CHAPTER SIX

SUMMARY OF RESULTS AND CONCLUSIONS

The literature review indicates that almost all the research studies concerned with manual materials handling have origin in other countries. Since manual lifting capabilities are functions of the worker's physical conditions and anthropometry and also the environmental or climatic conditions of work, it is probable that the results of those studies may be inapplicable to the Indian conditions and Indian physique. The present study has been undertaken to cater to this need to a certain extent.

The entire research has been carried out in three stages. During the first stage, a series of experiments is conducted on the variables affecting lifting capacity. During the second stage, another series of experiments related to the estimation of metabolic cost of lifting activities is conducted. In the final stage, experiments are conducted to determine and model manual lifting capacity.

In this chapter, the important results and conclusions are summarized.
6.1 SUMMARY OF FIRST SERIES OF EXPERIMENTS

Under the first series of experiments, the variables-type of container (shape), frequency and height level, body twisting and free style lifting posture are investigated. The following is the summary of results.

1. The type of container significantly affects the lifting capacity. Bucket type of container improves the lifting capacity. It has been found that the average increase in maximum acceptable load of lift for the bucket is 9.5 percent compared to the rectangular type of container when both are lifted with handles.

2. Change of origin of lifting does not influence the lifting capacity significantly for lifts up to waist level as indicated by the percentage rise in heart rate.

3. Frequency of lifting has significant effect on the percentage rise in heart rate irrespective of the origin of lifting. That is, with increase in frequency the stress due to lifting (percentage rise in heart rate) increases and hence the lifting capacity will decrease.

4. For low level lift, torso twist does not greatly influence the lifting capacity as indicated by the percentage rise in heart rate. And with change of
origin of lifting from floor, lift with twist becomes more strenuous than sagittal lift.

5. The analysis of articulation torques and the compression force on L5/S1 disc during free style lifting reveals that the peak compression force may be the limiting factor for low level lifting tasks. An equation is developed to predict the adjusted back stress on L5/S1 disc as a function of load lifted. Using this equation the peak compression force on L5/S1 disc can be obtained for any individual knowing his body height and body weight.

From the results obtained the following conclusions can be made.

1. For single man lifting, bucket type of container may be used with advantage over the usual rectangular container, especially when uniform density material is to be lifted.

2. Wherever possible it is better to design the lifting tasks at lower levels. Also lifting tasks should be designed such that heavier loads are lifted at lower frequencies and lower loads at higher frequencies.

3. The equation proposed for predicting the compression force on L5/S1 disc without actually tracing the posture is very useful to determine the lifting capability of an individual for infrequent
lifting tasks provided the limiting value for the compression force on L5/S1 disc is known.

6.2 SUMMARY OF SECOND SERIES OF EXPERIMENTS

A simple methodology is suggested to estimate the metabolic cost of lifting activities under field conditions. The equation developed by Bernard et al is validated for estimating the oxygen consumption of lifting tasks performed at low level. Another equation is proposed to estimate the pulmonary ventilation during lifting activities performed at moderate work levels.

Pulmonary ventilation can be estimated using the proposed equation. And using this value of pulmonary ventilation and the age of the subject, the oxygen consumed by the subject during lifting can be obtained from Bernard's equation.

This procedure eliminates the measurement and analysis of expired air. However, if accurate metabolic information is required, measurement and analysis of expired air is a must.

6.3 SUMMARY OF THIRD SERIES OF EXPERIMENTS

Under this series, experiments are conducted to determine the maximum acceptable load of lift. Models for predicting lifting capacity are then developed for both
single-man lifting tasks and two-men lifting tasks. The models are developed with job specific dynamic lift strength as one of the independent variables. The other independent variables are the individual's age, height and weight. The following is the summary of the results.

1. For single-man lifting two models are developed. The first one is applicable to industrial workers experienced in manual lifting. The second model is developed using student subjects inexperienced for the task. The two men lifting model is developed using industrial workers.

2. There is no significant difference between the maximum acceptable load obtained for workers and students.

3. The average maximum acceptable load for Indian industrial workers is different from those reported in literature, obtained for other populations.

The following conclusions can be drawn from the results obtained in this series of experiments.

1. With a simple measurement of job specific dynamic lift strength, the prediction models can be used for deciding the selection and placement of workers for manual lifting tasks.

2. It is fairly evident that the predictive models and other lifting guidelines as to how much to lift,
carry etc., should be specific for the particular population to which they are to be applied.

3. The parameter, job specific dynamic lift strength introduced in this study correlates better than the job specific static strength parameters used by earlier investigators in obtaining the maximum acceptable load. This parameter is particularly useful for measuring the combined strength in case of two-men lifting together for which the available strength measuring techniques are not suitable.

4. For the Indian industry the following recommendations can be made.
   a. It is preferable to limit single-man lifting load at lower levels to 21.5Kg. and two-men lifting load to 47Kg. These are loads, which nearly half of the industrial worker population should be able to lift without discomfort. If larger loads are to be lifted, the personnel may be chosen on the basis of the predictive models presented herein.
   b. It is suggested to adopt two-men lifting wherever possible. Because, with proper pairing of subjects, with two-men lifting, significantly more load can be lifted per lift compared to the sum of the loads lifted by the two men independently.
6.4 SUGGESTIONS FOR FUTURE WORK

The following are some of the interesting possibilities open for future research.

1. Analysis of posture needs further investigation to confirm the results obtained. Future studies need to use higher experimental loads and also inertial effects of the lifting motions need to be considered. Also, a procedure needs to be developed to determine the allowable L5/S1 compression force for each individual considering his/her capabilities and limitations for performing the task. Then only proper lifting capacity limits for each individual can be developed.

2. Further experiments may be conducted in manual lifting considering all the important variables which affect lifting capacity so that a comprehensive data base and predictive models can be established for use in Indian industries. The effect of training and experience on lifting capacity may be systematically examined.

3. Further investigation may be made on the two-men lifting task. Also, a suitable device may be developed to measure the dynamic strength for two-men lifting tasks.
LEGEND FOR PLATE 1

Figure 3.4  Action of lifting with body twist  
            (frames: 5, 6, 7 and 8)

Figure 4.1 a  Use of respiration gasmeter  
                (frames: 13 and 14)

Figure 4.1 b  Gas analysis apparatus  
                (frame: 15)

Figure 5.1  Action of single-man sagittal plane  
             lifting  
             (frames: 1, 2, 3 and 4)

Figure 5.6  Action of two-men lifting activity  
             (frames: 9, 10, 11 and 12)