CHAPTER 1

INTRODUCTION

Ergonomics is the science of fitting workplace conditions and job demands to the capabilities of the working populations. Effective and successful “fits” assure high productivity, evading of illness and accidents risks, and increased satisfactions among the workforce. From a practical point of view, ergonomics is an area which integrates information derived from the human sciences in specific anatomy, physiology and psychology to match job tasks, systems, products and surroundings to the physical and mental abilities and limitations of workers. In the workplace, Ergonomics is oriented toward identifying workplace conditions that cause occupational accidents and can be improved to encourage the health, productivity and safety of workers.

Applying ergonomic principles, however, is beneficial not only to the workers; the benefits to employers are equally significant. Healthy workers can be nearly three times more productive than those in poor health. These benefits to the workers and employers are both observable and measurable. The costs of ignoring these basic principles might include:

**For workers:**

- Pain and suffering due to accidents and occupational diseases.
- Induced mechanical stresses in the musculoskeletal systems leading to sprained joints or torn muscles.
- Medical care cost.
- Lost work time.
- Lost future earning and fringe benefits.
- Reduced job security and career development.
- Lost home production and child care.
- Home care costs provided by family members.
- Adverse effects on family relationships.
- Lost sense of self-worth and identity.
- Adverse effects on social and community relations.
Adverse effects on recreational activities.

**For employers:**

- Increased absenteeism and lost working days.
- Low-quality work.
- Adverse effects on worker relations.
- Higher insurance and workers compensation costs.
- High administrative and workers costs.
- Increased possibility of accidents and errors.
- Constraint, job allocation and higher turnover of workers.
- Scrap and declined production.
- Less standby capacity to deal with emergencies.

Ergonomic problems at the workplace and bad work organization are part of the contributing risk factors to the above mentioned occupational safety and health problems.

### 1.1 Manual Material Handling (MMH)

One of the tasks that man is increasingly called upon to perform in modern industrial situations is Manual Materials Handling (MMH). In spite of the increasing degree of mechanization and automation in industry, still millions of tons of goods and materials are being handled and lifted manually. Interestingly, the introduction of mechanized/automated workplaces may not eliminate the need for MMH tasks, only modify the nature of the demands and perhaps introduce new tasks. The need for MMH may be dictated either by the type of the task performed or by the space available which does not permit the use of suitable mechanical devices. In many cases, the human being acts as a material transfer device in loading and unloading products from pallets, carts, machines or shelves to conveyors or overhead railings and/or performing weighing, inspection or sorting on objects to and from moving conveyors [Rod86]. Likewise, carrying groceries to the kitchen or garbage cans to the curb, picking up sticks in the yard or mowing the lawn, or simply holding a child in your arms are forms of MMH we encounter at home. Manual materials handling permeates all aspects of life on and off the
job. Even with all the technology available today, MMH will always be with us.

MMH exposures are complex in nature. Jobs in a variety of sectors (e.g., manufacturing, service, transportation etc.) often require workers to perform multiple types of MMH tasks and in different stress demanding situations. In some occupations (e.g., military, some maintenance jobs etc.), advancements in technology have burdened workers with more equipment and gadgets to handle.

The manual handling of tasks constitutes a considerable proportion of work done in industries around the globe, but particularly in developing areas [Sco04]. Manual load transport is widespread in industrially developing countries (IDCs) and has important socioeconomic implications because a significant proportion of the population derives their income solely by carrying loads [Dat71, Dat73, Sam81]. Workers involved in manual work in IDCs often have limited physical work capacities due to their poor socioeconomic status [Sco93]. They are employed as laborers in construction sites, agricultural projects and in industries.

1.2 Work Related Musculoskeletal Disorders (WRMSDs)

MSDs may be considered as work related when aches and pains in the body region (e.g. neck, shoulders, back, arms etc.) are associated with physical strain in these body areas during the course of work, and at the same time no other visible sign of general illness is affecting the musculoskeletal system. MMH creates special problems for different workers worldwide. It is defined as the unaided moving of objects, often combined with twisting and awkward postures, and contributing to Musculoskeletal Disorders/Diseases. Manual carrying has been a major source of hazards of industrial workers [Cat23, Nor67, Duk77]. Laborers engaged in jobs which require lifting/lowering, carrying and pushing/pulling of heavy materials have increased the rates of Musculoskeletal Disorders (MSDs), similarly military sector have also recognized that stress of load carrying during prolonged marching can lead to a number of clinical disorders [Dev75, Sta78].
MSDs are no recent problem [Nor97], already in 1706, Bernardo Ramazzini, an Italian physician considered as the father of occupational health, wrote about office work: “The disorder arises from three core causes: first constant sitting, the perpetual motion of the hand in the same manner, and thirdly the attention and the application of the mind. Constant writing also considerably fatigues the hand and the whole arm on account of the continual and almost tense tension of the muscles and tendons [Buc02].

Awkward postures, repetitive work or carrying heavy loads are amongst the risk factors that may damage the bones, joints, muscles, tendons, ligaments, nerves and blood vessels; leading to fatigue, pain and MSDs. Heavy manual work during more than 2 hours a day is reported by about 30% of the European workers [Pao91-92], which is also a key generator of MSDs. Collected data of the European foundation even show an increase: the proportion of Europeans involved in heavy work for more than 50% of the working time was 19.4% in 1996 vs. 14.7% in 1992. Upper limbs (hand, wrist, elbow and shoulder), neck and lower back are particularly vulnerable to MSDs.

