>
<td>Moderate work</td>
<td>90-110</td>
</tr>
<tr>
<td>Heavy work</td>
<td>110-130</td>
</tr>
<tr>
<td>Very heavy work</td>
<td>130-150</td>
</tr>
<tr>
<td>Extremely heavy work</td>
<td>150-170</td>
</tr>
</tbody>
</table>
The circulatory organs may also be affected during the lifting of heavy loads, particularly if they are already in poor shape; the HR and blood pressure rise in each and every person and brain haemorrhage has been reported in some older arteriosclerotic persons.

Although measurements of blood pressure immediately after carrying loads (up to 20% of the body weight) did not show any significant difference, but after sometime there was a rise in SBP (Hong et al, 2000). SBP rises in direct proportion to rises in exercise intensity (Rowel, 1986).

Dynamic exercise is used for those types of physical activities where muscle groups undergo repetitive and continuous muscle contraction involving a change in muscle length. During acute bouts of dynamic exercise there is steady increase in SBP, which is, proportional to the exercise intensity while DBP does not change significantly (Dehn and Mitchell, 1979; Dlin, 1986). Blood pressure levels are dependent primarily on the relationship of SV, HR and TPR. During transition from rest to exercise, or during exercise of increasing intensity, cardiac output increases in both SV and HR, blood pressure increases are offset to some degree by decreases in TPR (Keul et al, 1981).

It is stated that during exercise or activities, blood pressure increases linearly as a result of an increase in cardiac output. Both nervous as well as chemical influences bring about these increases. It is also observed that exercise or activities affects SBP than DBP or MBP. This is due to the fact that during exercise the resistance to blood flow is decreased. The decreased resistance is the result of vasodilatation that takes place in the arterioles or the working muscle (Shaver, 1982).

Women are less strong physically than men and hence their ability for sustained heavy physical work is substantially low. If they attempt to carry excessive loads, their
intra abdominal pressure may suddenly rise and cause disturbances in blood circulation in the pelvic organs and lower limbs, menstrual disorders, prolapsed, miscarriage or stillbirth. These disorders are more predominant if the woman has been carrying heavy loads from an early age. Unfavourable effects on the normal formation of pelvic bones resulting in flat and narrow pelvises have also been reported.

In children and adolescents strenuous work of this type may affect body growth, particularly skeletal growth. Deformities of the spinal column, pelvis and thorax may occur. As the growth of the musculoskeletal and circulatory system is unequal, stress on these systems during childhood and adolescence may have permanent adverse effect.

ENVIRONMENTAL EFFECTS ON MMH

THERMAL ENVIRONMENT: HEAT STRESS

Being a homiothermic animal, human being possesses an amazing thermoregulatory mechanism that maintains an internal thermal balance in spite of large environmental temperature variation. Nevertheless, thermal changes may sometimes cause injuries and illness to the exposed individuals. Extensive studies have been done on the effect of thermal changes and these studies provide the basis for the prevention of health impairment and physiological damage to workers. (Stephenson et al, 1974)146. A number of heat stress indices have been formulated, for e.g. heat stress index of Belding and Hatch (1955)147; predicted four hour sweat rate (Mc Ardle et al, 1947)148, WBGT index (Yaglou and Minard, 1957)149 and effective temperature (Yaglou, 1927)150. All these indices try to quantify heat stress in a steady state, while taking into account air temperature, relative humidity, radiant heat for calculating heat stress (Mc. Cormick, 1992)144.
The temperature of air is referred to as the dry-bulb temperature and is measured by using different measuring devices such as mercury or alcohol in glass thermometer, thermo electronic thermometers, thermocouples and thermistors (Khogali and Karim, 1987). The relative humidity can be assessed if the dry and wet bulb temperatures are known. They can be measured by the use of a sling, whirling psychrometer or a motor driven psychrometer.

Air speed is determined by the use of anemometers. When the air is turbulent (multidirectional) it is preferable to use a hot wire anemometer or a Kata thermometer is the instrument of choice.

