CHAPTER 9

CONCLUSION

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. 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 (MSDs). Manual carrying has been a major source of hazards of industrial workers.

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. MSDs are the most common work-related disorders and also affecting quality of life. They affect nearly one half of the nation’s workforce at some time, resulting in time lost and earnings lost from work. 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.

India occupies 2.4% of the world's land area and supports over 17.3% of the world's population. 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. Nutritionally, the Indian industrial worker makes a poor comparison with their more fortunate brothers in advanced countries.

In India, according to the survey conducted by the National Sample Survey Organization (NSSO) in 2009-10, the total number of workers was 437
million. About 29 million of the total workforce is engaged in organized sector and remaining 408 million (about 93%) in unorganized sector. 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.

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. Women work in unorganized sectors are more prone to work related musculoskeletal disorders (WRMSDs) due to their low level of qualification; this made them vulnerable to psychosocial stress, in terms of exploitation, less bargain power for wages.

The International Labour Organization 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. 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.

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.

In developed countries there are maximum permissible weight limit to be handled by workers 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. The existing Indian Factory Rule (1948) is not sufficient to take care of the Indian Industrial/operational workers.

In this context, present study was carried out with the aim of estimating optimal carrying load for male and female Indian industrial/operational
workers involved in organized sector (Foundry and Sugar Industry) and unorganized sector (Women carrying water and Scaffolders) by considering the Physiological, Biomechanical and Psycho-physiological approaches. A real gender difference was also considered because male and female workers are affected by MSDs in different manners and also the carrying load limit of female workers is also less than the male workers. The male and female workers selected in this study were divided in the age group of 21-30 years, 31-40 years and 41& above years.

The review of literature discussed in Chapter 3 conclude that factors such as personal characteristics of workers, field environment parameters, shift work and extending working hours, work stressors, physiological cost of carrying load considering heart rate recovery cost, work-rest/pause allowance and heart rate variability, bio-mechanical and psychological cost of load carrying, are the factors which are associated with load carrying and plays a vital role in generating MSDs among industrial/operational workers.

So, for conducting the study, the methodology used is discussed in Chapter 4. The optimal load carried by the selected workers of organized and unorganized was based on field and laboratory study. It included the procedure of collection of data through a specially designed questionnaire by considering the physical characteristics, prevalence of pain in different body region and also the psychosocial variables which act as work stressors among workers. It also included the method of calculating dietary intake of workers, field environment parameters, 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. In the present work, for physiological study both the field and laboratory data were collected. Method of calculating the association of work stressors with MSDs is also discussed.

Chapter 5 was focused on Indian Industrial workers involved in organized sector. In this chapter, optimal safe load to be carried by Indian industrial workers had been calculated by considering the Physiological, Biomechanical
and Psycho-physiological approaches. So, for the current study male and female workers of Agra Foundry and Daurala Sugar Industry had been chosen.

Physical Characteristics of foundry workers showed a significant differences (p<0.002) in the body weight, body fat and lean body weight. It was observed during the field study that the commonly adopted modes of load carrying by foundry workers were the head and shoulder, and by sugar workers were the head, shoulder and back.

Results of the questionnaire on body pain showed a high prevalence of pain in different body regions of workers viz. upper back, neck, leg and shoulder region. And it was also observed that in comparison to foundry workers, sugar workers indicated more pain in their body parts.

Results of the nutritional study observed that the average energy intake of foundry workers and sugar workers was much less considering their occupational workload which falls under heavy category. Analysis of blood also showed that average haemoglobin content of foundry and sugar workers was 10.6 gm/dl and 10.3 gm/dl respectively, which is lower than the normal population.

Field environment study showed that the foundry and sugar workers were working under positive heat stresses conditions. And the work terrain of foundry and sugar industries was very hazardous which creates problems in comfortable working and movements of the workers.

