CHAPTER- I

METHODOLOGY ADOPTED IN THIS STUDY

A) SELECTION OF SUBJECTS:

(i) The study was conducted both in the organized as well as in the unorganized sectors.

(ii) Among the organized sectors, Heavy Engineering Industry; Steel Mill and Construction Industry were selected for the study. Accordingly the study was done in the following Heavy Engineering Industries: JCL; GRSE; FTS; EEE and AAF.

(iii) The study was done in the following Steel Mills: BICF; TMC and BESCOL.

(iv) One Construction Industry (LT) was chosen for the study.

(v) 100 male workers involved in handling heavy loads were selected randomly from each of the above category of industry as the subjects for this study. In case of steel mills, amongst the numerous workers associated with different types of heavy load handling, only those engaged in handling molten iron manually have been selected randomly as the subjects for this study. In a similar manner the workers exclusively associated with cement bag handling in the construction industry have been randomly selected as the subjects for this study.

(vi) Among the unorganized sectors, Brick Kiln and Central Market Area were selected for the study.
(vii) 100 male workers involved in handling heavy loads were selected randomly from Brick Kiln and Central Market Area respectively as the subjects for this study.

(viii) Another 100 male workers belonging to identical socio-economic strata as that of the subjects of the unorganized sector but of a different profession (not engaged in load handling; they sell raw vegetables in the central market area) was selected randomly as the comparison group for this study.

(ix) There was no pre-determined age group of the subjects. It was observed in the industries of both sectors that a great majority of the workers engaged in heavy load handling fall in the age range of 30-40 years. So the subjects selected for this study were in the age category of 30-40 years.

(x) However all the subjects selected for this study possessed a minimum working experience of at least 5 years in their respective fields.

B) ASSESSMENT OF ANTHROPOMETRIC AND BODY COMPOSITION PARAMETERS:

Anthropometry is the means of quantifying variation in body size and shape. It is one of the most fundamental techniques of human biology. In the present study height and weight of the subjects were measured. The anthropometric measurements were made using standard techniques. The following instruments were used.

(i) Measurement of Height: The height was measured by means of a Martin's Anthropometer made by Martin and Co. Each subject was instructed to stand straight, with the arms held straight along the sides of the body and the ankles or feet together. The anthropometer was positioned behind him so that its lower end stand between the
heels and the beam passes vertically between the buttocks touching the back of the head. The anthropometric blade was brought down on the top and mid sagittal plane on the head and measurement was taken.

(ii) Measurement of Weight: The weight was measured by a Crown weighing machine made by Ramson Surgical Co. The body weight was taken using the weighing machine when subjects were without foot wears.

From the anthropometric data, the following parameters were calculated:

i) Conicity Index (CI) = Waist circumference (m)/0.109 x \sqrt[4]{\text{weight (kg)/height (m)}} (Valdez et al, 1993)\textsuperscript{193}

ii) Body Mass Index (BMI) in kg/m\textsuperscript{2} = Weight in kg / height in m\textsuperscript{2} (Poskitt, 2000; Cole et al, 2000)\textsuperscript{194,195}

iii) Body Surface Area (BSA): The modified Dubois and Dubois formula (Banerjee and Sen, 1955)\textsuperscript{196} was used.

BSA in m\textsuperscript{2} = (weight in kg)\textsuperscript{0.425} x (height in cm)\textsuperscript{0.725} x 0.007466

iv) Waist-Hip Ratio (WHR) = Waist circumference (cm.) / Hip Circumference (cm.) (Valdez et al, 1993)\textsuperscript{193}

C) QUESTIONNAIRE STUDY:

The appeal of questionnaires lies in their ability to obtain large amounts of information from a large number of people, at relatively low cost, and relatively quickly (Wilson and Corlett, 1995)\textsuperscript{197}. Identifications of the prevalence of work related musculoskeletal disorders by means of questionnaires are an important part of the
occupational health service activities. Development of questionnaire is a surprisingly complex and difficult task.

After obtaining consent from the management to carry on the study in their industry and assuring to maintain anonymity, the questionnaire study was performed. Initially each subject who participated in the study was approached by the interviewer for explaining the aim of study in a layman’s term. Only on acceptance from the subject, the interview started on the basis of the questionnaire.