MSDs are the most common work-related disorders and also affecting quality of life. They are manifestations of the ergonomic hazards and are the leading cause of disability of people during the working years. Blue collar employees experience many more MSDs than white collar employees, especially service, shop and market sales workers; labourers in mining, construction, agricultural, manufacturing and transport; plant and machine operators, and assemblers. According to Levy and Wegman [Lev88], occupationally caused or aggravated MSDs rank first among the health problems with the frequency which they affect the quality of life. Many MSDs are transient, with symptoms disappearing with rest or change of activity. But some MSDs may become persistent or irreversible. Some MSDs are specific, with clear clinical features, while others are non-specific, without evidence of a clear specific disorder. In Europe, one-quarter of adults are affected by long standing musculoskeletal problems that limit everyday activities. MSDs are considered to be one of the biggest health problem facing contemporary
workforces. They affect nearly one half of the nation’s workforce at some time, resulting in time lost and earnings lost from work. Based on lost earnings, worker’s compensation payments and medical payments, MSDs are more costly than any other single health disorder. Figure 1.1 shows the distribution of costs due to work-related injuries/diseases [She10]. It can be observed that the biggest single reason for economic losses is Musculoskeletal Diseases.

**Figure 1.1: Compensated Costs of Injuries/Diseases**

The compensated MSDs vary widely between countries due to different diagnosis criteria and different compensation systems [Put94]. The cost of work related MSDs is immense; the US Department of Labor had estimated overall costs at nearly US $100 billion a year when such factors as lost work time, lost productivity and retraining costs are added [NIOSH96]. The cost of MSDs were estimated to have ranged from 2.7% to 5.2% of the Gross National Product (GNP) in Nordic countries in 1991, at a time when all costs due to illness were estimated to range from 15.8% to 22.2% of the GNP [Han03]. An attempt to evaluate the etiologic fraction of musculoskeletal disorders due to work resulted in an estimate ranging from 15% to 49%. It was predicted that in United Kingdom by 2030 there will be a 9% increase in MSDs, affecting more than 7 million workers [Vau09].
Work organization, working time arrangement, different work schedules also produce negative impacts on the health of workers. Transitions in work time arrangements are related to changes in health [De07]. Working long hours has been shown to be associated with poor subjective health, more injuries, unhealthy behavior, and increased morbidity and mortality [Har94, Spa97, Spu97, van03, Van04].

Work-related musculoskeletal disorders (WRMSDs) are recognized as multifactorial conditions [Mar07]. Various risk factors have been studied and proposed to be associated with WRMSDs. Potential risk factors associated with WRMSDs include:

1. **Occupation or Physical factors:** Duration of employment, high repetitious and forceful work, awkward, sustained or extreme postures, manual handling of loads, distance travelled, job duration, mechanical pressure, working environment, work terrain, frequency of lift, height of lift, range of lift, vibrations, mode of carrying load, heavy physical work, etc. are some of the important occupation or physical factors.

2. **Work organization and psychosocial factors:** Time pressure, poor work/rest schedule, overtime, content of the work, monotonous work, low job control, personal relations at work, low co-worker support, high psychological demands, dissatisfaction with the job, feeling exhausted after work, organizational structure, atmosphere within the workplace, supervision, economic aspects of the job, etc.

3. **Individual factors:** Age, gender, body weight, physical work capacity, strength, seniority, gender, parity, strong hand preference, elevated body mass index, previous musculoskeletal related consultation with a health care practitioner, low avocational exercise level, smoking, caffeine consumption, alcohol use/alcohol abuse, stomach reactions, menstrual disorders, gynecological surgery, diabetes mellitus, pregnancy, etc.

Although the act of MMH is being seen in daily routine work, several questions related to manual load handling have arisen today. (i) How much load should one carry without causing any injury to his/her body? (ii) Which
is the best mode of manual load carrying? (iii) Should it be carried on head, shoulder, back, waist, by hands, yoke or by any other modes? (iv) What should be the frequency of load carrying? (v) How long one should be allowed to carry load? etc. Ample literature is available today indicating that problems of MMH are a serious concern but Scientific studies on efficient and proper methods of carrying loads are somewhat lacking.

1.3 Status of Occupational Health in India

India is a developing nation and presents the demographic features similar to the other developing nations of the world. The demographics of India are inclusive of the second most populous country in the world, with over 1.21 billion people [IC11]. It occupies 2.4% of the world's land area and supports over 17.3% of the world's population. Its high population density makes it appear as a resource poor country despite its significant achievements in the fields of medicine, literature, nuclear physics, information technology, agriculture and also numerous other industries. India has a literacy rate of 74.04% with male 82.1% (Rural 78.6% and urban 89.7%) and female 65.5% (Rural 58.8% and urban 79.9%). Majority of Indian population lives in rural areas, (68.8% rural as compared to 31.2% urban population) where the pace of progress in literacy, education, employment and technology is slow.

Growing population is considered as the principal obstacle to the economic growth of the country, which emerged occupational health problems along with the traditional public health problems like communicable diseases, malnutrition, poor environmental sanitation and inadequate medical care. Health and nutrition are the most important contributory factors for human resource development in the country. Nutritional intake is mainly dependent on the socio-economic status particularly in developing countries such as India. India has been classified by the World Bank as a country with a low income economy, with GNP per capita of US $950. It ranks 160th in terms of human development among 209 countries [DGI10]. Among the Indian population, 37.2% (about 28% in the rural and 26% in the urban areas) are estimated to be below the poverty line, which is defined as the expenditure needed to obtain an average energy intake of 2400 Kcal per capita per day in
the rural areas and 2100 Kcal in urban areas. Widespread poverty contributes to lower energy intakes of much of India’s manual workforce which is highly unlikely to match the energy expenditure requirement of the manual nature of much of the work.