The radiant temperature is measured by using a black Globe Thermometer. To estimate the MRT, the determination of the dry-bulb temperature and air speed at the same time and in the same place with the globe thermometer is essential. Bedford and Warner (1934) computed MRT from the globe thermometer, air speed and air temperature measurements and these calculations are now embodied in the nomograms, which are used to calculate the MRT. MRT is by far the major cause of heat-load gain in the tropics and subtropics.

**Heat Stress Indices:**

**Effective Temperature (ET):** One of the first practical scales was designed by Yaglou in the 1920s and is called the Effective Temperature scale. The ET index is mainly based on subjective assessment of the environment, combining temperature, humidity and air movement. The dry and wet bulb temperatures and air speed should be recorded before determining the ET.

Bedford (1936) modified the ET scale when he included a factor for radiation. The CET is determined by using the same method, but by substituting the globe temperature in place of the dry bulb temperature.
Belding and Hatch Index: The scale that can be used indoor particularly in industry is the Belding and Hatch (1955)\textsuperscript{147} index. This index is effective over a wide range of temperatures but it is complicated to evaluate. For this reason it has not been so widely used in industry as it should have been.

The Predicted Four Hour Sweat Rate (P4SR): P4SR is a scale based on the physiological response of the individual. It was developed from many experiments carried out in climatic chambers by Mc Ardle et al (1947)\textsuperscript{148}. From measurements of the sweat rate of subjects wearing particular clothing and doing specific work over a 4 hour period- nomograms were constructed. From this empirical approach, it is possible, by measurement of the dry and wet bulb temperatures together with air movement to predict 4-hour sweat rate. The scale is particularly useful in very hot and humid conditions, but there are some limitations, which are due to the way the scale was determined. Nevertheless, in spite of this, experience has shown that the P4SR is a reliable index and one that has been used in a wide variety of situations with many different subjects (Kerslake, 1972)\textsuperscript{154}.

Wet Bulb Globe Thermometer (WBGT) Index: The WBGT index is used worldwide, specially in industrial safety and occupational health. This was also designed by Yaglou together with Minard (1957)\textsuperscript{149} and was intended as a simple scale to be used out of doors. It is a simple and appropriate technique to measure the environmental factors, which correlate with deep body temperatures and physiological response to heat. WBGT was adopted by the American Conference of Governmental Industrial Hygienist and used to develop the TLV for heat stress.

WBGT index is the simplest and the most convenient index having a fairly intimate correlation with physiological responses. Individual differences in heat tolerance, type of work, clothing, air circulation vary within a wide range, but in spite of
this, ‘safe’ heat exposure limits based on WBGT index have been recommended by agencies like ACGIH (1994)\textsuperscript{155} and NIOSH (1986)\textsuperscript{156}.  

**TABLE 3: PERMISSIBLE HEAT EXPOSURE THRESHOLD LIMIT VALUE [WBGT (°C)] (ACGIH, 1994)\textsuperscript{155}**

<table>
<thead>
<tr>
<th>Work-Rest Regimen</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Light</td>
</tr>
<tr>
<td>Constant Work</td>
<td>30.0</td>
</tr>
<tr>
<td>75% Work, 25% Rest each hour</td>
<td>30.6</td>
</tr>
<tr>
<td>50% Work, 50% Rest each hour</td>
<td>31.4</td>
</tr>
<tr>
<td>25% Work, 75% Rest each hour</td>
<td>32.2</td>
</tr>
</tbody>
</table>

An elevated ambient temperature or humidity level increases the cardiovascular load of a materials handler and a low temperature can substantially reduce finger flexibility and accuracy. An ideal thermal comfort zone is affected by a number of factors in addition to temperature and humidity. Among these are air velocity (producing a windchill effect), workload, radiant heat sources and amount and type of clothing. In general, the body’s core temperature should not vary by more than 1\(^{\circ}\) C in either direction, and the above factors should be adjusted to accommodate this range (ACGIH, 1996)\textsuperscript{157}.

Heat stress elevates core temperature and in turn metabolism of the body (Q10 effect). Other associated physiological effects include rise in heart rate, rise in blood circulation and increased sweating. Prolong exposure to heat may result in heat cramp, heat exhaustion and heat stroke etc. Hot and humid ambient environmental conditions
reduce the physical performance capabilities of the worker (McArdle et al., 1996)\textsuperscript{158}, while cold weather reduce hand dexterity, joint movement and thus negatively impact on lifting and carrying capability of personnel (Wilson and Corlett, 1992; Hancock and Vasmatzidix, 1998)\textsuperscript{159,160}.