A questionnaire on occupational health was developed on the basis of Modified Nordic Questionnaire (Kuorinka et al, 1987) and was used to carry out this study. It constituted a series of objective questions provided with multiple-choice responses. The questions were arranged and grouped into the following major sections dealing with:

- General working environment;
- Physical parameters of the workers;
- Occupational backgrounds, general health, nutritional status and their addiction habits;
- Detailed questionnaire on the subjective symptoms associated with work-related discomfort and pain etc.

**Occupational Background:** This portion of the questionnaire generally consists of questions on the number of years associated with the present occupation, the general work schedule including duration of work and rest every day, the total number of working hours in a day and number of working days in a week. The overall nutritional status and the addiction habits of the workers were taken into account.

**Subjective Symptoms of MSD:** In this part of the questionnaire the subjects were asked about any ailment they have been suffering from or any kind of discomfort that they felt in neck, shoulder, hands, wrist, elbow, upper back, lower back, or the lower extremity of
the body. The time when the discomfort was felt maximally, whether during work or after work, during sleep at night or all throughout the day, was asked.

D) ASSESSMENT OF PHYSIOLOGICAL PARAMETERS:

The measurement of heart rate during work is a common method to evaluate the cardiovascular strain (Wilson and Corlett, 1995). When a subject is engaged in physical work such as MMH, several physiological responses are affected. These include metabolic energy cost, heart rate and blood pressure etc. Heart rate can be adjusted according to the metabolic need. During sleep it falls and during exercise or during heavy or moderate type of activity the heart rate increases rapidly. So it can be said that heart rate is directly proportional to metabolic rate (Chatterjee, 1987).

According to recent cardiovascular research, detection of blood pressure is a valid indicator of the severity of physical activities. Increase of blood pressure is a natural and biologically useful component of the dynamic changes that an organism undergoes during different situations (Seibt et al, 1998). Guyton (1991) also emphasized that stretching of muscles during different physical activities caused vasoconstriction in muscles leading to restricted blood flow and in turn increased systolic blood pressure. He further reported that pooling of blood in any part of body caused vasodilatation in muscles and thus increased diastolic blood pressure.

The monitoring of blood pressure response is important to ensure the safety of the subject and to provide information on the strength of the cardiac contraction and the state of the peripheral resistance. When the subject begins to exercise, the normal blood pressure response is gradual elevation of systolic pressure with increasing workloads and generally no significant change or slight changes in diastolic pressure (Ellestad, 2000).
During physical activity, blood pressure increases rapidly as a result of an increase in cardiac output. These increases are brought about by both nervous and chemical influences. It was clearly seen that strenuous physical activities affect systolic pressure much more than diastolic or mean pressure. This is due to the fact that during such activities, the resistance to blood flow is decreased. The decreased resistance is the result of vasodilatation of the arterioles of the working muscles (Shaver, 1982)\textsuperscript{145}.

(i) **Measurement of Heart Rate:** A stopwatch (Make: Diamond) was used to measure the heart rate. The heart rate of the subjects was measured before beginning of work from radial pulse for one minute in sitting position and just after work by 10 beats method from the carotid pulse (Astrand and Rodahl, 1986)\textsuperscript{139}.

(ii) **Measurement of Blood Pressure:** Blood pressure may be determined either by direct (catheter) methods or indirect (sphygmomanometer) methods. In this study the measurement of blood pressure was done by indirect method.

The blood pressure of the subjects was measured with sphygmomanometer (Make: Diamond) and stethoscope (Make: Diamond) before and just after work. During measurement of blood pressure, the cuff is placed around the subject’s upper arm and should be approximately at the level of the subject’s heart. During measurement of blood pressure, the stethoscope was held in the right anticubital fossa for auscultation.

Systolic blood pressure is the pressure needed to occlude the brachial artery and it is found by listening (with a stethoscope) to the flow of blood just below the cuff. As the cuff pressure is gradually reduced, the pressure at which the sounds disappear or becomes muffled, is recorded as diastolic blood pressure. Mathematically, the difference between systolic blood pressure and diastolic blood pressure is referred to as pulse pressure.
Postural analysis tools have shown to be a valuable technique for reducing injuries and increasing productivity in different industry (Kivi and Matilla et al, 1991)\textsuperscript{202}. The maintenance of posture and the support of the load are particular examples of static work. To analyze posture measurement of the angles between body parts, distribution of masses of body parts, the forces exerted on the environment during the posture, the length of the time the posture is held and the effect on the person should be taken into account.