Nutritionally, the Indian industrial worker makes a poor comparison with their more fortunate brothers in advanced countries. Calorie intake is much falls short of requirements. Intake of protein and other essential food constituents reaches only 75% in terms of quality, and the major intake is vegetable proteins. Theoretically, adequate nutrient intake is not ensured especially among the lower strata of the economically active population, including industrial workers. Whereas, the United States industrial worker is, in general, much better off in this respect. Table 1.1 compares the average food consumption in various countries [FAO09].

<table>
<thead>
<tr>
<th>Country Name</th>
<th>Dietary Energy Consumption (kcal/person/day)</th>
<th>Dietary Protein Consumption (g/person/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States of America</td>
<td>3750</td>
<td>114</td>
</tr>
<tr>
<td>Italy</td>
<td>3650</td>
<td>112</td>
</tr>
<tr>
<td>France</td>
<td>3530</td>
<td>113</td>
</tr>
<tr>
<td>Canada</td>
<td>3530</td>
<td>105</td>
</tr>
<tr>
<td>Germany</td>
<td>3540</td>
<td>99</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>3450</td>
<td>104</td>
</tr>
<tr>
<td>Australia</td>
<td>3220</td>
<td>106</td>
</tr>
<tr>
<td>South Africa</td>
<td>3000</td>
<td>81</td>
</tr>
<tr>
<td>China</td>
<td>2960</td>
<td>89</td>
</tr>
<tr>
<td>Japan</td>
<td>2800</td>
<td>92</td>
</tr>
<tr>
<td>India</td>
<td>2360</td>
<td>56</td>
</tr>
<tr>
<td>Kenya</td>
<td>2030</td>
<td>58</td>
</tr>
</tbody>
</table>

Long-term malnutrition (under and over) leads to stunting and wasting, non-communicable chronic diet related disorders, increased morbidity and mortality and reduced physical work output. It is a great economic loss to the country and undermines development [DGI10].
Workers in India are living below the poverty line with high incidences of starvation, inadequate housing, poor sanitation and a high prevalence of disease. These are the major constraints that make the application of ergonomics principles more challenging. In comparison, developed countries tend to adhere to set ergonomic limits and have less poverty. Whereas workers in developing countries such as in India simply accept sub-optimal working conditions as the ‘norm’ and in such conditions the energy expenditure of job requirements tends to be high. Industries in developed countries adhere to keeping tasks within particular physiological limits, whereas mostly industries in developing countries do not. In a developing country like India have a need of more practical approach where workers are required to work at high levels of energy expenditure in order to “keep their job”. This is where the relationship between energy intake and energy expenditure becomes particularly crucial.

The labour force in a developing economy is generally comprised of two broad sectors, the organized and the unorganized. The organized sector consists of activities carried out by corporate enterprises and by government with the help of wage earners. It includes all government industries, departmental enterprises and public sector corporations. “Similarly, forestry, irrigation works, plantations, industries, recognized educational institutions, and hospitals which are registered as non-profit making bodies. On the other hand, the unorganized sector covers most of the rural labour. It includes activities that are being carried out by small and family enterprises, and depends partly or wholly on family labour. This sector is marked by low income, unstable, irregular employment and the lack of social and statutory protections. Unorganized sector also referred as informal sector.

In organized sector, the activities are often broken down into smaller elements and are repetitive in nature. This requires specific skills, which are performed by the qualified workers who have the necessary attributes, and skills. These workers, in such cases, do not carry out the whole of a job but only the part of the same. However, activities in unorganized sector are different. A worker engaged in this sector acquires a variety of skills, which
help the worker to complete the whole of a job from start to finish without depending on others. Such varied activities, in organized and unorganized sectors, call for different physiological, psychological and biomechanical demands.

In India, according to the survey conducted by the National Sample Survey Organization (NSSO) in 2009-10, the total number of workers were 437 million. About 29 million of the total workforce is engaged in organized sector and remaining 408 million (about 93%) in unorganized sector. Out of 408 million workers in the unorganized sector, 269 million workers were employed in agriculture sector, 26 million in construction and remaining were in manufacturing activities, trade and transport, communication and services [NSS09-10].

In India, workers engaged in the unorganized sector don't have social security and other benefits of organized sector. Most of them are engaged through contractor in rural areas, and works as daily labour and migrated labour in urban areas. Construction workers and other unorganized workers in agriculture and segments like street vending, rice mill, forest, handloom and power loom, fishing, gem-cutting and sugarcane-cutting face unprotected work with no guarantee of employment. The workforce is abundant, low skilled and easily available and high rate of unemployment, which makes them susceptible to exploitation. They work for low wages without medical and any other benefits. Getting work is more important than the hazards involved. Poverty, poor wages and the large family the wage earner has to support, make the plight of the ill-nourished worker only worse. The situation of unorganized workers has not improved since Independence. The labour productivity in this sector is low as compared to the organized sector, even though, their contribution to the national economy is substantial [Raj93]. On the contrary, organized sector generally uses traditional and unsophisticated technology. But the awareness about occupational health is at a low level even in this sector.

In India, the proportion of male: female working population which was 78:22 in 1991 was 68:32 in 2001 [Sai04]. Moreover, female workers often suffer
from musculoskeletal disorders because neither the tasks nor the equipment they use, which is normally designed for men, are adapted to their built and physiology. The physical constitution of women is not as strong as that of men, and their capacity for sustained muscular effort without undue fatigue is also substantially less. Carrying heavy loads result in disturbances of blood circulation in the pelvic regions combined with rapid rise in intra-abdominal pressure. Disorders in the menstrual and generative functions, such as excessive bleeding, premature delivery, still birth, miscarriage and prolapse of uterus due to heavy load carrying are also reported. In addition, female workers have specific stress-related disorders, resulting from job discrimination (such as lower salaries and less decision-making) and a double burden of work (workplace and home). Women work in unorganized sectors are more prone to WRMSDs due to their low level of qualification; this made them vulnerable to psychosocial stress, in terms of exploitation, less bargain power for wages. Gender bias in wages calculated from the National Sample Service Organization (NSSO) for 2004-2005 is shown in Table 1.2 [Bar11].