During physiological field study, it was observed in case of foundry workers that the average working heart rate of male foundry workers varied from 132 beats/min to 144 beats/min and, while for female foundry workers varied from 134 beats/min to 148 beats/min for different activities. In all activities of carrying load, the average resting heart rates was between 73 beats/min to 82 beats/min for both male and female foundry workers and average starting heart rate for all activities just before restarting the work after completion of one cycle was always above 100 beats/min. It was also observed that the average working heart rate for male sugar workers varied from 128
beats/min to 142 beats/min and for female sugar workers from 131 beats/min to 150 beats/min. The average resting heart rate for both male and female sugar workers were 73 beats/min to 81 beats/min.

It was observed that in both foundry and sugar industry, carrying activities by both male and female workers was performing under considerable amount of physiological stressful condition due to insufficient recovery time. The physiological workload of the male and female workers involved in carrying load activities in foundry and sugar industries could be graded from ‘moderately’ to ‘very heavy’ category based on average working heart rate.

In Laboratory Biomechanical study of foundry and sugar workers showed that the head mode is less stable and back mode is more stable because of changes in the axis with the increase of load. Significant differences (p<0.02) were also observed when normal condition was compared with a 10 kg load for the cervical region. Spinal curvature study inferred that no significant change to the cervical and lumber region anterior-posterior curvature (angle) occurred with different loads in different modes.

In Laboratory Physiological study, it was found through the lung function test that the FEV$_1$/FVC relationship in all the workers selected for the study indicated that the subjects were free from any kind of pulmonary problem because the normal value of FEV$_1$/FVC was more than 80%.

It was also observed during the physiological study that as the carrying load was increasing in case of male and female foundry and sugar industry workers in head, shoulder and back mode, heart rate variability (SDNN) shifted from low risk category to high risk category, which showed the effect of load on heart rate variability and the same response was also observed as the age was increasing.

The working heart rate and recovery heart rate of both foundry and sugar workers were plotted on the graph and it was observed that the working heart rate showed a rising trend in at the 5th minute and became constant for some time and then the heart rate showed a recovery trend. Then the values
of heart rate recovery cost were calculated with the help of a designed heart rate recovery cost model and when plotted on graph showed a rising trend with increase in age and load in case of foundry and sugar workers.

From the physiological point of view, it was observed by considering the heart rate (beats/min), energy expenditure (KJ/min) and maximum O₂ consumption that the acceptable load for male foundry workers of age group 21-30 years, 31-40 years and 41& above years engaged in carrying load activities should be up to 30 kg, 25 kg and 20 kg at 2.5 km/hr walking speed respectively, but in reality the actual walking speed in the field was 3.7, 3.6 and 3.2 km/hr respectively. Therefore for conditions in the field the recommended acceptable load should be less than 30 kg, 25 kg and 20 kg for male foundry workers of age group 21-30 years, 31-40 years and 41& above years respectively. These load carrying limit were prescribed because in the load recommended above the heart was more than 110 beats/min and maximum oxygen consumption was more than 35%VO₂ max, which are the prescribed limits by the different authors.

In case of female foundry workers the acceptable load of age group 21-30, 31-40 and 41& above years engaged in carrying load activities should be up to 20 kg, 20 kg and 15 kg at 2.5 km/hr walking speed respectively, but in reality the actual walking speed in the field was 3.4, 3.1 and 3.1 km/hr respectively. Therefore for conditions in the field the recommended acceptable load should be less than 20 kg, 20 kg and 15 kg for female foundry workers of age group 21-30, 31-40 and 41& above years respectively.

The difference in maximum carrying load between male and female foundry workers might be due to the difference in physical characteristics of the male and female workers.

In Case of Sugar Workers, from physiological point of view, the acceptable load for male sugar workers of age group 21-30, 31-40 and 41& above years engaged in carrying load activities should be up to 30 kg, 25 kg and 20 kg at 2.5 km/hr walking speed respectively, but in reality the actual walking speed in the field was 4.3, 4.1 and 3.9 km/hr. respectively. Therefore, for conditions in the field, the recommended acceptable load should be less than 30 kg, 25
kg and 20 kg for male sugar workers of age group 21-30, 31-40 and 41& above years respectively. In case of female sugar workers the acceptable load of age group 21-30, 31-40 and 41& above years engaged in carrying load activities should be up to 20 kg at 2.5 km/hr. walking speeds respectively, but in reality the actual walking speed in the field was 3.7, 3.6 and 3.5 km/hr respectively. Therefore, for conditions in the field, the recommended acceptable load should be less than 20 kg for female sugar workers of age group 21-30, 31-40 and 41& above years respectively.