One of the earliest whole posture coding system for industrial purpose was developed in Finland to investigate the working posture in a steel company. The company Ovako Oy in association with the Finish Institute of Occupational Health formulated the OWAS (Ovako Working Posture Analysis System) method (Karhu et al, 1977)\textsuperscript{203}. The success of OWAS is a result of several factors including applicability, validity and reliability. The versatility of its posture coding system provides applicability to most working postures.

The purpose of the OWAS was "to provide a system for analyzing and classifying working posture with the aim of developing methods consistent with the promotion of occupational health" (OWAS Manual: Salonen and Heinsalmi, 1993)\textsuperscript{204}.

There were three criteria used in creating the OWAS. Firstly, it could be used by persons who were not specifically trained in ergonomics. Secondly, it would provide non-oversimplified but still unambiguous results. Thirdly, it had to offer possibilities for correcting oversimplified ergonomics information (Karhu et al, 1977)\textsuperscript{203}.

The OWAS code for a posture constitutes a record for the posture itself, considering three body parts, viz., the back, arms and legs that are involved while the
load or force is applied. Thus the work activities can be sampled and from them the proportion of time, during which forces are exerted or posture held can be estimated. The assessment sheet explores the likely musculoskeletal load for a single posture on the back, arms and legs along with the action categories. This enables each posture to be assessed for appropriate remedial action. The final step is to assign a four level action code for task amelioration. The four action codes are defined as follows:

1) No corrective measures.
2) Corrective measures in near future.
3) Corrective measures as soon as possible.
4) Corrective measures immediately.

The OWAS method is based on two parameters: (i) Joint movements of back, upper and lower extremities and (ii) Load or force used while a posture is held. The OWAS codes cover four back postures; three arm postures and seven leg postures. They also include three force categories, with weights from 1 to 20+ kg.

The OWAS codes with their OWAS names are defined operationally as follows:

**Back Posture**

**Back Posture 1**: Straight.
**Back Posture 2**: Bent forward, backward.
**Back Posture 3**: Twisted or bent sideways
**Back Posture 4**: Bent and twisted or bent forward and sideways

**Arm Posture**

**Arm Posture 1**: Both arms are below shoulder level.
**Arm Posture 2**: One arm is at or above shoulder level.
**Arm Posture 3**: Both arms are at or above shoulder level.
**Leg Posture**

**Leg Posture 1:** Sitting  
**Leg Posture 2:** Standing with both legs straight  
**Leg Posture 3:** Standing with the weight on one straight leg.  
**Leg Posture 4:** Standing or Squatting with both knees bent.  
**Leg Posture 5:** Standing or Squatting with one knee bent.  
**Leg Posture 6:** Kneeling on one or both knees.  
**Leg Posture 7:** Walking or Moving. Subject uses his legs to move his body.

**Load/Use of Force**

**Load of Force 1:** Weight or force needed is 10 kg or less.  
**Load of Force 2:** Weight or force is needed exceeds 10 kg but is less than 20 kg  
**Load of Force 3:** Weight or force is needed / exceeds 20 kg.

In this study the OWAS method was applied with the aid of digital photography (Sony Handycam 360X; Model No.TRV76E) for analysis of working postures. Later on stick diagrams were drawn from freezed frame video records and analyzed. The different working postures of the subjects were taken into consideration for further analysis.

**G) ASSESSMENT OF PSYCHOLOGICAL STRESS:**

The assessment of the psychological stress generated at work is carried out by Standard Progressive Matrices (Raven, 1938)²⁰⁵. It is a non-verbal intelligence test designed to assess a person's intellectual and reasoning ability and the ability to make sense of complex data, to draw meaning out of ambiguity and to perceive and think
clearly. It is used to measure the two main components of general intelligence: the ability to think clearly and make sense of complexity, which is known as eductive ability (from the Latin root "educere", meaning "to draw out") and the ability to store and reproduce information, known as reproductive ability. Some of the most fundamental research in cognitive psychology has been carried out with the Raven’s Progressive Matrices (RPM).

Adequate standardization, ease of use (without written or complex instructions), and minimal cost per person tested are the main reasons for its widespread international use in most countries of the world. It has among the highest predictive validities of any test in most occupational groups and, even more importantly, in predicting social mobility, the level of job a person will attain and retain.