Table 1.2: Gender Bias in Wages Calculated from NSSO

<table>
<thead>
<tr>
<th></th>
<th>Male wages (Rs.)</th>
<th>Female wages (Rs.)</th>
<th>Index of gender bias in wage payments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organized</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>144.93</td>
<td>85.53</td>
<td>0.59</td>
</tr>
<tr>
<td>Urban</td>
<td>203.28</td>
<td>153.19</td>
<td>0.75</td>
</tr>
<tr>
<td><strong>Unorganized</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>55.03</td>
<td>34.94</td>
<td>0.63</td>
</tr>
<tr>
<td>Urban</td>
<td>75.1</td>
<td>43.88</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Recognizing the menace of MMH tasks, many countries have placed some limitation on the weight for manual lifting and/or carrying. Also, emphasis has been given to the administrative and personal interventions for better modes of handling loads, to minimize injury risk potentials. Therefore, in India it is necessary to prescribe some ceiling on the weight to be carried by an individual in order to ensure workers health, safety and wellbeing.
1.4 MMH Task Design Approaches

Tasks in manual material handling can be helped by improved job design and employee placement procedures in order that job demands can be controlled to stay within individual capacities. The four primary approaches to determine load carrying capacity are [Seu04]:

1. The Epidemiological approach,
2. The Physiological approach,
3. The Biomechanical approach, and
4. The psychophysical approach.

The fundamental assumptions underlying these control approaches include that (i) the incorrect method of handling the load is a risk factor for low back pain, and (ii) a protective, correct technique can be identified for most of the population. These approaches have been differently examined with reference to human characteristics (age, sex, isometric strength and endurance capacity), material characteristics (size and shape of the object handled), task components (distance travelled, duration, frequency, etc.) and the work practices including posture, techniques of load handling and safety functions.

1.4.1 Epidemiological Approach

Epidemiology is a science concerned with the identification of incidence, distribution, and potential controls for illness and injuries in a population. The factors which modify risk of injury are divided into job and personal risk factors. The characteristics of the job which contribute to risk are weight handled, size of load, and frequency of lifting. Personal risk factors include gender, age, anthropometry, lifting technique, altitude, training and strength. In a document of NIOSH, a number of factors identified in epidemiological studies regarding short and long term effects of manual materials handling [NIOSH81]. The survey showed that lifting of load does appear to increase the incidence of MSDs, and that the daily frequency of heavy load lifting and carrying could also be resulted in health hazards.
1.4.2 Physiological Approach

The physiological approach assesses the stress imposed upon the cardiorespiratory system. Heart rate, metabolic energy expenditure rate and oxygen consumption are the physiological measurements which have been suggested most often for determining the maximum work intensity that can be continuously performed without accumulating excessive physical fatigue. Mostly, the oxygen demand of work is determined and generally if it is less than a third of the individual’s aerobic capacity, the task is considered acceptable for an 8 hour work day. While this approach works reasonably well for frequently performed tasks, it is not sensitive to tasks that are performed occasionally or in tasks like holding loads, etc. There are also concerns about what percentage of the aerobic capacity should be considered safe and how should it be determined, e.g., bicycle ergometry, treadmill, lifting, and carrying. Often the technique requires trained personnel to carry out the testing under standard laboratory conditions.

1.4.3 Biomechanical Approach

If heavy lifting and carrying tasks performed occasionally, the stresses imposed on the musculoskeletal system of the worker become of primary concern. The biomechanical modeling approach attempts to evaluate the mechanical stresses imposed on critical points of the musculoskeletal system, particularly on the neck, shoulder and low back, by estimating the reactive forces and torques at various body joints. The basic approach in this type of model uses available information concerning body segment parameters. Utilizing these segment parameters and mechanics, it is possible to develop equations to describe the reactive forces and torques at the various articulations of the body while at different configurations. Although most of these models assume that the body performs the lifting/carrying tasks very slowly and therefore neglect the effects of acceleration, these models serve the useful function of establishing lifting/carrying limits in various body configurations in heavy slow lifting/carrying that is non-repetitive.
1.4.4 Psychophysical Approach

Psychophysics is concerned with the relationship between human sensations and their physical stimuli. The psychophysical methodology is by far the most traditionally used method for determining load limits/capabilities in the working population, for lifting and carrying tasks performed occasionally or repetitively. This approach assumes that both physiological and biomechanical stresses are present in any MMH task. While the contribution of each may vary as the task changes from frequent to occasional, both these stresses can be integrated under the measure of perceived stress. Using perceived stress that can be sustained without overexertion, individuals determine the maximum weight they are willing to lift or carry occasionally or frequently for different durations. Some researchers have expressed concern about the psychophysical approach due to its subjective nature; however, there is a reasonable agreement that the subject’s perceived workloads are also compatible with the physiological approach. The use of psychophysics in the study of MMH tasks requires subjects to adjust one of the task variables (frequency of lift or weight of the load) according to their own perception of muscular effort or force. Subjects participating in psychophysical studies are instructed to adjust their workload to the maximum amount that they can perform without strain or discomfort, and without becoming tired, weakened or over-heated, or out of breath. Psychophysics has been applied to many practical problems in many areas [Sno78].