Heat stress also considerably affects physical and cognitive performance (Hancock, 1981; Ramsey and Kwon, 1988)\textsuperscript{161,162}. According to the researchers the type of work actually mediates the effect of heat stress on performance. The reduction of heat stress can be accomplished by a systematic and comprehensive approach. Frequent rest breaks in a cooler environment is necessary. Limiting the total time spent in a hot environment could also serve the purpose.

**NOISE LEVEL AND WORK PERFORMANCE**

The workers frequently complain that there is too much noise and that distracts them from their jobs. Loudness is directly related to the mechanical pressure transmitted to the eardrum, although the sound frequency and other characteristics of sound determine the degrading effect it has on performance. The less predictable and controllable the sound, the more annoying it is.

Sound levels above 50 dBA may become increasingly intrusive, objectionable and fatiguing, depending on their frequency and predictability. Sound levels that exceed 85 dBA and continue for as long as 8 hours may cause hearing loss. If noise levels routinely exceed 85 dBA, it is necessary to control the sound source or provide other means of hearing protection. Workers should not be exposed to sounds above 115 dBA (ACGIH, 1996)\textsuperscript{157}. 
Many dye casting industries, involving manual mode of work, have generated high levels of noise in the range of 80-100dBA. This has resulted in physiological effects leading to reduced performance. The level of noise and load both were having statistically significant effect on human performance (Muzammil et al, 2004). According to Persson et al (2001) the quality of work performance and perceived annoyance may be influenced by a continuous exposure to low frequency noise at commonly occurring noise levels.

**ILLUMINATION LEVEL AND WORK PERFORMANCE**

The amount of light required to perform a specific task without feeling visual fatigue is a function of the visual difficulty of the task at the desired work speed and quality and the visual acuity of the worker. Degree of visual difficulty is typically determined by i) the contrast between the target and its backgrounds; ii) the spatial resolution and iii) the size of the target.

One or more of the following symptoms and signs may accompany a general feeling of tiredness of the eyes: oculomotor changes (esophoria, exophoria); ocular pain, itching, tearing, reduced ability of the eyes to accommodate and converge properly; headache and complementary colour reversals. Although ocular symptoms from over work do not cause permanent eye damage, yet these symptoms can affect productivity and a worker's sense of well-being. The recommended ranges of illumination for various types of tasks are shown in Table 4.
**TABLE 4: RECOMMENDED RANGES OF ILLUMINATION FOR VARIOUS TYPES OF TASKS (Eastman Kodak Company, 1986)**

<table>
<thead>
<tr>
<th>Type of Activity or Area</th>
<th>Range of Illumination* (Lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public areas with dark surroundings</td>
<td>20-50</td>
</tr>
<tr>
<td>Simple orientation for short temporary visits</td>
<td>&gt;50-100</td>
</tr>
<tr>
<td>Working spaces where visual tasks are only occasionally performed</td>
<td>&gt;100-200</td>
</tr>
<tr>
<td>Performance of visual tasks of high contrast or large size: reading printed material, typed originals; rough machine work; ordinary inspection; rough assembly</td>
<td>&gt;200-500</td>
</tr>
<tr>
<td>Performance of visual tasks of medium contrast or small size: reading pencil handwriting, poorly printed material; difficult inspection; medium machine work; medium assembly</td>
<td>&gt;500-1000</td>
</tr>
<tr>
<td>Performance of visual tasks of low contrast or very small size: reading hard pencil handwriting on poor quality paper, very poorly printed material; very difficult inspection</td>
<td>&gt;1000-2000</td>
</tr>
<tr>
<td>Performance of visual tasks of low contrast and very small size over a prolonged period: fine assembly, highly difficult inspection, fine machine work</td>
<td>&gt;2000-5000</td>
</tr>
<tr>
<td>Performance of very prolonged and exacting visual tasks: the most difficult inspection, extra fine machine work, extra fine assembly</td>
<td>&gt;5000-10000</td>
</tr>
<tr>
<td>Performance of very special visual tasks of extremely low contrast and small size: some surgical procedures</td>
<td>&gt;10000-20000</td>
</tr>
</tbody>
</table>