Results of the Electromyography study conclude that both male and female foundry workers in shoulder mode, for neck(r) muscle, significant difference was observed between 0 load and other loads. Significant difference was also observed in case of trapezoid(r) muscle between 0 and other loads. Most of the subjects hold the head load by the right arm. Both male and female sugar workers in back mode, for neck(r) muscle, significant difference was observed between 0 load and other loads except 20 vs 30 kg load in male sugar workers and 10 vs 20 kg load in female sugar workers. Most of the subject complained of a high degree of shoulder pain followed by neck pain.

It was observed that out of head, shoulder and back mode for male and female foundry and sugar workers, head mode demanded less physiological, muscular and biomechanical involvement. But the body was more stable in back mode than head mode.

Based on physiological and psycho-physiological responses and also considering the exiting uneven terrain, the existing work-pause schedule, walking speed, physiological strain index, heart rate variability and the environmental heat load during summer, it was concluded that for male industrial workers in head mode on horizontal surface that the load carrying limit should not exceed 25 kg for age group 21-30 years, 22 kg for age group 31-40 years and 19 kg for age above 41 years. In case of back mode for male industrial workers it should not exceed 24 kg for the age group of 21-30 and 31-40 years but for age group 41& above years it should not exceed 19 kg. In case of shoulder mode the load carrying limit for male industrial workers should not exceed 22 kg for age group of 21-30 years, 19 kg for age group of
31-40 years but 14 kg for the age group of 41& above years. It is also concluded for female industrial workers in head and back mode that the load carrying limit should not exceed 17 kg for age group 21-30 years, 31-40 years and 41& above years. But in case of shoulder mode for female industrial workers the load carrying limit should not exceed 12 kg for age group 21-30 years, 31-40 years and 41& above years.

Study of work stressors among industrial workers found that different work stressors are responsible for the prevalence of MSDs among the foundry and sugar workers. The study shows a real gender difference in the way male and female workers of foundry and sugar industry respond to the work stressors. There is also some evidence that psychosocial variables are relevant in the difference between male and female. The statistical analysis shows that long working hours (>8 h) and long job duration (>10 yr) have positive impact on the occurrence of MSDs among foundry and sugar industry workers. The effect of shift work in generation of MSDs is also observed among the male workers of foundry and sugar industry in contrast to female workers of foundry and sugar industry where no significance is found between shift work and the MSDs, because the less percentage of female workers were involved in shift work.

Correlation analysis in foundry and sugar industry shows significant relationship of dimensions of work aspects with pain and discomfort, substantiating that the work related MSDs are the results of interaction of multiple stressors associated with work and work environment, and other personal factors.

Study of work stressors shows a high association with MSDs and a real gender difference is also observed in the way male and female workers respond to the work stressors. Thus, it can be concluded from the study of work stressors that for preventing the industrial workers from musculoskeletal problems and for increasing the production rate the concept of identifying the work stressors among the industrial workers should be introduced. It would be for the benefit of industry and individual.
In Chapter 6, optimal safe load to be carried by Indian Operational workers involved in unorganized sector had been calculated by considering the Physiological, Biomechanical and Psycho-physiological approaches. So, for the current study Women Carrying Water (WCW) of Haryana and local Scaffolders had been chosen. Very few female workers were observed in scaffold activities because of heavy load carrying. So, the study was conducted only on male scaffold workers.

Study of prevalence of MSDs showed that in comparison to WCW, scaffolders indicated more pain in their body parts. The effect of aging was clearly observed on WCW and scaffolders. In comparison to the WCW, the scaffolders consume less calorie intake per day. For WCW the selected modes of carrying load was head, shoulder and waist and for scaffolders was head and shoulder modes.

Study of field environmental conditions showed that the work terrain of WCW and scaffolders was hazardous and they also work under positive heat stresses.