1.5 Documentation on Load Carrying

Load carrying, a basic task executed by manual workers consists of lifting an object, carrying it through some distance and then putting it down, still remains a requisite resource in many industrial operations. Although, load carrying is considered less risky for causing injuries than lifting, but previous studies have found a high incidence of back injuries among workers whose job requires heavy carrying [Mag87, Nor67]. Till date, numerous studies have been conducted on manual lifting. Studies on load carrying have been relatively few, so there is a need to review carrying task. No in depth
study on load carrying and resulting health problems of male and female workers has been reported. In load carrying, mental health problems, fatigue, repetitive strain injury and MSDs are more predominant in women than in men [Ost02]. Scientific studies on efficient and proper methods of carrying loads are somewhat lacking, especially in the context of a developing countries. For this study, a scientific approach to research the problems faced by workers in the area of manual material handling and the sociological aspect of the same have been used.

Most often in scientific researches the researcher tends to forget the socioeconomic aspect which is very important and is directly related to the health of the workers. Workers from low economic strata are amongst the most deprived section of the society. It has been found that many of these workers work in unorganized sectors and have to carry lot of load irrespective of their health and nutritional status. As present study is one of few studies carried out on workers, it was equally important to study their socioeconomic profile as one of the parameters.

In this part of the thesis an attempt has been made to find out different modes of manual load carrying by Indian workers in different activities by using the following basic techniques of quantitative research as well as the limitations of the study. The techniques used are:

- Observation
- Interaction & Discussion
- In-depth interviews with workers
- Analysis of the data
- Documentation of different modes of load carrying

An attempt has been made through quantitative research to document different modes of load carrying by workers as observed in various regions of the country, by still photography and video filming technique shown in Figure 1.2. Several modes were identified for the purpose of the detailed study. The occupations covered were Foundry industry, Sugar industry, Women Carrying Water and Scaffolders in construction sites.
Figure 1.2: Workers involved in Manual Load Carrying Activities
Based on the documentation, the following commonly adopted modes of load carrying by workers have been identified.

- Load on head
- Load on shoulder
- Load on back
- Load on head and close to waist
- Load on head and by hand
- Load close to waist
- Load carrying on waist and hand
- Load on back with shoulder support
- Load on hand
- Load carrying by both hands (sidewise)
- Load carrying by both hands (infront)
- Load carrying by both hands (backside)

During this documentation process, efforts were made to an excellent rapport with the workers for further extensive research in this area. This process took 9-10 months and helped in preparing the preliminary questionnaire indicating the variables to be studied. Based on the interactions and observations the questionnaire was administered for the following.

- Elicit information from the people.
- To conduct a pilot study based on the response of the group for addressing other relevant issues.
- In-depth interview with workers. This method revealed and opened up new areas.
- Ergonomic checklists i.e., work aspects and their details.
- The use of secondary data i.e. health and musculoskeletal problems among workers.

1.6 Identification of Area to be studied

Considering the availability of subjects, working conditions in the field, proximity of the location etc. the present study is restricted to the following organized/industrial and unorganized/operational sectors.
1.6.1 Organized/Industrial Sectors

1.6.1.1 Foundry Industry

The Indian Foundry Industry is well established. According to the recent World Census of Castings by Modern Castings, USA; India Ranks as 2nd largest casting producer producing estimated 9.05 Million MT (MMT) of various grades of castings as per international standards [Met12]. There are approximately 5000 units out of which 80% can be classified as small scale units and 10% each as medium and large scale units. The industry directly employs about 5 lakh people and indirectly about 1.5 lakh people and is labour intensive. The small units are mainly dependent on manual labour and manual carrying is the most prevalent causes of injury to foundry workers due to overexertion and poor lifting/carrying techniques [Mcl79, ICO80, OSHA77]. The laborers engaged require lifting/lowering, carrying and pushing/pulling of heavy materials and resulted in diverse musculoskeletal problems. For the WRMSDs study in foundry industry, Cupola furnace foundries were selected.

1.6.1.1.1 Cupola Furnace Foundry

In Cupola furnace foundry, castings are made from molten metal according to an end user specification. The workers carry out a variety of tasks to make products from metal and the work comprises: making the pattern, making and assembling the mold, charging cupola, melting and refining the metal, pouring the metal into the mold and finally removing all adherent sand and superfluous metal from the finished casting. Working in Cupola furnace foundry is hard physical labour involving the carrying of heavy loads and the workers continuously exposed to the heat of molten metal and vibration of tools. They are found to be very dangerous and having lot of stress on workers normal working.

1.6.1.2 Sugar Industry

India has 566 sugar mills in the country, of which 56% are in the cooperative sector, 34% in the private sector and the remaining 10% are in the public sector. India ranks second, next to Brazil in terms of area (4 million
hectare) and sugar production (about 26.4 million tonnes) according to Commodity Specific Studies on Sugarcane [CSSS10]. The Indian sugar industry comprises about 20% of sugar mills and 15% of sugar production of the world. It is the second largest agro-processing industry in the country, with total employed capital of Rs. 50000 crores and an annual turnover of Rs. 25000 crores. It plays a key role in rural development by creating direct employment to 5 lakh skilled and unskilled workers [Sin07]. In this industry, physical activities such as manual material handling (e.g., heavy load lifting, lowering, carrying, pulling, and pushing) and awkward working postures are very common. The production process is very labor intensive and workers are exposed to work related musculoskeletal disorders (WRMSDs) risk factors. In this situation, a high rate of occupational accidents is expected which should be taken care of.