*The choice of a value within a range depends on task variables, the reflectance of the environment and the individual’s visual capabilities.*
Common and recommended light levels indoor: The outdoor light level is approximately 10,000 lux on a clear day. In the building, in the area closest to windows, the light level may be reduced to approximately 1,000 lux. In the middle area it may be as low as 25 - 50 lux. Additional lighting equipment is often necessary to compensate the low levels.

Earlier it was common with light levels in the range 100 - 300 lux for normal activities. Today the light level is more common in the range 500 - 1000 lux - depending on activity. For precision and detailed works, the light level may even approach 1500 - 2000 lux. The table below is guidance for recommended light level in different workspaces.

**TABLE 5: RECOMMENDED RANGES OF ILLUMINATION IN DIFFERENT WORKSPACES**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Illumination (lux, lumen/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warehouses, Homes, Theatres, Archives</td>
<td>150</td>
</tr>
<tr>
<td>Easy Office Work, Classes</td>
<td>250</td>
</tr>
<tr>
<td>Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories</td>
<td>500</td>
</tr>
<tr>
<td>Supermarkets, Mechanical Workshops, Office Landscapes</td>
<td>750</td>
</tr>
<tr>
<td>Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres</td>
<td>1,000</td>
</tr>
<tr>
<td>Detailed Drawing Work, Very Detailed Mechanical Works</td>
<td>1,500 - 2,000</td>
</tr>
</tbody>
</table>
PSYCHOLOGICAL STRESS AND WORK PERFORMANCE

The human memory can be divided into non-declarative and declarative memory. The declarative memory is divided into i) working memory, short-term or recent memory and ii) remote memory or long-term memory (Guyton, 1991). Short-term memory is the recalling of events, which have occurred, seconds to hours or even days.

The impairment of short-term memory after exhaustive exercise was also observed by Hancock and McNaughton (1986), Fleury and Bard (1987) and Paas and Adams (1991). Davey (1973) found that in moderate amount of physical exertion there is improvement of mental performances but severe physical exertion tends to produce deterioration in mental performance. Stress, mental health and depression at the workplace have emerged as common and significant problems (Mino et al, 2006).

Tomporowski and Ellis (1986) indicated that the type of cognition task performed in combination with physical exertion is an important factor in the interpretation of that problem. Davey (1973) carried out an experiment on bicycle ergometer with a 15-item memory test. He had seen a mixed result, i.e., up to 10 minutes the physical exertion facilitated the cognitive ability but after 10 minutes it impaired the functions. Douchamps-Riboux et al (1989) stated that while performing experiment on the rowers of a rowing race on 4-item and 12-item memory tests, there was both increase in response time and error of cognitive function.

The influence of extreme physical exertion or extreme posture may produce a pronounced effect and cause a decrement in cognitive performance (Bhatnagar et al, 1985; Hancock and McNaughton, 1986; Fleury and Bard, 1987; Paas and Adams, 1991). Moreover during exhaustive exercise (maximal type) blood pressure may rise considerably and it has been seen that elevated blood pressure impaired short-term memory function extensively (Daseeva et al, 1995).
Cognitive reasoning of experienced workers may be used as an active device for the evaluation of strenuous physical activities such as lifting tasks. Lifting activities are significantly associated with musculoskeletal symptoms and effort may integrate the effects of both physical (lifting tasks) and non-physical (i.e., work dissatisfaction) factors, as well as perception of risk (Yeung et al, 2003).\textsuperscript{176}

Work conditions are an important determinant of psychological well-being and mental disorders, particularly depression, in the workplace have important consequences for quality of life, worker productivity, and the utilization and cost of health care (Muntaner et al, 2006).\textsuperscript{177} They also found that age and emotional strain have a statistically significant association with depression symptoms.

