CHAPTER 3

LITERATURE REVIEW

Despite of widespread mechanization in the industries, people stills performs manual tasks involving lifting, carrying, lowering of objects either by necessity or by choice. Most of time the load handled by them is very much above their physical capability. Physical capability of workers varies individual to individual. The limitations of physical capabilities are complex and interrelated. Each is dependent upon personal characteristics of worker. The performance of manual material handling tasks imposes high degree of cardiovascular strain, increased heart rate, blood pressure, muscular fatigue and musculoskeletal disorders (MSDs) [Aqu68, Ast86, Ayo81, Dur67, Ham69, Mit84a,b].

3.1 Categorization of Literature Review

The review of literature has been divided into following categories:

1. Factors associated with Manual Material Handling
   
   i. Worker Characteristics
      
      a) Age
      
      b) Gender
      
      c) Body Weight
      
      d) Body Composition
      
      e) Anthropometry
      
      f) Nutritional status
   
   ii. Load Characteristics
      
      a) Carrying Tasks
      
      b) Object Size
      
      c) Object Shape
      
      d) Load Distribution and Stability
e) Task Duration
f) Walking Speed

iii. Working Environment

iv. Studies on different modes of load carrying

v. Physiological Aspect
   a) Lung Function
   b) Rest pauses

vi. Biomechanical Aspect
   a) Posture
   b) Center of gravity
   c) Spine
   d) Forces on the vertebral column

vii. Physical Fitness
   a) Aerobic Capacity
   b) Studies on VO\textsubscript{2}max
   c) Heart Rate Recovery Cost
   d) Heart Rate Variability

viii. Electromyography

ix. Psycho-physiological Aspect

x. Assessment of workload

xi. Studies on Maximum Acceptable Weight

xii. Studies on Work Stressors

xiii. Studies on Shift Work and Extending working hours

2. Musculoskeletal Disorders

3. Artificial Neural Network

4. Biorhythm
3.2 Factors associated with Manual Material Handling

Researchers have done various studies to determine different factors like workers characteristics, load characteristics, working environment affecting manual material handling tasks in order to assess their importance, and to minimize the overall strain on the worker.

3.2.1 Work Characteristics

3.2.1.1 Age

Age has a significant effect on work capacity. The effect of ageing is likely to be associated with the decline in maximal heart rate [Rob38]. According to Aberg [Abe64] the reduction in work capacity starts after 20 years of age. A 60 year old has an aerobic capacity of about 70% of that of 25 years old. This decline is due to reduction in cardiac output and might be associated with loss of muscle function.

In a study by Powell [Pow73] on coal-miners, one of the prime reasons for men aged 45 years and older for leaving the occupation was that the older workers recognized of their inability to meet the physical requirements of the job.

Most of literature [Bro74, Her27, Hul54, Kos68, Mag69, Row69,83, Sch68] indicates greatest incidence of low back pain (LBP) in the 30 to 50 year old group. Heavy physical work performed in the early ages accelerates the rate of musculoskeletal and other injuries with ageing [Blo71, Bro71].

The maximal oxygen uptake declines with age but oxygen consumption at submaximal work load is not affected by age [Ada67, Dur67, Mul62, She74].

The reduction in maximal strength with age is however uncertain but [Mit80, Nyl78] observed that isometric arm and leg strength increases with age. Montoye and Lamphiear [Mon77] reported some decrease of strength with age. On the other hand, Petrofsky and Lind [Pet75a] did not observe any changes in isometric strength with age.
3.2.1.2 Gender

Gender is the single most important worker characteristic that divides the working population because of differing anthropometric, biomechanical and physiological variables between males and females [Gra78]. The physical capability of females is approximately two thirds that of males. According to Doelen [Doe81], differences in physical capability between the genders are due to difference in body weight and body size.

For highly repetitive and continuous material handling tasks women work closer to their maximum aerobic capacity than men [Mit84a,b, Tic70] and therefore, may be at a greater risk than their male counterparts when performing the same tasks. Women are at a disadvantage in comparison to men because they have lower \( \text{VO}_2 \text{max} \) and lower muscle strength, particularly in the arm muscles [Vog78].

Davis [Dav83] observed that the body stability in females is always less than in males, while holding loads above the waist level. ILO [ILO56] and US Department of Labour [UDL77] recommended that women should not permit to lift as much as men. The carrying capabilities of females, as determined from Snook’s [Sno74] data, ranges from 67-73% of carrying capabilities of males.

MSDs are also more common among women than men. This is a well-known fact that has often been discussed in literature and supported by a large number of studies, especially with regard to neck and shoulder disorders [Kil98, Pun00].

From the previous studies it can be concluded that as far as load carrying is concerned from the view point of sex differences, women in general are at more risk and danger. Therefore, acceptable load should be much less in comparison to that recommended for the male of same age group.

3.2.1.3 Body Weight

The body weight is an important determinant of a person's manual materials handling capability. Body weight influences all activities in which the worker
has to move his or her own body (e.g., walking, cycling, climbing etc.). As the body weight increases so does the metabolic energy expenditure rate [Kam71, Gar76, Wyn63]. This means that, for the same task, heavier people are more stressed which could lead to quick exhaustion or other cardiovascular problems.

The maximum comfort load should be related to the body weight. On the basis of the energy cost of load carriage, this rose steeply 40% of body weight. Body weight has a potentially complex effect on an individual’s risk injury during manual material handling. The body weight has a direct bearing on the metabolic rate of a person while lifting and carrying loads [Kam71]. Thus a heavier person would have a greater metabolic rate and concomitant circulatory load, which could lead to earlier fatigue or cardiovascular problems if the person were so predisposed. A heavier person is usually stronger than his lighter counterpart, and usually has the mass necessary to counter balance the handling of a large object [Kon73, Lar79, Lau69, Sno67, Tro69] though isometric muscular fatigue has been shown to develop more readily in overweight people. Individuals with a high body weight can therefore carry greater loads. Nag et al. [Nag78] studied that porters of mean weight 53 kg, carried load upto 100 kg on treadmill and it is also very common to find carrying load of 60-140 kg in vegetable market, dockyard etc.

3.2.1.4 Body Composition

Buskirk and Taylor [Bus57] indicated that as the lean body mass is highly correlated with VO\textsubscript{2}max it is therefore to be considered as a positive factor in load carrying ability. VO\textsubscript{2}max declines as the body fat increases with age [Dur84].

3.2.1.5 Anthropometry

Well build and strong individuals have a greater capability to perform MMH tasks than individuals who have a slight build and are relatively weak. Proportionately built person has greater lifting capacity than one who has larger torso and abdominal depth [Ayo89] although individuals with larger torso and greater abdominal depth tend to be stronger than other body types.
The later faces a great deal of difficulty in repetitive load handling and can get exhausted quickly particularly when the load is to be picked up from the floor [Gar76, Pet75, Wyn63].

Studies have shown that compared to shorter individuals, tall people are relatively weak and are more susceptible to back pain as they have to lean and reach further to pick up or set down a load [Cha77, Gyn74, Mer83, Tau70, Wat77].

### 3.2.1.6 Nutritional status

Nutrition is one of the main factors for poor health condition and also for work performance of the population. It is needless to mention that in order to maintain a good physical fitness standard, it is essential to have a balanced diet. Banerjee [Ban88] in a review on nutritional problems concluded that the most serious problem was a deficiency of calories.

Pheasant [Phe91] has review the evidence for a connection between low blood sugar, low performance and increased accidents.

According to Soekirman [Soe78] labourers who take meals twice a day have lower working productivity than those who take meals thrice a day.

### 3.2.2 Load Characteristics

#### 3.2.2.1 Carrying Tasks

Load handling implies both lifting and carrying which involves muscular work. Heavy muscular work involved in load carrying operations (industry, agriculture and in dockyards) demands for a greater degree of energy expenditure, which in turn is fulfilled by increased pulse rate, blood pressure, output of the heart, oxygen uptake etc.

It is evident from the previous studies that loads should be positioned close to the body in order to minimize energy expenditure during carrying [Ayo89].

Carrying is one aspect of dynamic work which together with heavy manual handling and lifting, has been implicated as risk factors leading to low back pain on the basis of epidemiological studies [Dul87].
Soule and Goldman [Sou69] said a variety of techniques for carrying heavy loads evolved in various parts of the world; probably trial and error led to the coolie’s gin pole, the Korean’s a frame, the native’s head jars and panniers, the milk maid’s yoke, and the soldier’s pack.

3.2.2.2 Object Size

The length and width of the object being lifted influences the maximum acceptable weight of lift, energy expenditure and spinal stresses. In terms of energy expenditure, Ayoub and Mital [Ayo89] recommended any increase in container volume should be accomplished by first increasing its height, then its width up to a limit of 20 inch (50 cm) and finally its length. Biomechanically, the width of the container should be as small as possible [Fri84, Kro85, Mit86, Tic71]. As the width increases, the center of gravity of the load is moved further away from the L5/S1 disc and compressive and shear forces on the vertebra increases. Light but large object can create greater forces on the back then some heavier but smaller objects, due to the difference in center of gravity – L5/S1.

3.2.2.3 Object Shape

[Gar80, Oko82, Smi84] have found the maximum acceptable weight of lift is higher when using collapsible containers bags than when using boxes (noncollapsible) because bags have the advantage as they can be carried closer to the body, and hence reducing the center of gravity – L5/S1. Mital and Okolie [Mit82] reported even an 18% difference.

3.2.2.4 Load Distribution and Stability

According to Ayoub and Mital [Ayo89] when the center of gravity of a load falls outside the center line of the body, the load causes a lateral bending moment on the lumber spine resulting in rotation of each vertebra on its adjacent vertebra. Such torsional stresses from asymmetric loading reduce the maximum acceptable weight of lift, but do not affect the level of energy expenditure. A continuous shift in center of gravity occurs while handling liquids in the containers which are not full and this can reduce maximum acceptable weight of lift as much as 31% [Mit82].
3.2.2.5 Task Duration

The duration for which a person can perform a given manual task depends on his endurance. Several studies have shown that as the duration increases, the worker’s energy expenditure level also increases [Bon62, Dei79, Gar80]. This increase may be due to the accumulative effect of the products of metabolism, changes in blood flow distribution, or deterioration in mechanical efficiency [Dei79]. A decreased level of energy expenditure rate should be maintained throughout the working time as the working time increases [Mit84,85]. If the task duration is more, appropriate rest allowances should be given.

3.2.2.6 Walking Speed

It is well established that the energy cost per unit distance traveled is minimal at an intermediate walking speed in humans, defining an energetically optimal walking speed. However, little is known about the optimal walking speed while carrying a load. Bastien et al. [Bas05] studied the effect of speed and load on the energy expenditure of walking and observed that the mass specific gross metabolic power increases curvilinearly with speed and is directly proportional to the load at any speed. At optimal speed (1.3 m/s), a load up to 1/4 Mb (body mass) seemed to be appropriate for long distance walks.

Samanta and Chatterjee [Sam81] defined that load carried and speed of carriage have the principal influence in determining the energy expenditures and the cardiorespiratory changes during work.