1.6.2 Unorganized/Operational Sectors

1.6.2.1 Women Carrying Water

Humans are all alike in facing the basic constraint of time and in needing water to drink every day. As well, water is needed for drinking, sanitation, bathing and food preparation. Adding all water needs together, the United Nations High Commissioner for Refugees [RUN10] suggested that 15 litres per person per day is required while the Human Development Report of UNDP set a standard of 20 litres per capita per day, and Gleick [Gle96] argued for a higher minimum 50 litres (approximately) per day per person. Whatever the exact level of this basic need, the residents of developed countries (and the majority of Indian Urban citizens) can simply turn the tap and satisfy it immediately, but in approximately 18.6% of rural Indian households somebody (usually female) has to spend an average of 47 minutes per day in fetching water for fulfilling their basic water needs.

Traditionally, fetching water has been a woman’s job. It does not matter if the women are old, young or pregnant, crucial household needs have to be met after weary day. For women there are no developed countries, they work for longer hours, the plight of poor rural women is rather worse. Every dawn brings with it a long search of fuel fodder and water. They generally fetch 15
to 35 litres of water in one time from a source within 1 km. of the user’s dwelling and fetch up to 80 litres of water for fulfilling their and family needs. Fetching and carrying water is women’s work in rural India. In the villages of the desert district of Banaskantha, women spend up to six hours a day bringing water from distant sources to their homes. They carry about 20 to 30 liters on their heads on each trip, often walking barefoot [Kap03].

In Haryana, where all the villages are provided with safe drinking water through community water supply since 1990, fetching water was found drudgery prone activity [Jin92]. In the year 1999-2000, AICRP (All India coordinated research project) conducted ergonomic evaluation of fetching water with the objective to see the risk involved in this activity. Fetching water is an extremely strenuous activity undertaken by rural women and it consumes an enormous amount of their time and energy and reduces it for the rest of work. However, very few studies have specifically investigated water carrying as it is performed by women in developing countries and used appropriate methodologies to investigate its association with health generally or musculoskeletal disorders specifically [Hem07, Pag96, Sim94]. Some women may experience high rates of perceived exertion and pain sufficient to limit their capacity to carry water containers [Llo10].

1.6.2.2 Scaffolders

The principal tasks of scaffolders are erecting and taking down large-scale scaffolds. During these tasks manual material handling is one of the most dominant activities due to manual lifting, lowering and carrying of heavy materials such as scaffolding poles and boards, guard rails and ladders [Mol01]. Scaffolds are obviously needed on construction sites to elevate construction workers and their materials to higher levels. There are many kinds of scaffolds, including wood pole scaffolds, tube and coupler scaffolds, fabricated frame scaffolds, mobile scaffolds, outrigger scaffolds, suspension scaffolds, swinging scaffolds, brick layer’s square scaffolds, horse scaffolds, and needle beam scaffolds. There are nearly 2.5 million construction workers who depend on scaffolding to do their job. According to the Occupational Safety and Health Administration [OSHA] there are approximately 4,500
Chapter 1

scaffolding-related injuries and 50 deaths each year. That’s roughly twelve injuries per day, four deaths per month according to Sample Lesson Plan Scaffolds [SLPS]. Scaffold erectors and dismantlers are at particular risk, since they work on scaffolds before ladders, platforms, planks and guardrails are completely installed. Injuries common to scaffolding accidents are: broken bones, especially broken legs, ankles, feet, arms, hands, spines and special kinds of MSDs due to manual handling of scaffolds which are beyond to the limit of load carrying capacity of scaffolders.

1.7 Occupational Health Hazards in India

Whether you work in a factory or a call centre, whether you are attached to a big enterprise or are self-employed, whether you are an officer or a salesman, whether studying or retired, each of us has an occupation. Even a housewife has an occupation- she is the homemaker. Every occupation- whether working on a machine or sitting in front of a computer, travelling to meet clients or studying for an impending examination, cutting vegetables at home- has an occupational health hazard, which if unseen may develop into an occupational accident. These occupational accidents also cause direct and indirect or hidden costs for the whole society.

In the past two decades, India has witnessed rapid urbanization, motorization, industrialization and migration of people resulting from socioeconomic growth and development. With mechanization and revolution in technology, traditional ways of living and working are being altered at the same time general awareness about occupational safety, occupational and environmental hazards is not spread in the society. With these structural changes the workers in low resources settings are more likely to be affected by the dangers of high technology than their counterparts in developed countries. The number of persons earning their livelihood in India solely by carrying loads is very large. Most of these workers belong to the lower economic status, carrying heavy loads for a small financial gain, ignoring their physical capabilities and possible health risks. They never think of their physical capacity, possible exhaustion and the dangers associated with handling heavy loads. Due to lack of education, unaware of the hazards of
their occupations, general backwardness in sanitation, poor nutrition and climatic proneness of this geographic region to epidemics aggravate their health hazards from work environment.

Many of the hazardous industries have also been moved towards India from developed countries due to increased labor costs. The challenges and demands to make nationally measurable progress in reducing the current epidemic of musculoskeletal injuries and diseases caused due to heavy load carrying among industrial/operational workers are significant. MSDs in industrial load carrying are common. The International Labour Organization [ILO05] estimated that more than 125 million workers were victims of occupational accidents and disease in a single year. Of these approximately 2.2 million workers died and about 10 million were seriously disabled. The ILO report said the number of accidents- in particular fatal accidents- appear to be increasing, particularly in some Asian countries due to poor reporting, fast development and strong competitive pressures of globalization. Still, every day, on average, some 5,000 or more women and men around the world lose their lives because of work-related accidents and illness. Concha-Barrientos et al. [Con05] estimated that annually approximately 3.1 million fatal unintentional occupational injuries occurred around the Globe. Hamalainen et al. [Ham06,07] estimated that annually about 2 million fatal work-related diseases and occupational accidents occur (3.4 million fatal occupational accidents and 1.6 million work-related accidents). They also estimated that annually 263 million occupational accidents occur that cause at least four days of absence from work.