Nakata et al (2006)\textsuperscript{178} examined the association between psychosocial job stress and occupational injuries among workers in small and medium-sized enterprises (SMEs). They observed that workers with high quantitative workload, high cognitive demands and low job satisfaction had a significantly increased risk of occupational injury. In manufacturing/production workers, high quantitative workload and high depressive symptoms were significantly associated with injury in men, while low social support from colleagues or family was related to injury in women.

Harada et al (2005)\textsuperscript{179} assessed the relationship between shift work and job stress in a Japanese steel company. Increase in the amount of overtime and decrease in the number of holidays led to a significant deterioration in job stress. The study revealed that the 3-shift system of employment increases work-related stress and that job control is low among shift workers. To reduce job stress in this occupational population, a reduction in the amount of overtime and an increase in the number of holidays seemed to be useful interventions.

Preckel et al (2005)\textsuperscript{180} reported that over commitment, indicating an exhaustive work-related coping style, is independently associated with vital exhaustion. It appears to
be an important personality trait that may contribute to feelings of exhaustion at times of increased job strain.

The effectiveness of a stress-management program at the workplace was investigated by Mino et al (2006)\textsuperscript{171}. This program was based on the cognitive behavioral approach and perceived work-related stress and psychological symptoms were evaluated. This sort of program may have potential for the prevention of depression.

**NUTRITIONAL STATUS AND WORK PERFORMANCE**

The sustenance of survival cannot be achieved without adequate and proper nourishment. Every individual needs adequate food for growth, development and to lead active and healthy life (Gopalan et al, 2002)\textsuperscript{181}. Man needs food as building blocks for tissues and for energy (Astrand and Rodahl, 1986)\textsuperscript{139}. The diet should provide adequate amounts of all nutrients for maintaining good health and physical efficiency (Swaminathan, 2000)\textsuperscript{182}.

The habitual diet pattern is similar in almost all parts of India. However the type and amount of foods included in the diet may depend upon the region and socio-economic level of the individuals. Each food in the diet contains major sources of several types of nutrients, serves as major source of one or two major nutrients (Gopalan et al, 2002)\textsuperscript{181}.

Physically active persons need more fuel. Different strenuous activities raise the body calorie needs. There is also benefit in strenuous activities, where the activity helps in regulating appetite. At mild or moderate levels of exertion during different sorts of activities, persons eat less than inactive counterparts. When the activity level rises above the mild or moderate to strenuous level, calorie needs are also increased (Srilakshmi, 2000)\textsuperscript{183}.
A human being needs a wide range of nutrients to perform various functions in the body and to lead a healthy life. The nutrients include protein, fat, carbohydrate, vitamins and minerals. These nutrients are chemical substances that are present in the food which we consume daily. Depending on the relative concentration of these nutrients, foods are classified as protein-rich foods, carbohydrate-rich foods and fat-rich foods etc. Protein, fat and carbohydrate provide energy and are generally referred to as proximate principles of food. Beside this, proteins also act as a major constituent of tissues and cells of the body. They form an important component of muscle, other tissues and vital body fluids like blood. On the other hand fat is a concentrated source of energy and it supplies per unit weight more than twice the energy furnished by either protein or carbohydrate (Gopalan et al, 2002).  

When an individual is performing different sorts of activities including manual work, which can be light, moderate or heavy, it calls for additional supply of energy. Even in the absence of manual work, individuals have to do minimum activity like sitting, studying, walking, dressing etc. and all these activities require energy, known as "maintenance energy", which is roughly 1.5 times of basal energy needed. The energy required for both basal metabolism and muscular activity have to be supplied through food (Gopalan et al, 2002).  

The energy requirements of Indians for same age groups vary for different activities. An adult male sedentary worker has a calorie requirement 1.0 ACU (1.0 ACU=2400 kilocalories), whereas adult male moderate and heavy worker have 1.2 and 1.6 ACU respectively. The above values differ in female, where adult female sedentary worker has a calorie requirement of 0.8 ACU and adult female moderate and heavy worker has 0.9 and 1.2 ACU respectively (Gopalan et al, 2002; Swaminathan, 2000). The calorie requirements of Indians as proposed by ICMR are given in the following table.
TABLE 6: CALORIE REQUIREMENTS OF INDIANS PROPOSED BY ICMR