In Field physiological study it was found that the average working heart rate of WCW varied from 136 beats/minute to 144 beats/minute for carrying water activity. While the average working heart rate of scaffolders varied from 125 beats/min to 148 beats/min for carrying scaffold poles or boards, guard rails and ladders. The physiological workload of the WCW and scaffolders involved in carrying load activities could be graded from ‘moderately’ to ‘very heavy’ category based on average working heart rate.

In biomechanical study, the upward shift in centre of gravity (CG) was observed in all the three modes viz. head, shoulder and waist modes of load carrying in case of WCW and also in head and shoulder modes in case of scaffolders and higher the load more was the shift. Significant difference (p<0.001) was also observed when normal condition was compared with a 10 kg load for the cervical region. From the spinal curvature study it was inferred that no significant changes to the cervical and lumber region anterior-posterior curvature (angle) occurred with different loads in different modes.
In Laboratory physiological study it was observed that as the load was increasing the value of heart rate variability (SDNN) of WCW in all the three modes of load carrying (i.e., head, shoulder and waist mode) shifted from low risk category to high risk category, which was showing the effect of load on heart rate variability and the same response was also observed for scaffolders. It was concluded from the current study that the heart rate variability is an important factor in deciding the optimal carrying load for industrial/operational workers involved in organized and unorganized sectors.

The heart rate recovery cost model showed a rising trend with increase in age and also with the load in case of WCW and scaffolders.

From the physiological point of view, it was observed that the acceptable load for WCW of age group 21-30, 31-40 and 41& above years engaged in carrying water activity should be up to 20 kg, 20 kg and 15 kg at 2.5 km/hr walking speeds respectively, but in reality the actual walking speed in the field was 3.4, 3.3 and 3.1 km/hr respectively. Therefore for conditions in the field the recommended acceptable load should be less than 20 kg, 20 kg and 15 kg for WCW of age group 21-30, 31-40 and 41& above years respectively.

From the physiological point of view, the acceptable load for scaffolders of age group 21-30, 31-40 and 41& above years engaged in carrying load activities should be up to 30 kg, 25 kg and 20 kg at 2.5 km/hr walking speed respectively, but in reality the actual walking speed in the field was 3.7, 3.6 and 3.3 km/hr respectively. Therefore for conditions in the field the recommended acceptable load should be less than 30 kg, 25 kg and 20 kg for scaffolders of age group 21-30, 31-40 and 41& above years respectively.

From the Electromyography study, it was concluded that in general the waist mode involves higher muscular activity than other modes in case of WCW. In case of trapezoid(r) muscle, significant difference was observed between 0 and other loads in scaffolders.

It was observed that out of head, shoulder and waist mode for WCW, waist mode demanded high physiological, muscular and biomechanical
involvement in comparison of head and shoulder mode. In case of scaffolders, it was observed that out of head and shoulder mode, head mode demanded less physiological, muscular and biomechanical involvement. But the body was more stable in shoulder mode than head mode.

Based on physiological and psycho-physiological responses and also considering the exiting uneven terrain, the existing work-pause schedule, walking speed, physiological strain index, heart rate variability and the environmental heat load during summer, it was concluded that for women carrying water in head mode on horizontal surface that the load carrying limit should not exceed 18 kg for age group 21-30 years, 17 kg for age group 31-40 years and 15 kg for age above 41 years. In case of shoulder mode, the load carrying limit for WCW should not exceed 12 kg for age group of 21-30 years, 31-40 years, and 41& above years. In case of waist mode for WCW that the load carrying limit should not exceed 10 kg of age group 21-30 years, 31-40 years and 41& above years.

It was also concluded for the scaffolders in head mode on horizontal surface that the load carrying limit should not exceed 27 kg for age group 21-30 years, 22 kg for age group 31-40 years and 20 kg for age above 41 years. In case of shoulder mode the load carrying limit for scaffolders should not exceed 20 kg for age group of 21-30 years, 19 kg for age group of 31-40 years but 14 kg for the age group of 41& above years.

It is concluded from chapter 5 and 6 that if an optimal load carrying limit as has been suggested in this study for industrial/operational workers is implemented in organized and unorganized sectors than the chances of workers getting stuck with the MSDs will be reduced to a greater extent and production rate will be improved because a healthy workers can be more productive than those in poor health. This study will be a boon for the workers and will safeguards their physical capabilities and possible health risks.