3.2.3 Working Environment

Climatic condition exerts a direct influence on the output of work. The hot and humid climates of tropical countries often considerably reduces the work output because the environmental conditions hinders body heat loss mechanism and puts stresses on the circulatory system. The physiological cost of carrying loads under such climatic conditions becomes high, leading to an increase in the pulse rate and in the body temperature in comparison to a comfortable environmental condition.
Biswas et al. [Bis11] assessed the effects of heat stress among workers engaged in sweet making activities in terms of physiological strain.

Durnin et al. [Dur66] found that while carrying load; metabolic rate, sweat rate and body temperature of acclimatized subjects, all were elevated in hot-wet and hot-dry climates, compared with similar work in a temperate climate.

In addition to demanding muscular exertion, hot and humid work environments in tropical regions set strenuous loads on the cardiorespiratory capacity and thermal regulation of workers [Gog90, Jue95].

Hafez and Ayoub [Haf91] conducted a study to assess the lifting capabilities of acclimatized individuals in hot environments. The results indicated that the maximum acceptable weights of lift selected by the subjects at 27°C wet bulb globe temperature (WBGT) were not significantly different from the weights selected at 22°C WBGT. On the other hand, the maximum acceptable weights selected at 32°C WBGT were reduced by approximately 13 percent. It was also concluded from the study that acclimatized subjects may be permitted to lift the same weights in a warm environment as in a moderate environment up to a temperature of 27°C WBGT. In warmer environments, specifically at 32°C WBGT, precautions should be taken either by reducing the load or by providing longer rest periods.

Kamon and Belding [Kam71] found no difference in the metabolic costs of carrying loads up to 20 kg in hot climates (35°C and 45°C) compared with those in a temperate climate, but the heart rate was found to increase by 7-10 beats for each 10°C increase in air temperature. Based on indices of physiological cost, fatigue and need for rest pauses; 15 kg appeared to be most suitable for those subjects.

Krajewski et al. [Kra79] investigated a load carriage task demanding 30% and then 75% of VO₂max for men and women in warm humid and hot dry ambient conditions in order to validate the length of rest periods required. Although both sexes worked at the same relative load, the males carried 12 kg and the females 10 kg and the males achieved higher blood lactate levels than the females.
Occupational Safety and Health Association [OSHA] recommended Wet Bulb Global Temperature (WBGT) for heat stress management should be 32°C for light work, 30.5°C for moderate work and 28.9°C for heavy work at air velocity of greater than 1.5 m/s.

Snook and Ciriello [Sno74] observed an 11% reduction in load carrying ability in a hot environment with significantly higher heart rate.

It is, therefore understood that while determining the acceptable load for carrying or any study on MMH, specially in a tropical country like India, one must indicate the climatic condition, as environmental factors like humidity, air movement, air temperature influences the work capacity of an individual.

3.2.4 Studies on Different Modes of Load Carrying

In common with many developing countries of the world, quite a large proportion of the laboring population in India is employed in transporting load manually on a whole time basis. The physiological cost associated with load carriage while walking has been extensively investigated in this country and abroad. Studies concerning the permissible weight to be manually transported by a worker have been carried out by [Das66, Dat67,71, Mal62, Mal65]. Most of them have reported studies on different modes of load carrying and their relative physiological costs.

Bedale [Bed24] determined the energy cost of walking with loads ranging from 9-27 kg in eight different carrying positions and demonstrated that the use of a yoke across the shoulders resulted in the minimum energy expenditure.

While evaluating different modes of load carrying Cathcart [Cat23] showed that cheapest (physiologically) method of carrying was by yoke. Carrying with hand at sides was also physiologically economical but with heavy loads tends to cause severe elbow and arm strains.

Daniels et al. [Dan52] reported that loads up to 32 kg are more economically carried in a shoulder pack then when it is distributed around the waist.
Gupta and Rohmert [Gup64] observed that the shoulder yoke method produced relatively less muscular fatigue as indicated by circulatory response.

Legg and Mahanty [Leg85] investigated the cardio respiratory, metabolic, and subjective responses to carry a load close to the trunk in five different ways and suggested that there may be physiological differences between the five modes of load carriage.

Lloyd and Cooke [Llo11] suggested that there was a tendency for the double pack system to be associated with better economy than the backpack system. In particular freedom of movement of the trunk in the sagittal plane may be an important consideration in the efficiency of load carriage systems.

Carrying loads on head is the most prevalent mode. However in this mode the long thin muscles of the neck are in a state of contraction and the stress is borne by the vertebral column and legs. Soule and Goldman [Sou69] observed that the ‘the limiting factor’ in carrying heavy loads on the head does not appear to be in the energy cost but rather in the mechanical load tolerated by the musculature.

Soule and Goldman [Sou69] reported that load carrying on the head mode was slightly more demanding than carrying a load on the torso at the same speed. The extra cost was due to the increased shoulder and neck muscle activity needed to stabilize the head. The limiting factor in head load carrying appears to be the mechanical loading tolerated by the neck musculature rather than the total energy cost. Head load carrying appears to be one of the most efficient of all methods of load carriage.

Carrying generally implies a static strain on many muscle groups, especially those of the arms and trunk. It involves not only continuous heavy muscular strain, but also a very heavy intermittent peek strain on the back and heart.

### 3.2.5 Physiological Aspect

Since the beginning of this century numerous research reports have described the physiological effects of load carrying [Cat23,27, Dat71, Sou69, Sou78].
In a study, Bhambhani and Maikala [Bha00] compared the biomechanical and physiological responses of healthy men and women during bilateral load carriage while they walked on a treadmill at their self-selected velocity. A-priori Scheffe multiple comparisons revealed the following significant gender differences during load carriage: (1) women supported a lower proportion of the load with the hands and transferred a greater amount to the body by resting the load against the chest, (2) the oxygen uptake increased by a greater amount in the women compared with men and the ventilator threshold also exceeded during the 20-kg walk in women, and (3) the cardiovascular stress, as indicated by the percentage of maximal heart rate and rate pressure product (product of heart rate and systolic blood pressure), was significantly higher in women compared with men during both of the load-carriage walks. The results of the study suggest that when carrying absolute loads of 15 kg and 20 kg, women are more susceptible to fatigue and are at a greater risk of cardiovascular complications than men.

Lloyd et al. [Llo10] conducted a study on comparison of the physiological consequences of head-loading and back-loading for African and European women.

Stress studies consistently show that females report significantly higher levels of physical stress than their male counterparts [Mak11].

Saha et al. [Sah07] studied the Physiological strain among healthy underground coal miners aged between 23-58 years. Heart rate was monitored continuously with heart rate monitor that revealed the tasks as heavy to very heavy for them and the oxygen consumption was measured directly by using oxylog-2 machine that corresponded to metabolic costs for different activities ranging from 4.96 kcal/min to 5.47 kcal/min. The results of the study revealed that mean relative aerobic strain was varied from 47.4%-56.8% and also the poor recovery responses. This entails that miners are exerting themselves beyond their capacities where inevitably older workforce face the maximum burden. Therefore, ergonomic interventions to reduce work load and to minimize thermal stress are of prime importance.
3.2.5.1 Lung Function Test

To understand the level of pulmonary function and effect of occupation on it, determination of Forced Vital Capacity (FVC) and Forced Expiratory Volume$_1$ (FEV$_1$) are considered as routine practice under clinical health checkup. If the FEV$_1$ of a person falls below 80% of FVC, it is considered that the person is suffering from some kind of pulmonary disease.

Therefore it is necessary to screen the subject before conducting any laboratory study to ascertain that the subject is free from any kind of pulmonary problem.

3.2.5.2 Rest pauses

Every function of human body can be seen as a rhythmical balance between energy consumption and energy replacement, or between work and rest. This dual process is an integral part of the operation of muscles, of heart etc. If all the biological functions of the organism as a whole are taken into account, rest is indispensable as a physiological requirement if performance and efficiency are to be maintained.

Shepherd and Walker [She57] have found that if heavy work is combined with frequent work conditioned pauses, absenteeism will be lesser than if the work is continuous. Introducing rest pauses actually speeds up the work, and this compensates for the time lost during the prescribed pauses. Various studies have shown that if prescribed pauses are introduced, the appearance of fatigue symptoms is postponed and the loss of work through fatigue is less. The rest pauses serve the following purposes (a) preventing fatigue (b) allowing opportunities for the refreshment and (c) time for social contacts.

The rest pauses are categorized as follows:

(a) **Spontaneous Pauses:** There are obvious pauses for the rest that the workers take on their own. They are not usually long but may be frequent if the job is strenuous.

(b) **Disguised Pauses:** The worker occupies himself with own easier, routine task in order to relax from his concentration on the main job, such as
cleaning some part of machine, sitting down comfortably or consulting a workmate, the foreman etc.

(c) **Work conditioned Pauses:** These pauses arise from the nature of work e.g., waiting for a machine to complete a phase of operation or for a tool to cool. These are very common in the service of industries also.

(d) **Prescribed Pauses:** These are breaks in work laid down by management e.g., midday breaks, tea breaks.

Rest pauses are essential in all work. They should be short and frequent [ILO62, Kli82, Roh62] with the increasing duration, frequency and intensity of the work, heat stresses, and also monotony of the work. Rest pause can be part of the work, by utilizing natural breaks in the work.

Therefore, it is necessary to make detailed study of a work activity, the stress involved, energy expenditure which systematically establishes the rest pauses.

### 3.2.6 Biomechanical Aspect

Kothiya et al. [Kot92] employed a biomechanical model to investigate and clarify the role of various biomechanical factors such as magnitude of load, individual anthropometric characteristics, shape, size and location of loads etc. involved in the load lifting process. From the model, the concept of determining optimal lifting postures based on minimizing the reaction force at the L4/L5 joint subject to all other muscle/joint complexes not being overstressed was developed. The model was able to propose many interesting and practical suggestions in the area of manual material handling tasks, especially the lifting aspect. It was suggested from the study that use of such a model is important in industrial work places where a variety of work situations may exist and the model may provide a guide to the workplace design. If model predictions can be combined with workers' personal anthropometric characteristics a considerable reduction in low back injuries in the workplace can be achieved.
Lim et al. [Lim11] investigated the effects of the back angle and the shoulder angle on the subjective discomfort, heart rates and muscle activities, as dependent variables. The findings of the study revealed that, the dependent variables increased, as the back and shoulder angles increased from 0° (neutral posture) to 45° for the back angle and from 0° through 135° for the shoulder angle, respectively.

For examining the biomechanical risk factors in occupational related back disorders, Marras et al. [Mar95] studied over 400 industrial lifting jobs in 48 varied industries. The medical records of these industries were examined so that specific jobs, historically categorized as low, medium, or high risk could be identified in relation with occupational related low back disorders.

Nelson-Wonga et al. [Nel10] conducted a study on acute biomechanical responses to a prolonged standing exposure in a simulated occupational setting to investigate the impact of a prolonged standing exposure on biomechanical profiles (trunk muscle activation, joint stiffness and kinematics) for load carrying during three functional movements.