<table>
<thead>
<tr>
<th>Type of Worker</th>
<th>ACU</th>
<th>Calorie Requirement (kcal.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult Male Sedentary Worker</td>
<td>1.0</td>
<td>2400</td>
</tr>
<tr>
<td>Adult Male Moderate Worker</td>
<td>1.2</td>
<td>2880</td>
</tr>
<tr>
<td>Adult Male Heavy Worker</td>
<td>1.6</td>
<td>3840</td>
</tr>
<tr>
<td>Adult Female Sedentary Worker</td>
<td>0.8</td>
<td>1920</td>
</tr>
<tr>
<td>Adult Female Moderate Worker</td>
<td>0.9</td>
<td>2160</td>
</tr>
<tr>
<td>Adult Female Heavy Worker</td>
<td>1.2</td>
<td>2880</td>
</tr>
</tbody>
</table>

**Carbohydrates in Nutrition:** 70-75% of the total daily calorie requirements should come from carbohydrates. The energy derived from carbohydrates should not preferably exceed 75% of the total calorie requirement and to prevent ketosis, should not fall below 20% of the total calories. However poor people of Southeast Asia, Bangladesh and India often derive more than 80% of the dietary calories from carbohydrates.

About 55-65% of the total daily calorie requirements should normally come from easily digestible macromolecular polysaccharides like starches and not more than 10-15% from monosaccharides and disaccharides like sucrose, lactose and fructose. ICMR recommendations restrict the intake of refined carbohydrates like sugar and jaggery to 5% of the total calories. High intakes of refined sugars may lead to dental caries and coronary diseases.

In addition, the daily diet should include at least 40 grams of indigestible dietary fibres made of cellulose, hemi cellulose, pectin, lignin, gum and mucilage. These polysaccharides do not supply calories or nutrients but act as roughage to enhance the bulk of food, delay the passage of food through the gastro intestinal tract and stimulate
intestinal peristalsis to prevent constipation. Some fibres lower the serum cholesterol and
the post-prandial blood sugar (Spiller and Kay, 1980)\textsuperscript{184}.

The heavy workers should take high-carbohydrate high-fat diets to provide large
amounts of calories and to prevent depletion of glycogen (Williams, 1976)\textsuperscript{185}.

**Proteins in Nutrition:** Normal adults need dietary proteins to maintain their nitrogen
balance by replacing the tissue proteins regularly catabolized. Protein requirement is
enhanced by an inadequacy of dietary carbohydrates and fats, poor digestibility or low
biological value of food proteins, impaired intestinal absorption or a deficiency of an
essential amino acid. Stress increases the requirement by exciting the secretion of
glucocorticoids that enhance protein catabolism (Goodhart and Shils, 1980)\textsuperscript{186}.

Even vigorous exercise or work does not enhance protein requirement – very
active athletes or heavy workers do not require significantly higher amounts of proteins
than non-athletes or sedentary workers (Williams, 1976)\textsuperscript{186}.

The daily protein allowances of adult man and adult woman have been
recommended by ICMR to be 55 grams and 45 grams respectively. About 30% or more
of the protein requirement should preferably be supplied by animal proteins of high
biological value to provide adequate amounts of all the essential amino acids.

**Fats in Nutrition:** 15-20% of the total daily calorie requirements should come from fats.
Dietary fat should not exceed 30% of the total dietary calories or 80 grams per day.
“Visible fats” such as vegetable oils, margarine, butter and ghee should range between 5-
15% of the total calories while another 10-20% of the total calories may come from
“invisible fats” present in cereals, legumes, soybeans, nuts, oilseeds, milk, meat, fish,
potato and vegetables.

In USA and Britain, more than 40% of dietary calories come from fat (Passmore
and Eastwood, 1986)\textsuperscript{187}. On the contrary, certain Indian tribes thrive well even with less
than 2% of their dietary calories coming from fat. Consumption of fats supplying more than 30% of the total calories may elevate the serum cholesterol in sedentary and moderately active individuals. However in athletes and workers engaged in heavy work, up to 45% of the total calories may come from fat to reduce the bulk of food necessary for the high calorie need because fat has a much higher calorie value than proteins and carbohydrates (Williams, 1976)\textsuperscript{185}. Moreover heavy muscular work prevents the rise in serum cholesterol and lipoproteins, otherwise produced by the high-fat diet.