Occupational injuries are a major public health problem in India. The statistics for the overall incidence/prevalence of occupational disease and injuries for India is described as that yearly over 48,000 workers die because of occupational accidents in India, and nearly 37 million occupational accidents occur which cause at least 3 days absence from work. The fatality rate is 11.4 per 1,00,000 workers and accident rate is 8700 per 1,00,000 workers. Leigh et al. [Lei99] have estimated an annual incidence of occupational disease between 9.2 million and 1.9 million, and 1.2 million
deaths in India. Based on the survey of agriculture injury incidence study by Mohan and Patel [Moh92] in Northern India, they estimated annual incidence of 17 million injuries per year, (2 million moderate to serious) and 53,000 deaths per year in agriculture alone. Many other authors have also been reported high prevalence of neck and upper limb disorders in the industry [And84, Dim89, Her81]. Hagberg and Wegman [Hag87] stated that there is an association between occupation and diseases of the shoulder and neck, which suggest that highly repetitive shoulder muscle contractions, static contractions and work at shoulder level are hazardous exposure factors. Constant material handling more than 5 minutes and working with the hands above the shoulder level are the most important contributing factors to neck and shoulder trouble.

In India, the number of non-fatal accident injuries was 18% (over a hundred thousand person days) in the years 1991 to 1993 and it increased to 20% in 1994 [Sin04]. This figure included all industries except the agriculture and service sectors. It was also mentioned that, in 1994, out of a total of 68,484 industrial injuries, 9,283 were caused during the handling of different objects. The most likely injury prone area in the occupational sector is that where the labourers are forced to manually handle heavy weights (around 100 kg per person). 15-20% of all the reported cases of inability to continue the job and about 25% of disabling injuries were reported to be due to rheumatic complaints [Sin04]. It was mentioned on industrial workers of Delhi that factory regulations potentially fail to prevent the exposure of workers to back stress [Jos01]. Moreover, in India, there are hardly any active consumer groups who regularly maintain the regulations from the view point of safety, occupational health hazards and wellbeing conditions of the workers. These workers live in slums, in an absolutely unhealthy environment and most of them are under-nourished or malnourished [Ban88]. They work under a scorching sun and barely use personal protective devices. These casual workers are employed by labour contractors on a daily wage basis without any safety protection as although they work regularly.
A safe and healthy work environment is the basic right of every worker. However, the global situation falls far short of this right. India urgently requires modern Occupational Health Safety (OHS) legislation for maximum allowable carrying load for males and females with adequate enforcement machinery and establishment of centers of excellence in occupational medicine, to come up with the rest of the world.

1.8 Weight Limitation (Existing Regulation in India)

In developed countries there are maximum permissible weight limit to be handled by workers according to ILO [ILO88] the maximum permissible weight varies from country to country from 15 kg to 75 kg for the workers but in developed countries it is to be around 15-20 kg for adult workers. According to the National Institute of Occupational Safety and Hazards [NIOSH91] the recommended weight limit is 23 kg.

According to The Factory Act, 1948 [Act No. 63 of 1948] as amended by the Factory (Amendment) Act, 1987, Excessive weights. (1) No person shall be employed in any factory to lift, carry or move any load so heavy as to be likely to cause him an injury. (2) The state government may make rules prescribing the maximum weights which may be lifted, carried or moved by adult men, adult women, adolescents, and children employed in factories or in any class or description of factories or in carrying or in any specified process. According to Joshi et al. [JOS01], the existing Indian Factory Rule (1948) is not sufficient to take care of the Indian industrial/operational workers.

But there is no such rule and regulation for maximum safe load handled by the workers in states of India except Maharashtra (Maharashtra Factory Rules, 1975, Rule (66)). In the Maharashtra Factory rule, 1975, Rule 66(1) [Dwi00], it is stated that in industrial environment, a load of 30 kg can be handled by an adult worker. In Rule 66(2), it is also mentioned that in any factory, no person in conjunction with other person, unaided by mechanical device, shall lift by hand or carry overhead or over the back of the shoulders, any material, article, tool or appliance if the weight thereof exceeds the sum
of weight permissible for each person separately, as fixed by the ‘safe load
limit value’ [Dwi00].

In India, the workers involved in unorganized industry, are continuously
over exhausted without protection of any law. These workers are employed
temporarily by labour contractors on daily wage basis. No records are
maintained on their health or industrial accidents.

In this context, present study is carried out for estimating maximum
acceptable load carried by male and female Indian industrial workers
involved in organized sector (Foundry and Sugar Industry) and operational
workers involved in unorganized sector (Women carrying water and
Scaffolders).

Determination of acceptable carrying load will be a boon for the workers and
will safeguards their physical capabilities and possible health risks. If an
Expert System is also made, which can classify the loads carried in different
categories of risk, than the potential risks involved can be avoided. Hence, a
Neural Network Model which will act as a Knowledge Base System for the
classification of carrying load in different risk categories will be of great use.
A Back Propagation Neural Network model is developed to classify the
carrying load into different risk potentials for physiological stress of male
and female (industrial and operational) workers to give a line of demarcation
for MSDs.