Constant lifting of massive and bulky drywall sheets creates overexertion hazards among drywall installers. So, Pan and Chiou [Pan99] carried out a study with the objective to gain understanding of the biomechanical stresses imposed on the workers while lifting and carrying drywall sheets. It was found that all four lifting techniques used in the study produced considerable biomechanical stresses at the workers’ shoulders, torsos, and hips. Only a limited percentage of the male population has sufficient strength capability to perform the task. The estimated L5/S1 and L4/L5 disc compression forces were consistently high, ranging from 655 to 1363 lb for various loads and postures analyzed. The study has also shown that four current methods for lifting and carrying massive and bulky drywall sheets create overexertion hazards among construction workers.

Pierrynowski et al. [Pie81] concluded that a biomechanical assessment could provide more information about load carrying and carrying devices than was possible from metabolic data alone. Under the biomechanical aspect needs to
study the posture, changes in the whole body center of gravity (CG) and probable loading on the vertebral column while carrying loads in different modes.

### 3.2.6.1. Posture

Posture may be defined as the relative state of orientation of different parts in space Pheasant [Phe82] and is acquired by the contracture of specific group of muscles. The human body acquires thousands of body postures while sleeping, sitting, or lying making it very difficult to classify them in reality. Although physiologically no two postures are similar but all posture can be broadly classified into three main categories: Lying, sitting and standing. Each of them can be classified depending upon the involvement of different body segments and their orientation in space.

While carrying loads for prolonged periods the postural muscles are under continuous contraction, and this cause lack of blood supply to the muscles [Ast67], leading to muscle fatigue, and if it is sustained for longer period will cause severe muscular injury.

The synchronized contraction and relaxation of different groups of muscles (antigravity muscles) help to mention the whole body center of gravity (CG) within the foot base [Ast86, Ben84]. A failure of this will cause an imbalance of the body.

### 3.2.6.2 Center of Gravity

The center of gravity is the equilibrium point where the sum of all the force moment acting on the body is zero [Wel76]. Whether the condition is static or dynamic, the stability of a body depends upon the location of its CG in relation to its base. The location of the CG of any object remains fixed as long as the body does not change its shape/position. If shape or position of an object changes, the location of CG will also change.

According to Croskey [Cro22] the location of CG is slightly higher in men than in women.
3.2.6.3 The Spine

Changes in the vertebral column are one of the major effects caused by postural changes [Smi94, Stu87]. The spine is shaped like an elongated ‘S’. In normal upright standing posture the lumbar region of the spine has a slight anterior convexity known as lordosis. The shape of the spine allows the body to cushion shocks when running and jumping. Between the bony vertebrae lie the intervertebral discs, formed of an internal pad of elastic viscous material surrounded by a tough resistant fibrous layer. The discs act as cushions between the vertebrae and give the spinal column its flexibility [Ben84, Gra73,88].

3.2.6.4 Forces on the Vertebral Column

In upright postures the forces on the vertebral column act downwards and because of the weight of the body, a pressure of 40-45 kg can easily fall on the lowest vertebrae [Gra73]. This strain increases more at the hips and trunk if the person bends forward.

According to Munchinger [Mun60] a force of 300 kg may be imposed on the lowest vertebrae because of the leverage while bending forward.

Along with the physiological stress analysis it is also necessary to assess the biomechanical aspect of load carrying in different mode as some of them might cause one sided shift of CG which will lead to serve MSDs.

3.2.7 Physical Fitness

Physically fit individuals are less prone to injuries and incapacity for work [Doe79, Bro67, Sco81]. They are likely to undertake more demanding jobs and might be absent from work due to a minor injuries. Their pain tolerance limits are usually higher.

3.2.7.1 Aerobic Capacity

Aerobic capacity (VO\(_2\)max) or maximum \(O_2\) uptake is a good measure of an individual’s ability to do manual work. This also gives a measure of the level of physical fitness. In occupational activities, a great deal of work is carried
out by manual labor. It can serve as a reliable yardstick by an individual during a work shift without any signs of undue strain and physiological fatigue.

In an aerobic task such as repetitive lifting an individual’s capacity to perform the task is often measured relative to an aerobic maximum [Mit97], and probably the most common method of assessing physical capacity is the maximal oxygen consumption test [Bal01, Noa89].

3.2.7.2 Studies on VO$_2$max

The physical work capacity or maximal aerobic capacity is the critical measure of a workers ability to perform physical tasks which stress the cardio pulmonary system.

[Ayo89, Bin62, Leh50] assured that an acceptable work rate should not exceed 33% of the VO$_2$max. [Leh62, Mic61] agree with this figure. Many researchers have set 50% VO$_2$max as an upper limit [Chr63, Ast56, 60, Wyn62].

According to [Mit58, Tay55] factors like physical training etc. will raise O$_2$ uptake and thereby will improve the ability to carry loads. The factors which have been associated with a decrease in VO$_2$max are dehydration Buskirk et al. [Bus58], increasing age Hermansen [Her78], semi starvation with consequent loss of lean body mass Keys et al. [Key50] and high altitude Pugh et al. [Pug64] etc. All these factors tend to the lower the maximal load carrying capacity or slow the walking speed at which the load can be carried. VO$_2$max will be a major determinant of assessing the severity of load carrying tasks which can be sustained for a prolonged period. VO$_2$max is correlated with body weight and in particular with muscle mass. Individual with high VO$_2$max and large load carrying capacity will also tend to have a high average body weight or muscle mass [Jor85].

Ghosh [Gho05] found the aerobic capacity of Indian young male fall within poor to average category compared with the data available in literature.

According to Jorgensen [Jor85] the maximum level of the tasks can be determined at 35% VO$_2$max and all the jobs with O$_2$ demand exceeding 0.6
l/min (approx.) should be banned as it might be serious implications for the industry.

Kinoshita [Kin85] cited that the weight of the individual load should not exceed 40% of the body weight for continuous carrying and 50% for intermittent or occasional carrying.

The VO$_2$max decreases due to age and is lower for women than men, and may be affected by the physical job demands [Ast97, Bus87, Lew83, Row93, Tan97, Tor00].

Previous studies in Thailand, Indonesia and India showed 25–30% higher Heart rates at submaximal VO$_2$ levels when compared to the Western data [Ast97, Van93, Yoo98].

3.2.7.3 Heart Rate Recovery Cost

Heart rate recovery measure helps to evaluate overall heart fitness level. Recovery heart rate measure one minute after stopping exercise, indicates how quickly a person recovered from an exercise session. Physically fit persons generally recover more rapidly because their cardiovascular systems are more efficient and adapt more quickly to the imposed demands.

Chen and Lee [Che98] developed a heart rate recovery cost (RC) model to validate it under various degrees of dynamic and static task components.

Datta et al. [Dat73] stated a high correlation of load carried and transported with peak heart rates and the energy expenditures.

In a laboratory experiment conducted by Swei-Pi [Swe00] observed that both the physiological costs (heart rate and oxygen uptake) and rating of perceived exertion (RPE) increased with an increase in lifting frequency though maximum acceptable weight of lift decreased.

3.2.7.4 Heart Rate Variability

Heart rate variability (HRV) is a physiological phenomenon where the time interval between heart beats varies. It is measured by the variation in the beat-to-beat interval. A healthy heart has a large HRV, while decreased or
absent variability may indicate cardiac disease. HRV also decreases with exercise-induced tachycardia. One aspect of HRV can be used as a measurement of fitness, specifically the speed at which a person’s heart rate drops upon termination of vigorous exercise. The speed at which a person's heart rate returns to resting is faster for a fit person than an unfit person. A drop of 20 beats in a minute is typical for a healthy person [FF2].

Ethnic and sex differences in resting HRV levels have been reported in the literature. Most of the available evidence [Lia95, Urb98, Wan05] indicates that African Americans (AAs) have higher HRV than European Americans (EAs). The evidence on sex differences is more controversial with some studies showing higher HRV in females [Eva01, Kos09] than in males or vice versa [Ume98, Bon03]. There are also studies reporting absence of any sex difference [Fag99, Slo08].

Dantas et al., [Dan10] measured the Reproducibility of heart rate variability parameters in healthy subjects at rest and after a postural change maneuver.

Measures of HRV may be used to assess autonomic function, and perhaps the risk of cardiovascular morbidity [Dit05].

Li et al. [Li09] found in a longitudinal study conducted among the youths that females display greater HRV response to stress than males.

McNarry and Lewis [McN12] performed a study on Heart rate variability reproducibility during exercise and found the reproducibility was slightly diminished during heavy intensity exercise relative to both unloaded baseline cycling and moderate exercise. Study also indicated that HRV parameters can be reliably determined during exercise, and it underlines the importance of standardizing exercise intensity with regard to fitness levels if HRV is to be reliably determined.

Palatini et al. [Pal00] undertaken a study to assess the reproducibility of office versus ambulatory heart rates and the results indicated that heart rate recorded over the 24 hours has a better reproducibility than office heart rate, and could thus be a better prognostic indicator than traditional measurement of resting heart rate in the hospital setting.
Sluiter et al. [Slu09] conducted a study on reproducibility and validity of heart rate variability and respiration rate measurements in participants with prolonged fatigue complaints.

Although predictive value of heart rate recovery (HRR) has been tested in large populations, the reproducibility of HRR in treadmill exercise test has not been assessed prospectively [Tul11].

3.2.8 Electromyography

Electromyography (EMG) is the process of recording electrical changes that occur in a muscle during or immediately before contraction. EMG is based on the fact that contracting muscles generate electrical impulses. The advantages of EMG are that it reveals both the intensity and the duration of the muscle action and discloses the precise time sequences of muscular activity in a movement.

Physiological assessment of muscular involvement is based on measurement of myoelectric (EMG) signals from muscles which are suspected of taking part in static and dynamic contracture during MMH.

It is important to evaluate the job to assess muscular involvement and occurrence of muscular fatigue. The EMG signals from these muscles are picked up by means of surface electrodes affixed to the skin. The amplitude of these signals reflects the degree of muscular involvement and it is therefore possible to assess the degree of muscular load from EMG measurements. Higher signal amplitude usually reflects higher muscular force development for a given task.

Electromyographic signs of fatigue can be used as indicators of muscular overload. High doses of muscular involvement causes ‘localized muscle fatigue’ Chaffin [Cha73] which involves muscular decrement, sensation of fatigue and pain with corresponding statistical changes in the EMG signals. These changes are closely related to the fatigue process which largely consists of a spectral shift from higher to lower frequencies.

Gallagher et al. [Gal11] investigated through EMG study on Underground coal miners who work in low-seam mines frequently handle materials in
kneeling or squatting postures that nine of 10 thigh muscles were affected by an interaction between posture and angular position of the load lifted. EMG activity for the majority of thigh muscles was affected by the size of the base of support provided by different postures, with lower EMG activity observed with a larger base of support and increased activity in postures where base of support was reduced. However, such postures are also associated with increased risk of meniscal damage.

Holewijn and Meeuwsen [Hol00] carried out a study to examine the effects of mass and the type of support (on the shoulder or on waist) on physiological and mechanical strain. It was observed from the study that while standing, oxygen uptake was not influenced by the type or mass of the backpack, and averaged 10% maximal oxygen uptake. The heart rate increased significantly by 9 beats/min while standing, wearing a backpack. And while walking (1.33 m/s) the mass significantly influenced both the heart rate and the oxygen uptake carried, but both types of strain remained below the tolerance limits for prolonged wear. Standing supporting a load did not significantly increase the EMG signal of the trapezius shoulder muscle (pars descenders). While walking, load carrying significantly increased the EMG of the shoulder muscles. The pressure on the skin under the shoulder straps during load carrying on the shoulders was more than a factor of three times higher than the threshold value for skin and tissue irritation.