In Chapter 7, an expert system was developed for industrial/operational workers continuously involved in carrying load activities. In this chapter an artificial neural network (ANN) model had been developed which can classify
the physiological risk in high and low risk category by considering the factors as carrying load, age, ponderal index, walking speed and working hours.

The developed diagnostic system classified 24 out of 26 cases correctly (92.31%) for male industrial and operational workers and also classified 21 out of 22 cases correctly (95.45%) for female industrial and operational workers. It has been seen that model developed classifies the jobs with greater accuracy compared to the models suggested by few other authors. MSDs are challenging problems and there are still lots of work need to be done in this area. The proposed system provides a faster response and a reduced cost compared to human experts. Such a system could be very useful in hazard analysis and injury prevention due to manual carrying of loads. Results of the study also suggests that LM training is faster than the general delta rule and it needs less input pattern for training than the other one. If larger and more homogenous data sets are provided than it will result in better training of ANN models with smaller errors and biases. So, such type of expert system can be an aid for the ergonomists who work on the prevention of injuries among industrial and operational workers, whose nature of job is drudgery.

Chapter 8 deals with the introduction of Biorhythm theory for preventing industrial accidents. It is predicted that human biological system is affected by three biocycles viz. physical, emotional and intellectual and the ability of human to perform a certain job changes with the change of phase of the biocycles. In the current study, accident prone days were measured in a variety of ways and also a new definition of biorhythm critical days was introduced by the author in this study. In this study biorhythm theory was implemented only in foundry and sugar industry because of unavailability of accidents date in case of WCW and scaffolders. The accident date data and birth date is used for plotting biocurves. The results of the study showed a high correlation in predicting the accidents occurrence in both foundry (67.5% of accidents) and sugar (64.1% of accidents) industries by new definition. Results of the study also confirm that biorhythm accident prone days play a vital role in predicting the industrial accidents.
Analysis of the study demonstrates a strong support of use of the biorhythm theory in the prediction of industrial accidents. Today, many of the workers are involved in manual material handling of objects in the industries so the chances of the workers to get stuck with the accidents are more in such industries due to handling of heavy loads. So, use of “biorhythm theory” can help the ergonomist in predicting the accident prone dates in advance and the worker may not be given hazardous task on those days to ensure safe and productive work.

**Recommendations to the Policy Maker**

The outcome of this research work suggested the following recommendations to the policy maker:

- An optimal load carrying limit as has been suggested in this study for industrial/operational workers is if implemented in organized and unorganized sectors of India than the chances of workers getting stuck with the work-related musculoskeletal disorders will be reduced to a greater extent and production rate will be improved because a healthy worker can be more productive than those in poor health. The Indian factory act should be amended with the following recommendations:
  - The optimal load to be carried by male workers should be up to 25 kg.
  - The optimal load to be carried by female workers should be up to 17 kg.
- The detailed study of work stressors conducted in this study showed a high association with MSDs and a real gender difference was also observed in the male and female workers. So, if the concept of work stressors is implemented in the industries than it will prevent the industrial workers from musculoskeletal problems and increase the production rate. It would be for the benefit of industry and individual.
- Use of Artificial Neural Network could be very useful in hazard analysis and injury prevention due to manual carrying of loads. Because such type of expert system can be an aid for the ergonomists
who work on the prevention of injuries among industrial and operational workers, whose nature of job is drudgery.

✓ The proposed system provides a faster response and a reduced cost compared to human experts.

➢ Today, many of the workers are involved in manual material handling of objects in the industries so the chances of the workers to get stuck with the accidents are more in such industries due to handling of heavy loads.

✓ Use of “biorhythm theory” can help the ergonomist in predicting the accident prone dates in advance and the worker may not be given hazardous task on those days to ensure safe and productive work.

**Future Scope of Work**

Future work will focus on validation of the ANN architecture, and consider utilization of other input variables for the modeling, including different modes of load carrying, individual characteristics of the workers, and the work stressors such as psychosocial variables.