1.9 Artificial Neural Network

An Artificial Neural Network (ANN) is a collection of large numbers of
processing elements, called nodes (or artificial neurons). In neural
computing, mathematical processing units (neurons) are linked together by
weighted connections. Each neuron processes its weighted inputs according
to its activation function, and its output is then connected to the inputs of the
next layer of neurons. Every neural network consists of three types of layers:
input layer, hidden layer and output layer. The number of neurons in the
input layer is equal to the number of input variables. The hidden layer
allows the model to handle the non-linearity and complexity of relationship
of variables. There is no general rule to determine the number of hidden layer(s) and neurons in hidden layers. Furthermore, there are two kinds of output; actual and target. Actual output refers to the output of the neural network and the target is the desired output, which the ANN is trained to recognize. The difference between the actual output and the desired output is the ‘network error’. The neural network has the ability to learn from the experimental data (for gaining knowledge) expressed by inter-unit connection strengths (weights) and can make the knowledge available for later use. By allocating appropriate values to the weights, an ANN can perform complicated operations on its inputs. ANN models require to be trained with acceptable accuracy before being used for data analysis. Learning process in ANN models is accomplished through special training algorithms that are developed to mimic the learning mechanism of biological systems [Che94, Zil01].

Classification of loads in different risk categories will safeguard the workers’ health and will avoid MSDs to a large extent, but still lot of accidents take place in the organized and unorganized sectors due to the negligence of the workers. These accidents are more predominant during the critical days of each worker. These critical days or caution days are associated with an increased potential for human error and consequently with an increased likelihood of accidents. An information system is required which would be helpful in indicating the accident prone dates of the industrial/operational workers involved in the concerned sector so that in those dates the workers may not be given hazardous task. So, the theory of Biorhythm is used to develop this information system.

1.10 Biorhythm

The science of “Biorhythm” is the science of predicting human performance by means of understanding biological rhythms. Its formation was primarily due to the research of three men working independently, namely Swodoba, Fleiss and Teltscher. It proposes that people’s behavior is affected by three biological cycles that start at birth and continue through life. Biorhythm cycles are believed to originate from the day of birth and from a base line
begin their cyclical variation with an initial upward swing. These cycles have been termed: (1) Physical cycle is the biological cycle which lasts 23 days originates in the muscle cells and fibers, and helps to govern the degree of strength, vitality, endurance, resistance and physical confidence of the individual; (2) Emotional cycle is the biological cycle which lasts 28 days governs the nervous system and influences creative enterprise, feelings, love, cooperation, and all coordination dealing with the nervous system; (3) intellectual cycle is the biological cycle which lasts 33 days governs the brain and regulates intelligence, logic, mental reaction, alertness, sense of direction, decision-making, judgment, power of deduction, memory, and ambition [Tho73]. These cycles have traditionally been depicted as sine curves. According to the theory each cycle has three distinct phases. The first, or positive, phase i.e., above the birth base line is said to be associated with strong, creative, stimulating activity while the second, or negative, phase i.e., below the base line is said to be associated with weak, irritable, indecisive activity. The third is the critical or transition phase that cross the base line means the period during which the biorhythm changes from positive to negative or vice versa. This phase is said to be an unstable or turbulent period during which “a person’s predisposition to react to vital situations is not at an optimal level” [But77]. There are two critical days for each cycle [Sha78]. Taking each cycle in turn it is, then, possible to predict the state of the individual. However, as the cycles are not of the same length, they very rarely coincide with one another. Hence, on any particular day you have a mixture of rhythms that have to be interpreted accordingly.

In India, the concept of biorhythm has not been explored at all and there is no much literature available in this area. The development of such an information system will help in avoiding the accidents of industrial /operational workers in various sectors.

Present study will also be of great use if its outcome could help the government and concerned authorities to develop more specific guidelines for carrying loads for male and female Industrial/Operational workers of Organized and Unorganized sectors.
1.11 Organization of the Thesis

The entire thesis has been arranged in nine chapters. Brief description of the contents of all chapters is as under:

**Chapter 1:** An introduction has been made on conditions of workers involved in MMH and the problems of MSDs faced by these workers. This chapter describes the status of Indian workers involved in carrying load. This chapter also contains fundamental approaches to the analysis of MMH tasks, documentation on different modes of load carrying, areas to be studied, occupational health hazards, weight limitations and thesis organization.

**Chapter 2:** Describes the aims and objectives of the study.

**Chapter 3:** Covers an extensive literature review on the subject and its related areas.

**Chapter 4:** Describes methods and methodological aspects for calculating physiological cost in terms of heart rate, work-rest pause pattern, determination of center of gravity, spinal curvature measurement, lung function test, Heart rate variability and Electromyography to understand the muscular involvement of the workers and statistical analysis of the data. This part also includes the method of measuring work stressors among industrial workers and their statistical analysis with MSDs.

**Chapter 5 and 6:** Contains results obtained from the study and detailed discussion on the results. This chapter includes personal and medical history of workers, discomfort feeling by workers, anthropometric dimensions of workers, the nutritional and socioeconomic status, and walking speed of workers in field. Along with this, chapter also includes the determination of optimal safe load to be carried by Indian industrial/operational workers involved in organized and unorganized sectors by identifying the loads in various risk categories considering the effect of field environment parameters, correlation of physiological cost with bio-mechanical and psychophysiological cost of load carrying, heart rate recovery cost, work rest allowance, reproducibility and heart rate variability measurement, association of work stressors among male and female workers with the
prevalence of WRMSDs along with the effect of shift work and extending working hours on occupational injury.

Chapter 7: Contains development of a Back Propagation Neural network model as an expert system which classifies the load carried by male and female industrial/operational workers into high and low risk category, to give a line of demarcation for preventing MSDs.

Chapter 8: Contains introduction to Biorhythmic theory and also the results and analysis after identifying the accident prone dates of the industrial workers involved in the concerned sector.

Chapter 9: Describes conclusion of the study covering its usefulness and scope for further work.

The structure of thesis is also represented with a block diagram and is shown in appendix.