3.2.9 Psycho-physiological Aspect

Psychophysics is a very old branch of psychology that is concerned with the relationship between sensation and their physical stimuli. According to modern psychophysical theory the perceived strength of a sensation is directly related to the intensity of its physical stimulus by means of a mathematical power function. The perception of muscular effort and force has been found to obey the psychophysical power law. The use of psychophysics in the study of manual handling tasks required the subject to adjust on of the task variables according to their own perception of muscular effort or force.
Workers carrying weight are not only engaged in industries but in other areas too. It is a problem which involves biological and practical factors. It required a study of the workers physiological capacity and its variation depending on biomechanical, psychophysical and climate conditions.

The Borg RPE scale Borg [Bor73] is a well-known rating scale for subjective measure of physical effort. Workers are asked to rate the level of exertion they perceive when carrying out a task on a scale from 6-20 (corresponding minimum and maximum heart rate of 60-200 beats/min).

In the field of heavy physical work and the perception of effort and exertion, one of the most popular methods is the rating of perceived exertion. For checking this perceived exertion Borg [Bor91] developed a Psychophysical CR-10 scale with rating 1 (nothing at all) to 10 (extremely strong).

Ciriello [Cir08] used a psychophysical methodology, whereby the subjects were asked to select a workload they could sustain for eight hours without “straining themselves or without becoming unusually tired, weakened, overheated or out of breath.” The results revealed that the maximum acceptable weights (MAWs) and forces (MAFs) of all tasks performed by women and all but one MAF of one task performed by men were not significantly affected by the back belt use.

In the year 1991, manual materials handling guidelines were published by Liberty Mutual Research Institute for Safety. In these guidelines, MAWs and MAFs for lifting, lowering, pushing, pulling, and carrying were derived from studies conducted in a 20 year span. Ciriello et al. [Cir10] carried out the study to check whether the present generation of workers has retained the same gender differences and absolute values in psychophysically determined MAWs and MAFs as those reflected in the guidelines of Liberty Mutual Research Institute for Safety. Results exposed that in females, MAWs of lifting, lowering, and carrying were averaged 53% of the present-day male values, similar to the 55% in the guideline. MAFs of pushing and pulling were 83 and 86% of the present-day male values but slightly higher than the 73 and 78% in the guideline respectively for initial and sustained forces. Such decreases may reflect a new psychophysical set point; however,
considerations about adjusting existing guidelines on lifting, lowering, and carrying may not be appropriate until additional data from other sources inside and outside the US confirm the present findings.

The effect of time on an individual’s lifting capacity over extended periods using a psychophysical approach was studied by Fernandez et al. [Fer91]. Twelve male subjects estimated their lifting capacity in a 25 min period, and then attempted to lift this weight for an 8 h period under varying conditions. For one experimental condition the subjects were allowed to adjust the weight, the final adjusted maximum acceptable weight of lift (MAWOL) averaged 85.4% of the original MAWOL determined in the 25 min session. The subjects also attempted to lift for an 8 hr period, without any weight adjustments. All 12 subjects lasted the 8 hr at 2 lifts per min, but at a frequency of 8 lifts per min only three subjects completed the eight hour lifting task. Slight fluctuations were also noted in heart rate and oxygen consumption which were recorded every hour.

A laboratory experiment was conducted by Swei-Pi [Swe00] to determine the effects of asymmetric lifting on psychophysically determined maximum acceptable weight limit (MAWL) and the resulting heart rate, oxygen uptake and rating of perceived exertion.

Wu and Chen [Wu03] carried out a psychophysiological study to investigate the influence of adjustment periods on the maximum acceptable weights of lift (MAWL) and the resulting responses (heart rate and rating of perceived exertion) on participants during lifting a container from the floor to knuckle height at various frequencies. The results showed that: (1) The adjustment period had a significant effect on the MAWL, and the MAWL decreased significantly as adjustment period increased. However, the effect of the adjustment period on the heart rate was not significant. In addition, the effect of the adjustment period on the rating of perceived exertion was significant. The ratings of perceived exertion (RPE) value increased as the adjustment period increased; (2) Even though the lifting frequency significantly affected the maximum acceptable weights, the lifting frequency had no significant effect on the percentage of decrease in MAWL from the 20-
min adjustment period values. The participants lifted 3%, 11% and 11% less MAWL when the lifting task was performed at 30, 40, and 50 min adjustment periods, respectively.

In a Psychophysical study, Wu [Wu09] found that the maximum acceptable weight of lift (MAWL) decreased significantly as adjustment period increased. The participants lifted 4.2, 7.5 and 11.9% less MAWL when the lifting task was performed at 30, 40, and 50 min adjustment periods, respectively. The value of rate of perceived exertion (RPE) also increased as the adjustment period increased.

It is known that feeling very tired may be dangerous to health when performing continuous work. Study by Yu and Li [Yu90] reported that carrying 15 kg was acceptable to all the subjects as under this load none complained of feeling ‘very tired’ and only 5% complained of being ‘very tired’ after carrying 25 kg. 30 kg was considered unacceptable as subjects were extremely tired. In the study 95% of the subjects had heart rate below 120 beats/min when carrying the load of 20 kg.

3.2.10 Assessment of Workload

To understand the physiological workload emphasis was earlier given on the energy expenditure study [Chr63, Mal66, Sah76]. But the method itself is cumbersome and requires trained personal along with the elaborate instrumental setup which is the practical difficulty faced by the researchers while conducting such studies in the field.

Most of the scientists therefore, prefer monitoring heart rate as an index to the physiological workload. It is needless to mention that heart rate has a direct relationship with the oxygen consumption. Therefore attempts have been made to classify the workload based on heart rate and oxygen consumption. Table 3.1 contains classification of workload as recommended by [Ast77, Bro60, Sen69].
### Table 3.1: Classification of Workload

<table>
<thead>
<tr>
<th>Work Load</th>
<th>Very Light</th>
<th>Light</th>
<th>Moderate</th>
<th>Heavy</th>
<th>Very Heavy</th>
<th>Extremely Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brouha [Bro60]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO₂ (Litre/min)</td>
<td>0.5-1.0</td>
<td>1.0-1.5</td>
<td>1.5-2.0</td>
<td>2.0-2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart Rate (Beats/min)</td>
<td>60-100</td>
<td>100-125</td>
<td>125-150</td>
<td>150-175</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Expenditure (kcal/min)</td>
<td>2.5-5.0</td>
<td>5.0-7.5</td>
<td>7.5-10.0</td>
<td>10.0-12.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Astrand and Rodahl [Ast77]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO₂ (Litre/min)</td>
<td>&lt;0.5</td>
<td>0.5-1.0</td>
<td>1.0-1.5</td>
<td>1.5-2.0</td>
<td>&gt;2.0</td>
<td></td>
</tr>
<tr>
<td>Heart Rate (Beats/min)</td>
<td>&lt;90</td>
<td>90-110</td>
<td>110-130</td>
<td>130-150</td>
<td>150-170</td>
<td></td>
</tr>
<tr>
<td>Energy Expenditure (kcal/min)</td>
<td>&lt;2.5</td>
<td>2.5-5.0</td>
<td>5.0-7.5</td>
<td>7.5-10.0</td>
<td>&gt;10.0</td>
<td></td>
</tr>
<tr>
<td>Sen [Sen 69]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO₂ (Litre/min)</td>
<td>&lt;0.35</td>
<td>0.35-0.7</td>
<td>0.7-1.05</td>
<td>1.05-1.4</td>
<td>1.4-1.75</td>
<td>&gt;1.75</td>
</tr>
<tr>
<td>Heart Rate (Beats/min)</td>
<td>&lt;75</td>
<td>75-100</td>
<td>100-125</td>
<td>125-150</td>
<td>150-175</td>
<td>&gt;175</td>
</tr>
<tr>
<td>Energy Expenditure (kcal/min)</td>
<td>&lt;1.75</td>
<td>1.75-3.5</td>
<td>3.5-5.25</td>
<td>5.25-7.0</td>
<td>7.0-8.75</td>
<td>&gt;8.75</td>
</tr>
</tbody>
</table>

Brouha [Bro60] classified the workload into four different categories for western industrial male workers in terms of their physiological responses. Later on Astrand and Rodahl [Ast77] classified the same under five categories. Brouha [Bro60] termed ‘light work’ for all the activities which demand heart rate between 60-100 beats/min. But Astrand and Rodahl [Ast77] considered heart rate of below 90 beats/min as very light work. For Indians, Sen [Sen69] considered heart rate below 75 beats/min as very light and between 75-100 beats/min as light category. Although all of them used heart rate, oxygen uptake and energy expenditure as the tools to evaluate
the workload. Classification by [Bro60, Ast77] are based on western male data while Sen [Sen69] is applicable on Indian male workers.

### 3.2.11 Studies on Maximum Acceptable Weight

There has been considerable effort to develop estimates of the maximum acceptable weight (MAW) that can be safely handled in MMH tasks. In many industrial environments there may be a wide variety of different and often complex MMH tasks; each of which may need to have their maximum acceptable weight limit (MAWL). MAWL is determined by the workers, as the highest acceptable workload, which can be lifted comfortably based on their perceived exhaustion level [Gam85]. To establish acceptable workloads in MMH, investigators have used a variety of work evaluation approaches including physiological, biomechanical, subjective, observational, focus groups, psychophysical, postural analysis, and a combination of the all these [Bur92, Bus05, de94, Kem90, Kiv91, Str96, Van der Bee05, Wai91, Wat93, Win94]. Use of psychophysical method in determining MAWL in repetitive lifting jobs is well established [Leg81, Sno78]. Snook [Sno78] first introduced the term MAWL for the industrial workers engaged in different types of repetitive lifting tasks. In his report, Snook [Sno78] proposed a methodology to determine MAWL, where the subjects were asked to select the maximum acceptable load effectively of their own choice that they can lift under a specific condition for 8 hours workday ‘without straining themselves or without becoming unusually tired, overheated, weakened or out of breath’. Many authors [Agh85, Cir90, Fer91, Kar86, Leg81, Mit83] suggested that the psychophysical approach is a reliable method in assessing the perceived exertion during MMH tasks.

After performing 42 variations of lifting, lowering, pushing, pulling, and carrying tasks, Ciriello et al. [Cir93] found in a psychophysical study among male industrial workers that lifting with extended horizontal reach produced consistent decreases in maximum acceptable weights when compared with lifting close to the body.
Ezell [Eze92] stressed on the concept of "load tailoring" in order to eliminate the danger of overloading over infantryman for successfully concentrate and win on tomorrow's battlefields.

Garg and Ayoub [Gar80] reviewed three different criteria (physiological, biomechanical, and psychophysical) to determine the “safe” weight and permissible workloads that a person can lift/carry.

Kamon [Kam71] determined on the basis of metabolic and cardiac cost, fatigue, and need for rest pauses that 15 kg must be preferable to 10 and 20 kg packages when large amounts of material to be moved and carried by hands.