The RPM are offered in three different forms for different ability levels and age ranges. They are:

i) Coloured Progressive Matrices (CPM) (meant for younger children, older adults and special groups like the intellectually impaired);

ii) Standard Progressive Matrices (SPM) (meant for persons from 6 years to adults with average ability);

iii) Advanced Progressive Matrices (APM) (meant for above average adolescents and adults for example managers and graduates).

**General Arrangement of the Scale:** In this study the SPM have been used to measure a worker’s ability to form perceptual relations and to reason by analogy independent of language and formal schooling. It is the most widely used RPM. The SPM consists of 60 items arranged in five sets (A, B, C, D and E) of 12 items each. Each item contains a figure with a missing piece. Below the figure are either six (Sets A and B) or eight (Sets C to E) alternative pieces to complete the figure, only one of which is correct. Each of the problems or items within SPM is presented in the form of a sequence of symbolic figures. The subject is required to understand the nature of the relationships within each sequence and select one figure which completes each sequence. By so doing,
the subject demonstrates the degree to which a systematic method of reasoning has been developed.

Each set involves a different principle or "theme" for obtaining the missing piece and within a set the first item is self-evident, the others are roughly arranged in increasing order of difficulty. The term "Progressive" within the test's name refers to the fact that each set of items gets progressively harder, requiring greater cognitive capacity to encode and analyze. To ensure sustained interest and freedom from fatigue, the figures in each problem are boldly presented, accurately drawn and made as far as possible pleasing to look at. The raw score is typically converted to a percentile rank by using the appropriate norms.

The test can be administered to groups, individuals or self-administered. However in this study the individual test (only one subject at a time) is given preference over the group test. A group test is cumbersome because: a) equal attention cannot be paid to all in a group at a time, particularly as in this study a large number of subjects are involved; b) difficulty in arranging a large number of sets/booklets or their photocopies; c) more time consuming and d) confusion and turmoil can easily creep in.

**The Individual Test:** At first the subject appearing for the test was explained clearly that on every page there is a pattern with a part of it left out. He would have to point out, each time, to the correct piece from the pieces given below to complete the pattern. Everyone was given the same series of problems/items in the same order and was asked to work at his own speed, without interruption from the beginning to the end of the series. The decisions were recorded on a separate record form. The score gained by a subject depended on the total number of problems/items solved correctly while working through the series from the beginning to the end. The obtained total score will provide an index of the worker's intellectual capacity (Spearman, 1939). According to the score obtained it is possible to classify these workers as:
Grade I: “Intellectually superior”: If his score lies at or above the 95th percentile score for people of his age.

Grade II: “Definitely above the average in intellectual capacity”: If his score lies at or above the 75th percentile.

Grade II (+): If his score lies at or above the 90th percentile.

Grade III: “Intellectually average”: If his score lies between the 25th and 75th percentile.

Grade III (+): If his score is greater than the median or 50th percentile score for his age.

Grade III (-): If his score is less than the median.

Grade IV: “Definitely below average in intellectual capacity”: If his score lies at or below the 25th percentile score.

Grade IV (-): If his score lies at or below the 10th percentile.

Grade V: “Intellectually defective”: If his score lies at or below the 5th percentile score for his age group.

The workers of both the sectors were asked individually to solve the SPM prior to work and just after the completion of a single work cycle to assess whether their strenuous physical heavy load handling tasks were responsible for the generation of mental stress. This would be evident from the alterations in their scores while solving the problems before and after work and consequently would examine their reasoning or decision-making ability before and after work.

H) STUDY OF WORK ENVIRONMENT OF DIFFERENT SECTORS:

Heat is a serious physical hazard that threatens most workers in the industries. With severe heat stress, there can be a rapid rise in body temperature and heart rate. Drinking water is most important in maintaining workers' health and performance in the
heat. A leading cause of heat illness is dehydration, which reduces the body's ability to disperse heat through sweating. The water needed to replace lost body fluids varies among individuals, and is affected by temperature, humidity, and type of work.

Sutter (1994) suggested that work/rest cycles should be flexible. Even among acclimatized workers, there are differences in work capacity and heat tolerance, and tolerance can vary from day to day. It was suggested by him that rotating tasks should be included when it was possible. Generally rotation among workers must be compulsory in case of heavier tasks, whereas it is also necessary for medium and light work.