The consumption of low-fat diets may reduce the availability of fat-soluble vitamins that remain with and are absorbed with food lipids.

\textbf{Vitamin and Mineral Requirements:} The requirements of minerals and most of the vitamins do not decline with age. Their intakes may become insufficient due to a fall in total food intake. The intakes of thiamine, riboflavin and nicotinamide may become insufficient. The absorption of some of the micronutrients like iron, calcium and fat-soluble vitamins may decline with age. As a consequence of such deficiencies, nutritional anemias, either microcytic or megaloblastic, often appear and poor hemoglobin levels and low plasma folate concentrations are frequently seen. Poor night vision and abnormal electroretinogram may result from vitamin A deficiency (Slater and Kritchevsky, 1980)\textsuperscript{188}.

Anemia is a major nutritional problem affecting all segments of the populations in general and children. Anemia in our country is essentially due to iron deficiency, which is generally observed in children and women (Gopalan et al., 2002)\textsuperscript{181}. Recently World Health Organization (WHO) statistics indicated a worldwide anemia prevalence of about 30 percent with higher rates in developing countries. Young children and pregnant women are the most affected group with an estimated global prevalence of about 40 percent and 50 percent respectively (Srilakshmi, 2000)\textsuperscript{183}. To overcome the situation, locally available inexpensive food sources enriched with vitamins and minerals should be incorporated in the diet and consumed on a regular basis.
AIMS AND OBJECTIVES

"Handling heavy load manually" – is one of the oldest occupations of the world. Lifting and carrying are among the activities that subject the body to the greatest strain. Thousands of people have chosen this job as their main economic activities in India. And, the number is increasing, as the current phase of globalization and liberalization has hastened the pace of improvement of peasants and landless agricultural labours. Large-scale displacement of people from their habitats, closure of industries, retrenchment of workers and insecurity of employment has made manual load carriage a relatively stable subsistence income though at the cost of the porter’s life.

In India although the organized sectors follow stringently the OSHA and ILO rules regarding manual lifting tasks and the workers earn fixed salaries for their job but in the unorganized sectors, the situation is worse. These sectors do not abide the rules and regulations laid down by the statutory body. Here more load handling means more monetary returns and this indulges the poor workers in performing such strenuous tasks for prolong periods, thereby leading to over exhaustion of the whole body, particularly the back muscles, the shoulders, the neck, the arms and the legs. Nevertheless musculo skeletal disorders are quite frequent among the workers of both the sectors. From the above facts, it is very much evident that work related musculo skeletal disorders, associated with manual material handling, are becoming a matter of grave concern in our country.

In developed countries various sophisticated and expensive experiments have been undertaken on manual material handling for e.g. analysis of stress in MMH by "Fuzzy -modeling"(Karwoski & Ayoub, 1984). But in developing countries such experiments are lacking. Thus in those countries the official reporting of occupational disease is limited and the information available primarily comes from a number of field studies carried out by different institutions.
Indeed it is a distressing fact that a large number of people throughout the country is forced into manual heavy load handling on a daily basis primarily due to their poor socio-economic condition. Consequently in the quest of financial gains, they succumb to a host of work-related disorders and aggravate their misery to an even greater proportion.

The aims and objectives of the research work are as follows:

1) To assess the prevalence of MSD among the heavy load handling workers of the organized sector.

2) To assess the prevalence of MSD among the heavy load handling workers of the unorganized sector.

3) To specify the probable risk factors that contribute immensely to the development of such occupational health disorders in both the sectors.

4) To identify the physiological stresses of the workers associated with heavy load handling tasks.

5) To identify the psychological stresses of the workers associated with heavy load handling tasks.

6) To assess the stresses related with the work environment of these workers.

7) To assess the nutritional status of the workers of both the sectors.

8) To modify the existing working procedures and thereby enhance the efficiency of the work system.

9) To improve the health and safety of the workers involved in heavy load handling.
PART- 1: ORGANIZED SECTOR