Maiti and Ray [Mai04] calculated the maximum load limit as around 15 kg and the workers give this a psychophysical rating as in the moderate to heavy category.

Myles [Myl79] found in a treadmill test that the heavier load placed an extra strain on the cardiopulmonary system.

An ergonomic study using psychophysical methodology was conducted by Snook et al. [Sno70] to determine man's physical capacities while performing manual materials handling tasks in a local industry. Workers performed three lifting, three lowering, four pushing, one pulling, one walking, and six carrying tasks. The results are used to predict the maximum weights and workloads that are acceptable to different percentages of the male industrial population.

Van der Hulst [Van03] showed that heavy load carrying is associated with adverse health as measured by several indicators as cardiovascular disease, diabetes, disability retirement, subjectively reported physical health, subjective fatigue.

Long-term heavy work impairs employees, and may result in premature retirement [Wul12].

The need to estimate safe levels of loading for manual handling activities has arisen with the confirmation that MMH is associated with different MSDs.
There have been attempts to establish safe load levels for manual work during subjective analysis or based on cardiovascular, respiratory or metabolic criteria [Dat73, Jor85, Kam71, Mai04, Sno67, Sno74].

3.2.12 Studies on Work Stressors

In addition to lack of necessary skills, inherent characteristics, incorrect beliefs, and attitudes, one of the most important causes of unsafe behaviors is high work stresses [Wad03]. In the field of occupational health psychology researchers have mostly focused their attention on negative effects of long term work characteristics, in particular chronic work related stressors, such as job overload, shift work, role conflict, and lack of social support. Implications of these sources of work related stress include the effects on workers’ satisfaction and productivity, mental as well as physical health, absenteeism, and the potential for employer liability. Job stress factors cause a fall in concentration and the ability of decision making, and an increase in absent-mindedness, poor memory, and doubtfulness in people that lead to do unsafe acts of employees [Sau90]. Several studies have also proved that stress has played a role in 37% of the accidents & injuries in industry [Gol03].

Zare et al. [Zar09] also argues that stress plays a role in non-fatal accidents. Employee health and well-being have gained increasing societal attention, driven by both rising worker compensation claims and the considerable personal, organizational, and medical costs associated with stress-related illness [Smi03]. For example, the annual costs of employee stress, including costs for missed wages due to absenteeism and reduced productivity and health care costs, have been estimated to be $200-350 billion in the United States, $64.8-66.1 billion in the United Kingdom, and $232 billion in Japan [Mir07]. The fact that psychological stress can increase the risk of WRMSDs has received considerable attention, but there has been little research on this phenomenon in the occupational context.

Brick et al. [Bri08] carried out a survey among urban elite of young Afghans in Kabul to examine the social stressors, mental health, and physiological stress. It was found that subjects expressed major feelings of frustrations,
related to physical, economic, social, and political stressors of day-to-day life in Kabul. There were striking gender differences for psychosocial and physiological markers of wellbeing; specifically, women showed poorer mental health. Diastolic blood pressure was associated with a subscale of family stressors among women, but not among men.

Nowadays, occupational accidents are one of the most important problems in developing countries. Job stress and unsafe acts have been also recognized as effective factors in increasing the risk of occupational accidents. So, a study was performed by Fam et al. [Fam10] with the goal to evaluate the relationship between job stress and unsafe acts with occupational accidents.

Houtman [Hou94] examined the relationship between work stressors and the following health indicators: psychosomatic complaints, health behavior, and musculoskeletal problems. Results of the study revealed that High work pace, low intellectual discretion, and physical stressors were associated with increased health complaints (both psychosomatic and musculoskeletal) and musculoskeletal disorders after adjustment for gender, age, education, and sports participation. Psychosocial stressors are not only associated with psychosomatic complaints and health indicators, but also with musculoskeletal problems, both acute and chronic.

Women are more likely than men to be diagnosed with depression and anxiety-related disorders, and it has been hypothesized that this difference is related to sex differences in stress reactivity. Women typically report higher levels of negative affect than men in response to psychosocial stressors [Kel08].

High job strain and effort reward imbalance seem to increase the risk of cardiovascular mortality. The evidence from industrial employees suggests that attention should be paid to the prevention of work stress [Kiv02].

Luiter et al. [Lui99] found in a study that apart from high job demands and low job control, need for recovery was a major predictor of psychosomatic complaints, sleep complaints, and complaints of emotional exhaustion in coach drivers.
Stress studies consistently show that females report significantly higher levels of psychological stress than their male counterparts [Mak11].

Miller et al. [Mil00] conducted a cross-cultural study among four countries to check occupational stress and gender difference.

In a prospective study Nahit et al. [Nah03] determined that psychosocial distress and individual psychological factors (job demand, poor support from colleagues, and work dissatisfaction) increase the risk of pain across regional sites of newly employed workers.

It was found in a prospective study conducted by Park et al. [Par10] that males experienced work stress in job demand, job control and social support.

Park et al. [Par09] investigated the association between depressive symptoms and job stress, among Korean employees in small and medium sized enterprises, and also examined which components of stress are involved in the risk for depression among males and females.

Ploeg and Kleber [Plo03] found that most of the ambulance workers had been confronted with acute stressors in their work. Of the participants, more than a tenth suffered from a clinical level of post-traumatic distress, one tenth reported a fatigue level that put them at high risk for sick leave and work disability and nearly a tenth of the personnel suffered from burnout. Main risk factors have to do with social aspects of the work environment, in particular lack of support from the supervisor as well as colleagues and poor communication.

Punnett [Pun98] reported in a study among vehicle manufacturing operations that MSDs of the upper extremities were strongly associated with exposure to combined ergonomic stressors.

Punnett et al. [Pun04] also conducted a study among automotive manufacturing workers for examining the association between Ergonomic stressors and upper extremity musculoskeletal disorders.

Unbalanced relationships between job demands and individual capacities may lead to serious health and safety risks [Ram83, Rut90].
A questionnaire survey with a Likert-type scale ranging from 1 (very dissatisfied) to 7 (very satisfied) was conducted for the significant relationship of job satisfaction to total sickness absence duration [Roe08].

A study was also conducted by Shimazu and Kosugi [Shi03] on job stressors and psychological distress among Japanese employees.

Stroud et al. [Str02] conducted a study to check the sex differences in responding the stress.

Suri and Rizvi [Sur08] performed a study to find out the stress and mental health among call center employees.

Changes in autonomic nervous system function have been related to work stress induced increases in cardiovascular morbidity and mortality [Uus11].

3.2.13 Studies on Shift Work and Extending working hours

The term "shift work" means different things to different people. Shift work is popularly regarded as work in which employees "shift" schedules on some regular basis from daytime to evening or nighttime. Many researchers define shift work as employment in which two or more groups of employees work at different times of a 17-hour or 24-hour time span, including a so-called "day" shift.

It is argued that shiftwork attracts many people because shift workers receive competitive income, without requiring tertiary education that can be increased by long shifts and weekend work. Generally, although shiftwork does not lead to increased employee turnover the retiring age of shift workers is relatively younger than in other sectors. Shiftwork contributes to increase absenteeism, especially among younger employees and those who have been doing shiftwork for only a short period. Shiftwork affects employee health, family and social lives, personal and workplace relationships, and communication skills. While older workers become tired more easily and less motivated, younger workers tend to experience higher rates of absenteeism [She08].

Industrial and commercial activities that operate outside normal work hours have become widespread in recent years; services such as banking,
communications, transport, catering, and retailing are routinely available during evening hours, and often round-the-clock. Consequently, the work patterns of a substantial proportion of the population now extend beyond regular day-work hours; variable schedules (often including evening or night work) and rotating shifts are both widespread. In a recent European survey, 28% of the workforce had variable work patterns, 10% had evening or night schedules, while 17% worked two-shift [Boi03]. Further analyses showed that the proportion of shift workers remained relatively constant up to age 45 years, but fell sharply at higher ages, particularly over 55 years [Eur03], reflecting older workers’ difficulties in adjusting to shiftwork. Similarly, analyses of U.S. survey data showed that, in 1997, 27.6% of the workforce had flexible work schedules, while 16.8% of full-time employees had ‘alternative’ schedules involving work outside normal day time hours (06.00-18.00 hrs), 6.4% of whom worked night or rotating shifts [Bee00] or three-shift rotating schedules. These proportions varied by occupation; rotating shifts were particularly common in security services (16.3%), mining (12.5%), and catering (8.7%), but infrequent among professionals and managers (1.7%). Night work is prevalent in health care, manufacturing, and manual occupations. Global trends towards a ‘24-hour society’ suggest that these proportions are likely to rise; thus, the implications of shiftwork for physical and mental health is not only a matter of current concern but also one that is likely to become increasingly important in the future [Cos01, Raj01].

Amelsvoort et al. [Ame01] conducted a study to assess the influence of working at night on cardiac autonomic control and HRV levels in shift workers.

Amelsvoort van et al. [Ame04] investigated that both body mass index and low-density lipoprotein/high-density lipoprotein cholesterol ratio decreased significantly in shift workers compared with daytime workers. This may explain as a part of the excess cardiovascular disease risk reported in shift workers.
Demerouti et al. [Dem04] designed a study to test the impact of rotation and timing of shifts on work/home conflict, job attitudes, health and absenteeism among the military police.

De Raeve et al. [De07] have shown the considerable impact of work time arrangements on the individual worker, employer and society; and suggest the need for interventions addressing work time arrangements in order to reduce or prevent their impact on employee health.

Harrington [Har94] proposed a minimum daily rest period of 11 consecutive hours in each 24 hour period, at least one rest day a week, four weeks' annual leave, and a restriction on night work to a maximum of eight hours on average for avoiding the health problems among the European employees due to over exhaustion of work.

Harrington [Har01] explained that the main physiological consequence of shift schedules is disruption of circadian rhythm which can have a deleterious effect on performance, sleep patterns, accident rates, mental health, and cardiovascular mortality. Reproductive outcome effects may be linked to disruption of menstrual cycles.

Inoue et al. [Ino03] conducted a study to compare heart rates during rest and work among shift workers with different styles for determining their effect on cardiovascular disease.

More than 13.5 million American workers, close to 20 percent of the workforce, are assigned in evening or night shifts. In some industries such as automobile, petrochemical and textile manufacturing the proportion of shift workers is greater than 50 percent. Twenty percent of workers are unable to tolerate shift work [Lad82].

To examine the effect of shiftwork on lifestyle and mental health, a self-administered questionnaire survey was conducted among employees of a leading electrical appliances manufacturing company in Japan. The findings suggested reduction of physiological and psychological stress due to shiftwork among employees [Nak97].
A review study was conducted by Salminen [Sal10] to examine the effect of shift work and extended working hours on occupational injuries. A calculation based on four studies showed that the risk of occupational injury during afternoon shifts was 6% lower than that during morning shifts. The same kind of calculation showed that the risk of occupational injury during night shifts was 15% lower than during morning shifts. A review of eight studies showed that the risk of occupational injury was 41% higher for 10-hour working days compared to 8-hour working days. On the other hand, working 12-hour days increased the risk of occupational injury by 14%. When working more than 12 hours per day, three studies showed a 98% increase in involvement in occupational injury. Extended working hours was related to elevated risk of occupational injury. Thus shift work and long work hours did not suit for all employees.