Even under conditions of rest, prolonged exposure to hot and humid environments can lead to profound disruption in the body's ability to maintain a stable internal environment for its cell and tissues. Strenuous activities can accelerate the appearance of these harmful effects of heat exposure, not only because working muscles produce heat and thereby add to heat load of the organism, but also because changes in the circulation associated with heavy and strenuous activities tend to decrease the body's ability to rid itself of excess heat (Lamb, 1984).

(i) Measurement of Thermal Load: The WBGT index was calculated for assessing the thermal load at the workplace (Yaglou & Minard, 1957). It is a weighted average of Natural Wet Bulb temperature (NWB), Globe Temperature (GT) and Dry Bulb temperature (DB).

The relative humidity was estimated from a psychometric chart developed by Weksler Instrument Corporation, New York (Tayyari, 1997). For this, wet-bulb depression (i.e.; subtracting mean values of NWB from the mean values of DB) was calculated from mean values and relative humidity was read from the chart, at the intersection of DB (column) and the wet bulb depression (row).
The formulae for calculating WBGT index are as follows:

For outdoors with solar load (under sun shine):

\[ WBGT_{\text{out}} = 0.7 \ \text{NWB} + 0.2 \ \text{GT} + 0.1 \ \text{DB} \]

For indoors or outdoors without solar load (in shade):

\[ WBGT_{\text{in}} = 0.7 \ \text{NWB} + 0.3 \ \text{GT} \]

**Instruments used for Measuring WBGT Index:**

The instrument used in the study is called “Whirling Psychrometer” that houses both the dry bulb and wet bulb thermometers in wooden grooves. A handle is attached at one end, around which the psychrometer can be rotated. The description of its components is as follows:

The Dry Bulb temperature (DB) was measured using mercury in glass thermometer exposed to air. The thermometer must be shielded against the sun and other radiant heat without restricting the airflow around the bulb. For this, the psychrometer was whirled around at a rate of 200-300 rpm.

The Natural Wet Bulb temperature (NWB) was measured using mercury in glass thermometer whose mercury reservoir was covered by cotton wick. The wick extends over the bulb of the thermometer, covering the mercury reservoir about an additional bulb length. ACGIH (1994)\textsuperscript{155} recommended that the cotton wick should be wetted by direct application of distilled water from a syringe, 30 minutes before each reading was taken. Further the cotton wick should always be clean.

The Globe temperature (GB) for radiant heat, was read from a standard mercury in glass thermometer inserted into a 15 cm diameter copper globe (Vernon Globe
Thermometer) whose outside surface was painted with a matte black finish. The mercury reservoir of the thermometer was situated at the center of the globe. The thermometer was hung from a convenient location at the workplace and readings were taken at 30 minutes interval for 2 hours.

(ii) Measurement of Illumination Level: The illumination level of the workplace during working hours was determined by a luxmeter (Make: Lutron).

(ii) Measurement of Sound Level: The sound level at the workplace during work was also calculated by means of a sound level meter (Make: Lutron).

I) STATISTICAL ANALYSIS:

Extensive statistical analysis was done to analyze the data obtained from the subjects of the organized and unorganized sectors as well as from the comparison group. Student “t” test was performed among the workers to find out whether there is any significant difference between any measured parameter for the chosen level of significance ($p < 0.05$) (Das and Das, 2005)\textsuperscript{209}.

A two-tail chi square test of independence was applied to determine whether or not the test item had any significant association with discomfort feeling. The frequencies of paired observations were first arranged into 2 x 2 contingency tables showing the combined distribution of the variables. Yates' correction was applied wherever required. The computed $\chi^2$ were next compared with the critical $\chi^2$ values for the chosen level of significance ($p < 0.05$) (Das and Das, 2005)\textsuperscript{209}. 


A two-tail chi square test of independence was applied to determine whether or not the intellectual capacity had any significant association with before work as well as after work conditions. The observed frequencies (f₀s) were entered into 3 x 2-fold contingency tables and the marginal totals fᵣ (frequency of a row) and fᵣ (frequency of a column) were computed and entered therein. The expected frequencies (fₐs) were calculated and entered in the tables against the respective f₀s. The computed χ² were next compared with the critical χ² values for the chosen level of significance (p < 0.05) (Das and Das, 2005).