Shields [Shi99] found in a study that women who worked long hours have increased chances of subsequently experiencing depression and moving from standard to long hours is associated with unhealthy weight gain for men.

Shields [Shi02] described in his study that load carrying in evening shift is associated with increases in psychological distress levels among both sexes.

Sparks et al. [Spa97] claimed long working hours in load carrying and their effects on health is a prominent issue in research and the public arena worldwide. In Japan, although there has been a drop in the average annual working hours, still Japanese employees work 200-500 hours longer than Western employees.

Spurgeon et al. [Spu97] concluded that there is currently sufficient evidence to raise concerns about the risks to health and safety of long working hours. However, much more work is required to define the level and nature of those risks and also suggested that the duration of shift should not be extended to 10 or 12 hours as complaints of fatigue are greater on the long shifts and this translates into poorer performance and increased accidents.

A longitudinal study conducted by Suwazono et al. [Suw08] on the effect of shift work on weight gain among male Japanese workers revealed the increase in Body Mass Index (BMI).
Tucker et al. [Tuc96] performed a study to identify the impacts of 8 and 12 hours shifts on health, wellbeing, and alertness during the shift.

Van der Hulst [Van03] showed that long work hours are associated with adverse health as measured by several indicators as cardiovascular disease, diabetes, disability retirement, subjectively reported physical health and subjective fatigue.

Wirtz et al. [Wir07] conducted a study for analyzing the gender differences in the effect of weekly working hours on occupational injury risk in the United States working population. The findings indicated an increase in injury risk with increasing working hours among women but not men.

Long working hours can lead to an accumulation in fatigue that may increase worker’s risk of injury [Wir12].

Zhao and Turner [Zha06] conducted a review study to examine the impact of shift work and the results revealed that shift work impacts negatively on daily health habits and can lead to adverse health outcomes, such as poor dietary intake, smoking, and becoming overweight.

3.3 Studies on Musculoskeletal Disorders

MMH and the factors associated with MMH resulted in musculoskeletal disorders. They are work-related when the work activities and work conditions significantly contribute to their development [Buc02]. WRMSDs describe a wide range of inflammatory and degenerative diseases and disorders. These conditions result in pain and functional impairment and may affect, besides others, the neck, shoulders, elbows, forearms, wrists and hands. They do not include injuries resulting from slips, trips, falls, or similar accidents. Some of the studies carried out on WRMSDs are discussed below:

Abduljabbar [Abd08] performed a study with the objective to find out the prevalence and distribution of musculoskeletal symptoms among dentists in Saudi Arabia. Results of the study revealed that eighty-three of the responding dentists had pain or discomfort in the neck, shoulders, lower back
or head. The female dentists had a significantly higher frequency of pain, headache and weakness than their male counterparts.

According to Agnihotram [Agn05] occupational research is more complex issue in India, which includes poor industrial legislation, vast informal sector, less attention to industrial hygiene and poor surveillance data across the country.

Ahlgren et al. [Ahl12] conducted a study with the objective to assess the relationships between physical and psychosocial work exposures, engagement in domestic work and work-home imbalance in relation to symptoms of musculoskeletal disorders and emotional exhaustion in white- and blue-collar men and women. For the study, three thousand employees from 21 companies were asked to answer a questionnaire on family structure, household and child care tasks, work exposure, work-home imbalance and symptoms of neck/shoulder disorders, low back disorders and emotional exhaustion. Results of the study revealed that women reported more musculoskeletal disorders and engagement in domestic work. Women in both white and blue-collar work had a higher total work load than men when engagement in domestic work was added to employed work. Women also had higher prevalence’s of neck/shoulder and low back disorders compared to men. Reported work-home imbalance was associated with neck/shoulder disorders in women and with emotional exhaustion in both women and men.

Alhemood [Alh05] found in a study among Manual material handlers that the prevalence rates of MSDs cases ranged from 1.82% to 34.55%. In particular, the lower backs as expected had the highest rates, followed by the neck (27.27%), knees – lower legs (25.45%) ankles – feet (23.64%), upper back (20%), and shoulders – upper arms (20%).

Aydeniz and Gursoy [Ayd08] conducted a study with the aim to determine upper extremity musculoskeletal disorders among computer users. And the results suggest a high prevalence of MSDs of the upper extremities among intensive computer users.
It was found in a study that men whose work entailed kneeling or squatting were more likely to prone knee disorders. It was also concluded that playing soccer is confirmed as a strong risk factor for knee cartilage injury [Bak03].

Banerjee and Gangopadhyay [Ban03] conducted a study on the prevalence of upper extremity repetitive strain injuries among the handloom weavers of West Bengal and found that more than one third of the subjects have had discomfort in the upper limbs, and the incidence amount is more than 70% in the hand/wrist.

Bell and Steele [Bel12] found that the cleaning workers who perform the task of vacuum cleaning are at risk of work-related upper-limb musculoskeletal injury.

Bhuyar et al. [Bhu08] surveyed mental, physical and psychosocial problems among call centre workers from two cities Pune and Mumbai by both qualitative and quantitative methods. The results revealed that high proportion of workers faced sleep disturbances and associated mental stress and anxiety. There was also disturbance in circadian rhythms due to night shift. Physical problems such as MSDs, obesity, eye and hearing problems, and psychosocial problems were also present.

A prospective study was performed by Bergstrom et al. [Ber07] to identify risk factors for new episodes of sick leave due to neck or back pain.

Musculoskeletal pain in the low back and neck-shoulder regions is a major problem among the working population all over the world. The prevalence of musculoskeletal pain was found to be higher among women than men [Bin10].

Bishop et al. [Bis11] developed an induced musculoskeletal pain model of acute low back pain and examine the relationship among pain, disability and fear. Results of the study revealed that pain intensity ranged from 0 to 68 with 57.5% of participants reporting peak pain at 24 hours and 32.5% reporting this at 48 hours. The majority of participants reported pain in the low back with 33% reporting pain in the legs.
Bongers et al. [Bon93] reviewed the epidemiologic literature to establish whether it presents evidence of an association between psychosocial work factors and musculoskeletal disease. It was concluded that monotonous work, high perceived work load, and time pressure are related to musculoskeletal symptoms. The data also suggest that low control on the job and lack of social support by colleagues are positively associated with musculoskeletal disease. In addition, stress symptoms are often associated with musculoskeletal disease, and some studies indicate that stress symptoms contribute to the development of this disease.

Bongers et al. [Bon02] reviewed from the epidemiological literature that psychosocial factors are the risk factors for upper extremity problems (UEP). Reviewed results showed that the large majority of the studies reported an association between at least one work-related psychosocial factor and adverse upper extremity symptoms or signs. High perceived job stress was consistently associated with all upper extremity problems (UEP) in high and lower quality studies. Although not often studied, non-work-related stress was also consistently associated with UEP. In addition, high job demand is also in most studies associated with these disorders.

Bongers et al. [Bon06] found through the epidemiological studies on work related neck and upper limb symptoms that psychosocial work characteristics, high work demands or little control at work are often related to these symptoms.

WRMSDs are a significant problem within the European Union with respect to ill health, productivity and associated costs [Buc02].

A cross-sectional study conducted among teachers of the municipal elementary education network of Salvador, Bahia, Brazil showed that there was a high prevalence of musculoskeletal pain in lower limbs (41.1%), upper limbs (23.7%) and back (41.1%). The overall prevalence of musculoskeletal pain related to any of the three body segments was 55%. The prevalence of musculoskeletal pain was associated with the following occupational variables: working over five years at the school, high level of physical exertion, and reporting heat in the classroom [Car09].
Chee and Rampal [Che04] conducted a cross-sectional study on work-related musculoskeletal problems among women workers in the semiconductor industry in Peninsular, Malaysia. The results showed that the overall prevalence of body pain was 80.5%, in which highest prevalence of pain was in the lower limbs, neck/shoulder, and upper back and highest exposures were prolonged hand/wrist movement, standing, and lifting loads with hands.

Choobineh et al. [Cho07] conducted a cross-sectional study on musculoskeletal problems among workers of an Iranian communication company. The results of Nordic musculoskeletal questionnaire revealed that WRMSDs occurred at a high rate.

Choobineh et al. [Cho07] found in an Iranian rubber factory that the vast majority of the workers (73.6%) had suffered from some kind of musculoskeletal symptoms. The highest prevalence was reported in the lower back (50.2%), knees (48.5%) and upper back (38.1%) and the most common ergonomics problems were found to be awkward postures and manual material handling.

Results of the study conducted on Iranian sugar-producing factory workers showed that most workers (87.1%) suffered from some kind of MSDs. The highest prevalence was reported in knees (58.6%) and the lower back (54.3%). Awkward postures, MMH, and long hours of standing were the major ergonomic problems [Cho09].

Cole et al. [Col01] conducted a study to describe the prevalence of musculoskeletal problems in the Canadian working population and to determine cross-sectional associations between such problems and work factors, particularly job strain and physical demand variables.

Cote [Cot12] critically reviewed the recent literature on physical and functional sex/gender differences, with focus on physical determinants associated with neck/shoulder musculoskeletal injuries. He found that recent studies have shown differences between men and women in sensory hypersensitivity characteristics associated with neck/shoulder injuries.
Datta and Ramanathan [Dat71] conducted a comparative study of seven modes of carrying an identical load on the level ground and found that the double pack mode was ergonomically the best mode.

A cross-sectional study of task demands and musculoskeletal discomfort among ten casual dining restaurants was conducted by Dempsey [Dem06]. Results of the study revealed that, 42% reported musculoskeletal symptoms in the past year, with the lower back area (18%) and shoulder (11%).

Deros et al. [Der10] found in a cross-sectional study carried among the workers of an automotive manufacturing plant that the highest prevalence of MSDs was lower back pain, followed by pain at feet/ankle and pain at upper back regions.

Dovrat and Katz-Leurer [Dov07] described the prevalence of musculoskeletal symptoms, particularly low back pain (LBP) among cold storeroom workers in Israel. The results of this study strengthen the hypothesis that workers in cold environments are at a greater risk of LBP.

A cohort study conducted among Dutch computer office workers revealed that physical and psychosocial risk factors such as irregular head and body posture, number of working hours/day with the computer and time pressure (job demands) are responsible for the neck, shoulder and forearm/hands complaints [Elt09].

Fernandes [Fer10] used a cross-sectional study to check MSDs among workers of plastic manufacturing plants in Brazil. Results of multiple logistic regression showed that distal upper limb MSDs were related to manual handling, work repetitiveness, psychosocial demands, job dissatisfaction, and gender.

The prevalence of MSDs symptoms were estimated among union construction iron workers by Forde et al. [For05]. The prevalence of self-reported MSDs symptoms was high for the lower back (56%), wrist/hands/fingers (40%), knees (39%), and shoulders (36%). Generally, the prevalence of MSD symptoms increased with duration of employment.
Analytical results of hotel employer records of housekeeper injuries combined with evidence from earlier surveys showed that housekeepers face disproportionate rates of workplace injury, with strains and sprains as the leading type of injury, accounting for nearly half of all housekeeper cases. The contribution of working conditions and overexertion were also the leading cause of housekeeper injuries [Fru06].

Gamperence and Stigum [Gam99] carried out an interview based questionnaire survey in two spinning industries in Lithuania and found that packers had the highest risk of arms or neck problems while carrying load, whereas, spinners had the highest risk of back or leg problems.

Gangopadhyay et al. [Gan05] conducted an ergonomic study on posture-related discomfort among preadolescent agricultural workers of West Bengal, India while carrying load. It was concluded that workers suffer from discomfort or pain in different parts of their body specifically the lower back, neck and knee regions.

Gangopadhyay et al. [Gan07] showed that workers in brass metal industries in West Bengal, India performing rigorous carrying and hand intensive jobs are likely to suffer from MSDs.

Gangopadhyay et al. [Gan08] conducted a study on the prevalence of MSDs among prawn seed collectors of Sunderbans, India and observed that workers were working continuously in awkward postures and carrying loads during certain prawn seed collection activity. It was also found that 62% of male prawn seed collector and 40% of female prawn seed collector suffered from severe pain before and after sleep at night.

Gangopadhyay et al. [Gan10] conducted a study of the effect of working posture on the occurrence of MSDs among the sand core making workers of West Bengal, India and concluded that the health of the workers were highly affected by different awkward postures and load carried which creates different musculoskeletal disorders mainly in the low back region.

Ghosh et al. [Gho10] carried out a study on goldsmiths in India to identify occupational disorder of the goldsmiths, which revealed that MSDs were the
major problem of the goldsmiths due to highly affected improper and hazardous body posture and workload.

Low back pain (LBP) is a common problem in the working population of developing countries. Age and gender as well as certain work-related physical and psychosocial factors influenced the prevalence of LBP [Gha06].

It was found in a cross-sectional study performed among residential carpenters in the Denver Metro area of Colorado that occupational LBP was the leading safety and health challenge for many industries [Gil07].

It was found among the members of the chartered society of physiotherapy that 42% of the members reported WRMSDs [Glo05].

A survey was conducted by Grover and Gandhi [Gro11] in Hisar district of Haryana, India to find out the musculoskeletal problems of computer users. Results of the survey revealed that majority of the respondents (81.5%) reported musculoskeletal problems. The magnitude of pain was highest in neck and lower back. Reasons mentioned for pain in different body parts by computer users were watching the screen at a stretch, holding neck more or less in the same position for a long time, and sitting in poor posture for a long time.

Grzywinski et al. [Grz10] carried out a research on a group of woodcutters in western and northern Poland, and found that after work there was an increase in disorders in all of the analyzed parts of the body, particularly in the case of the upper back, shoulders, elbows and knees while carrying load.

Habibi et al. [Hab08] conducted a study on workers of steel making company in Iran for clarifying prevalence of WRMSDs and the associated lost work days due to load carrying.

Habib et al. [Hab12] carried out a cross-sectional survey on women from Nabaa, a low-income community in Lebanon for exploring the relationship between housework and musculoskeletal symptoms among homemakers. Both psychosocial and physical factors showed significant associations with musculoskeletal symptoms. Related psychosocial factors included feelings of stress associated with homemaking or homemakers, number of children, and
self-rated health. The physical factors associated with musculoskeletal pain were feeling fatigued at the end of a housework day, working long hours and working in awkward postures or frequently engaging in repetitive hand movements. Ergonomic stressors were also associated with pain in the back, and upper or lower extremities. This study found that homemakers engage in a large number of hours of housework, which involves them in repetitive hand movements, bending, kneeling and squatting. These postures and movements were associated with musculoskeletal pain.

Helen et al. [Hel10] conducted a cross-sectional survey to investigate the association of physical and psychosocial risk factors in carrying loads with MSDs among the New Zealand nurses, postal workers and office workers.

Results of a study conducted among construction workers revealed that only 8% of the workers reported no experience of musculoskeletal symptoms. Working with the hands above shoulder level increased the prevalence of neck and shoulder symptoms. Working in kneeling or stooping postures increased the prevalence of severe low back pain. Frequent handling of materials was also associated with low back pain [Hol92].

Generic job stress, health models and multivariable models of work related upper extremity disorders (WRUEDs) were described and evaluated by Huang et al. [Hua02] to understand job stress and its relation with WRUEDs in order to enhance future efforts.

Huang et al. [Hua03] emphasized the need to consider both biomechanical factors and specific work organization factors, particularly time pressure in reducing musculoskeletal-related morbidity.

Hussain [Hus04] performed a study to investigate the prevalence of musculoskeletal symptoms in a group of truck assembly workers and found that 79% of workers had been troubled with musculoskeletal symptoms. The commonest musculoskeletal symptoms were from the lower back (65%), neck (60%) and shoulders (57%). Musculoskeletal symptoms were related to age, length of service, occupational subgroup and general health questionnaire (GHQ12) score.
Both work-related physical and psychosocial factors showed strong associations with low-back pain and upper-extremity complaints [Ijz04].

Ismaila et al. [Ism08] conducted a study for determining the highest permissible spinal shrinkage during carrying loads. The main aim of the study was to establish the highest permissible spinal shrinkage when under any working conditions.

Ismail et al. [Ism09] conducted a study with the aim to reveal the discomfort experience by the operators during performing the task in the Malaysian automotive industries. The results showed that the operators work in an inadequate working environment with awkward postures, transfer the products and arrange the wooden boxes were involved in the poor working postures and high motion repetitiveness. Results of the questionnaire also revealed that majority of operators complaint severe pain in lower back, foot, lower leg, knee, thigh and shoulder. 62.5% of operators applied sick leave when they felt pain or discomfort during their work.

Ju et al. [Ju10] found through the logistic regression technique that the average working hours were the most significant predictors for WRMSDs occurrence among athletic trainers.

It was found among Iranian zinc industry workers through nordic musculoskeletal questionnaire that the vast majority of the study population (77.6%) had experienced some form of symptoms of MSDs and the highest prevalence was reported in the lower back (47.9%) and upper back (34.6%) [Kar08].

Injuries and disorders caused by overexertion and repetitive motion are the leading causes of compensable lost-time cases in the United States [Key00].

Klussmann et al. [Klu08] conducted a cross-sectional study to determine the prevalence and the predictors of musculoskeletal symptoms in the upper extremities and neck at visual display terminal workstations.

Lifting, carrying, pushing and pulling at work are assumed to be related to increased risks of musculoskeletal injury, mainly in the low back and shoulder region [Loo01].
Lorusso et al. [Lor10] found through a questionnaire collected data that LBP was the most frequently reported symptom (27%), followed by neck (16%), shoulder (11%), leg (8%) and hand/wrist (5%) pain. Results also showed a significant association between poor physical activity and the presence of MSDs in young university students.

The average lifetime prevalence of LBP among the adolescents was 36% and 62% among adults. The findings support the global burden of disease of LBP, in addition to suggest that LBP prevalence among Africans is rising and is of concern [Lou07].

A longitudinal study was performed by Maul et al. [Mau03] among nurses employed by a large university hospital in Switzerland and it was found through nordic questionnaire that LBP was highly prevalent with an annual prevalence varying from 73% to 76%.

McGreevey [McG03] said that no employee should be assigned to continuous high demand work (constant, rapid, muscular action or fixed positions for extended periods of time, or that is highly repetitive) for more than 4 hours per day.

Study among waste municipal solid waste workers showed collection of solid waste results in musculoskeletal symptoms in one or more of the 9 defined body regions among 65% of participants due to repeated heavy physical activity such as lifting, carrying, pulling and pushing [Meh08].

It was found in a study among Brazilian pottery workers that general working conditions of pottery manufacturers were poor with a prevalence of 38.5% musculoskeletal pain. Repetition, tool use, lack of control over decisions, worries regarding work demands, relationship issues, work dissatisfaction and the wish to move on to another function were all associated with pain [Mel10].

Mettgud et al. [Met08] carried out a cross-sectional observational type of survey in spinning section of small scale labor intensive woolen textile factory Belgaum district, Karnataka, India. It was reported that the musculoskeletal problems were abundantly present and the subjects suffered
from at least one work-related musculoskeletal pain in relation to length of occupational exposure during carrying.

Age and work demands are also associated with MSDs [Mon09].

Morken et al. [Mor00] conducted a study with the aim to determine the prevalence of musculoskeletal symptoms (MSS) in the aluminium industry workers and the results revealed that the higher prevalence of MSS among operators and the association between their duration of employment and MSS suggests that a higher risk of MSS is related to the working environment.

Morken et al. [Mor07] reported upper limb disorders for 53% and back disorders for 20% of all work-related musculoskeletal disorders among Norway's offshore petroleum industry workers.

Motamedzade and Moghimbeigi [Mot12] determined the factors associated with self-reported UEMSDs among female carpet weavers in Iran. Type of carpet weaving looms, weaving style (Persian vs. Turkish), daily working hours and work experience as well as personal factors including age and marital status were significantly and independently associated with self-reported UEMSDs, while education, handedness and weight of weaving comb were not. The root cause of ergonomic factors for musculoskeletal symptoms in carpet-weaving operations was ill-designed weaving workstations. Study also revealed that there was a high rate of UEMSDs among female carpet weavers in Iran. Increased daily working hours and years of work experience were also associated with UEMSDs.

Murtezani et al. [Mur10] conducted a study on power plant workers at Kosovo Energetic Corporation, Kosovo and revealed that low back pain predict sickness absence among workers during carrying.

Niu [Niu10] said the changes in the working environment in recent decades have created new ergonomic related health problems among the different working populations.
Nordin et al. [Nor97] said the workplace modification should begin in grade school, where children of all sizes are expected to conform to schoolroom furniture.

Paoli [Pao91-92] found in a survey on European countries that the opening of borders can enable-products to flow freely between the different European countries, this might create a conflict between national standards which have set a high level of health protection and imported products designed to lower standards.

Pekkarinen [Pek09] conducted a study on cleaning workers to evaluate the physical stress factors in cleaning work and their relationship with MSDs during carrying.

Pinto et al. [Pin04] carried out a study among four groups of information technology (I.T.) industries in Goa, India and found that among all occupational diseases low backache, straight spine syndrome, pain in neck and shoulder, leg cramps and carpal tunnel syndrome were present in a significant percentage of the population indicating that WRMSDs are the second most prevalent disorders among the I.T. professionals.

Results of the study conducted by Pope et al. [pop97] revealed that an increased risk of shoulder pain and disability in men were associated with carrying weights on one shoulder, whereas those who reported working with hands above shoulder level, using wrists or arms in a repetitive way, or stretching down to reach below knee level had about twice the risk of shoulder pain and disability. Men working frequently in very cold or damp conditions had a fourfold and sixfold risk respectively of shoulder pain and disability. Reporting of shoulder pain and disability were also more common among men and women who reported that their work caused a lot of stress during carrying.

Sachdev et al. [Sac06] conducted a study on salt manufacturing unit workers of Rajasthan, India to identify work-related health problems experienced by the salt workers in carrying loads.
A cross sectional survey was initiated to understand the frequency of occupational injury occurrence and the associated factors in the fish processing industries of western India involving women subjects [Sah06].

Saha et al. [Sah10] stated that the chief complaints reported by the workers of garment industry in load carrying were musculoskeletal problems.

An attempt was made by Sahu et al. [Sah10] to ergonomically evaluate the posture and the MSDs of the female workers engaged in the brick manufacturing units of West Bengal, India.

Sakineh et al. [Sak09] conducted a study in Pharmacy packaging Industry workers and observed relatively (36.8%) high incidence of back spinal disorders during heavy load carrying.

Workers involved in manual carrying work in industrially developing countries often have limited physical work capacities due to their poor socioeconomic status [Sco93].

Scott and Charteris [Sco04] asserts that, notwithstanding the forces of globalization, the gap between industrially advanced countries “haves” and industrially developing countries “have nots” is increasing. Poverty, deprivation, over-population, illiteracy, and sub-optimal working conditions attend this scenario.

Sluiter et al. [Slu09] performed a study on reproducibility and validity of heart rate variability and respiration rate measurements in participants with prolonged fatigue complaints.

Stanitski et al. [Sta78] felt that stress fractures are caused by excessive repetitive muscle forces acting across the affected bone while carrying load.

In a study conducted among the United States (US) workforce revealed that 13% of the total workforce experienced a loss in productive time during a two week period due to a common pain condition. Headache was the most common (5.4%) pain condition resulting in lost productive time. It was followed by back pain (3.2%), arthritis pain (2.0%), and other musculoskeletal pain (2.0%). Workers who experienced lost productive time
from a pain condition lost a mean (SE) of 4.6 (0.09) h/wk. Lost productive time from common pain conditions among active workers costs an estimated $61.2 billion per year [Ste03].

Stock [Sto91] examines the epidemiological evidence of the relationship between workplace ergonomic factors such as repetition, force, static muscle loading, and extreme joint position and the development of muscle, tendon, and nerve entrapment disorders of the neck and upper limbs of exposed workers.

Swei-Pi [Swe00] found in a study that the most stressed body parts were the lower back and the arm.

Talwar et al. [Tal09] conducted a study of visual and musculoskeletal health disorders among computer professionals in NCR Delhi, India and reported that there was a gradual increase in visual complaints as the number of hours spent for working on computers daily increased and the same relation was found to be true for musculoskeletal problems as well.

Taanila et al. [Taa09] conducted a study among Finnish defence forces for checking status of the MSDs. It was found from the study that the occurrence of MSDs was peaked in summer months. The most common types of MSDs were low back pain (LBP, 20%), lower limb overuse injuries (16%) and sprains or strains (13%). Overuse-related MSDs were more prevalent (66%) than traumatic ones (34%). Fractures, knee ligament ruptures, dislocations and muscle strains accounted for the highest number of service days lost.

Tappin et al. [Tap08] conducted a study in the New Zealand meat processing industry and found that the main factors responsible for MSDs were job demands, job design, economic factors, cultural factors, environmental factors and payment systems.

It was concluded in a cross-sectional survey on Nigerian nurses by Tinubu et al. [Tin10] that 84.4% of the nurses have had WRMSDs once or more in their occupational lives.

Tiwari et al. [Tiw03] carried out a study among cotton textile workers of Sri Bapurao Deshmukh Sut Girni, Wardha, India. Working position involving
prolonged hours of sitting was found to be significantly associated with development of low back pain among workers.

The results of epidemiological studies suggest that women have had significantly higher prevalences than men for many types of UEMSDs, even after controlling for the type of data source and confounders such as age or work factors [Tre04].

A cross-sectional study was performed by Tsigonia et al. [Tsi09] among cosmetologists in Athens, Greece, showed that Neck pain was the most prevalent musculoskeletal complaint, reported by 58% of the subjects, while hand/wrist and low back complaints resulted more frequently in self-reported consequences. Significant relationships were also found between self-reported physical risk factors like prolonged sitting, use of vibrating tools, reaching far and awkward body postures and the occurrence of musculoskeletal disorders at various body sites.

Van Vuuren et al. [Van05] conducted a study in a semi-automated South African steel industry to identify and establish the association of occupational risk factors with the prevalence of low back problems in steel plant workers during load carrying.

Vaughan-Jones and Barham [Vau09] stated that the health promotion in the workplace can make a significant contribution in reducing disease and support the health of the nation as a whole.

In a study by Whittfield et al. [Whi05] on New Zealand secondary school students, musculoskeletal symptoms were reported by 77.1% of the students. Symptoms were most prevalent in the neck, shoulders, upper back and lower back and the carriage of heavy schoolbags is a suspected contributory factor.

Widanarko et al. [Wid12] found that self-reported awkward or tiring position at work, dissatisfaction with contact and cooperation with management, and perceived work stress were significant risk factors for low back system (LBS) for women, but not for men. However, longitudinal studies with valid and reliable tools are necessary to provide better estimation of risk factors for LBS with gender differences.
Chapter 3

Wirtz et al. [Wir12] conducted a cross-sectional study among US workers and investigated gender differences in the effect of weekly working hours on occupational injury risk. Results of the adjusted logistic regression model indicated an interactive effect of working hours and gender on injury risk. Injury risk increased among women working 41–50 hours/week and >50 hours/week compared to 31–40 hours/week but not among men. The findings indicated an increase in injury risk with increasing working hours among women but not men.

3.4 Studies on Artificial Neural Network

A neural network model was developed by Chen et al. [Che04] for accurately predicting the risk of injuries in industrial jobs. According to Draghici [Dra97] a neural network based artificial vision system can be developed to analyze the image of a car given by a camera, locate the registration plate and recognize the registration number of the car. Hashemi and Clark [Has07] trained an artificial neural network (ANN) on chassis dynamometer data and used to predict the oxides of nitrogen (NO\textsubscript{x}), carbon dioxide (CO\textsubscript{2}), hydrocarbons (HC), and carbon monoxide (CO) emitted from heavy-duty diesel vehicles and the results showed an average predicting accuracy of 0.97 for CO\textsubscript{2}, 0.89 for NO\textsubscript{x}, 0.70 for CO, and 0.48 for HC.

Liu et al. [Liu09] developed an artificial neural network model for identification and classification of high risk groups for Coal Workers. A research was carried out by Moayed and Shell [Moa11] to demonstrate that ANN models can perform better than Logistic regression (LR) models with data sets comprised of all ordinal variables, which has not been done so far. And the result of the study revealed that ANN models performed significantly better than LR models. Mohaghegh and Ameri [Moh95] found an artificial neural network can assist petroleum engineers in solving some fundamental petroleum engineering problems, such as formation permeability prediction from geophysical well log responses with accuracy comparable to actual core analysis and well test interpretations.

Rahman [Rah10] made a neural model for Fault diagnosing and found that neural network is able to detect and isolate two fault studies with a nice
pattern classification. Seckiner [Sec09] proposes two distinct modeling approaches—multiple linear regression and artificial neural network for prediction of computer user comfort with respect to the existing settings of the workstation. Results showed that, while multiple linear regression could not be used to adequately predict the computer workstation comfort, the neural network was deemed superior. This approach allows ergonomists to aid in the decision making process of computer environment design and the prediction of the health risk in an occupational environment.

Zhang [Zha06] developed an artificial neural network method to estimate classified vehicle volumes directly from single-loop measurements. An artificial neural network based diagnostic system was developed by Zurada et al. [Zur97], which can classify industrial jobs according to the potential risk of low back disorders due to manual handling of loads in industrial environments.

### 3.5 Studies on Biorhythm

Popular claims have been made that industrial accidents are more likely to occur during a person’s critical days and that the biorhythmic model can be used to prevent these incidents. In Switzerland, where airline pilots were not allowed to fly on the days when they had a physical crossover the minor accident rates due to pilot error fell by some 70% and in the same country Dr. Wehrli testified that he performed over 10,000 operations without a single failure or complication for fifteen years by selecting the best days for operations. The Nagahama Transport division of the Omi Railway did this and established a totally accident free record over 4 million kilometers. The Meiji Bread Company cut their annual vehicle accident rate by 45% and saved 3.5 million yen the year they began using the Biorhythm theory. A number of studies have found evidence to support this view and few studies, however, have moderate support to Biorhythmic analysis [And73, Bro77, Kha77, Lat77, Lyo78, Per78, Pin75, Wea74, Wil75].

The person most responsible for the growth of biorhythms is George Thommen. In his book, Is This Your Day?, Thommen has collected and
documented reports on biorhythms into the most authoritative book on biorhythms. Some of the results reported by Thommen [Tho64] in his book “is this your day” are discussed under:

With the growing interest in accident research, Hans Schwing, a student at the Swiss Federal Institute of Technology in Zurich, Switzerland in 1939, studied the relationship of biorhythms to accident and death reports. Schwing’s research, based on 700 random accidents, reported by Swiss insurance companies and 300 deaths from the records of the city of Zurich, found that 322 of the accidents fell on a single critical day, and 5 on a triple critical day. The balance of 299 accidents were on “normal days”. Almost 60 percent of the accidents occurred on critical days. In his research toward death affinity, of the 300 deaths, 197 fell on critical days or 65 percent. Schwing’s research supports the theory that one experiences days when basic reflexes and physical abilities are impaired to the degree that these days are more conducive to accident or human error. Reinhold Bochow, investigated accidents involving workers using agricultural machinery in Germany. Amazingly, only 2.2% of the accidents occurred on “normal days”, while a startling 97.8% fell on critical days. The application of biorhythms to the study of aircraft accidents where human failure is suspected, coincided about 80% with the critical day of the pilot, as supplied by the Aviation Safety Center at Cornell University, through the cooperation of R.H. Woodham. In September, 1956, a report was released by the Department of Sanitation of Haannover, Germany, prepared by head engineer O. Tope. His report covered accidents suffered by shop workers, street cleaners, and truck drivers, who were charted using the biorhythms theory. Tope concluded that 83% were related to critical days. Another project done in the United States by R.K. Anderson, a safety consultant firm member, found that of all the accidents over a three year period in factories, almost 70 percent of the accidents occurred on a critical day.

Golovachev [Gol80] conducted a study in Dneprodzerzhinsk Metallurgical Plant by using biorhythm theory in industrial accidents and found that number of accidents cut among workers engaged in transport by 41.6% and
44% among drivers. Such selective evidence has convinced many people as to the benefit of 'biorhythms' theory in planning for peak activity. Hendriek and Jones [Hen78] reported an association between physical biorhythm and pilot error accidents and incidents.

Hirsh [Hir76] reported that business enterprises have also displayed interest, and some companies have been reported to use biorhythms in an attempt to reduce accidents. Klug [Klu73] did a study on “An Analysis of Biorhythms and Their Effect on Athletic Injuries” to find the relationship existing between the date of an athletic injury and specific position on the biorhythm scale known as a critical day.

MacKenzie [Mac73] cited the success of a Japanese railway company which reduced the number of driver accidents by 50% in a year by predicting bad days from biorhythm charts. Thommen [Tho75] claimed success of 'biorhythms' applications, particularly in sports and industry, has led to the present popularity of the theory.

According to Reily et al. [Rei83]; Wallerstein and Roberts [Wal73] claimed great success in predicting team performance from consideration of individual biocurves. Willis [Wil72] found that performance in spring American college football games could be predicted by considering critical days.