REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The chapter presents the review of related literature. The review was undertaken to provide an empirical support to the conceptual and theoretical basis of the study. Various research studies conducted in India and abroad relevant to the study were reviewed to get an idea about what has already been done and what needed to be done. The studies have been chronologically presented under the following subheads:

1 Anthropometric characteristics

2 Physiological cost assessment

3 Postural stress

4 Muscular stress

5 Body discomfort

6 Weeding

2.1 Anthropometric characteristics

The word 'anthropometry' was coined by the French naturalist Georges Cuvier (1769-1832). It was used by physical anthropologists in their studies of human variability among human races and for comparison of humans to other primates. Anthropometry literally means 'measurement of man' or 'measurement of humans', from the Greek words anthropos, a man, and metron, a measure. Anthropometry focuses on the measurement of bodily features such as body shape and body composition ('static anthropometry'), the body's motion and strength capabilities and use of space ('dynamic anthropometry'). Static dimensions are measurements taken when the body is in a fixed (static position).dynamic dimensions are taken under conditions in which the body is engaged in some physical activity. The basic anthropometric measurements of humans include: linear measurements, angular measurements, circumferences, force measurements. Linear measurements include breadth, height and length measurements. These are measured between recognized anthropometric points. Angular measurements are carried between planes and lines that cross the human body.

Static anthropometric data can be translated into dynamic measurements, **Kroemer(1983)** offers the following rules of thumb for the translation:
Heights (stature, eye, shoulder, hip): reduce by 3 percent.
Elbow height: no change, or increase by up to 5 percent if elevated at work.
Knee of popliteal height, sitting: no change, except with high-heel shoes. Increase by 20 percent for extensive shoulder and trunk motions. Anthropometric data is useful for designing things.

Davies et.al. (1980) carried out an anthropometric study of female hand dimensions using 92 subjects belonging to three ethnic groups, Western Europeans (51), Indian (20) and West Indian (21). For the larger measurements i.e. finger tip to elbow, finger-tip to axilla, a meter rule was used and an accuracy of ± 0.5 cm was aimed for. For the hand measurement, i.e. length of hand, width of hand, length of fingers, an accuracy of 0.5 mm was aimed for. For the finer measurements of the fingers, i.e. width of fingers, depth of fingers, a vernier caliper was used and an accuracy of ± 0.25 mm was aimed for. A Lafayette hand dynamometer was used for measuring hand grip strength. A set of 28 measurements was taken. There were no significant differences between European and Indian groups. There were significant differences between West Indian and Indian, and West Indian and European groups

According to the study by **Sanyal (1982)**, conducted on thirty four subjects the body dimensions were linearly related to the stature. The percentiles values were used to design work place layout of a power tiller seat. **Gupta (1983)** also found out linear relationship of stature with other body dimensions.

In order to meet an increased demand for up - to - date data on the physical characteristics of Egyptian women an anthropometric survey was carried out by **Moustafa et al. (1987)**. A set of 44 body dimensions were taken from a sample of 4960 Egyptian female subjects in the age group of 20-55 years.

The subjects were selected randomly and covered all socio-economic, religious and ethnic groups. A specifically designed portable anthropometer and four other traditional anthropometric instruments, a light weight medical weighing scale, a specially treated cloth tape for measuring girths, two calipers of different hinges and two charts were used throughout the survey. Results showed an increase in most body dimensions in the middle years and gradual decline with advancing age. It was found that the average Egyptian women in the age group 30-40 tend to have the largest body dimensions with the exception of elbow height, knee height and waist girth. The environmental conditions also reflected their influence. The women coming from the deserts are light weight and lean while those from the relatively colder regions tend to be heavier and fatter but also taller and larger in most body segments.

Fernendez et al. (1989) conducted an anthropometric survey on female workers at the Daewoo corporation factory in Pusan, the second largest city in Korea. As majority of the equipment used in industry is imported from Japan, Europe, and the USA, therefore anthropometric data was collected as part of a project to modify work stations that utilized equipment from other countries. One hundred and one female subjects were selected using a random number table on the list of all female employees. A set of 23 body measurements were taken for each subject and anthropometric data were compared with three different ethnic groups. The results indicated that the body dimensions of the Korean female are different from the Western and Japanese female. However, the relative body proportions of the Korean female are more like those of the western female than those of the Japanese female.

Considering the need of anthropometric data for proper design of agricultural equipment for better efficiency and more human comfort, an effort was made by **Gite and Yadav (1989)** towards generation of useful data on Indian workers for machinery design. Fifty two dimensions necessary for the design of agricultural equipments were identified and measurements were carried out on 39 male farm workers of the 15- 60 years age group. The subjects covered under the survey were the laborers working in the institute (in the Central India region). While selecting the dimensions, recommendations of the conference on standardization of anthropometric techniques and technology (Hertzberg, 1968) were given the due consideration. A portable stadiometer and a sitting height table having an accuracy of ± 0.2cm were fabricated. Three anthropometric scales of different lengths 0.6m, 1.5m and 2.5 were also fabricated to measure the various dimensions easily and precisely. Internal grip diameter was measured using wooden cone specially made for the purpose. Middle finger palm grip was measured using Inco grip dynamometer of 100Kg capacity and a readability of 1Kg. The collected anthropometric data were analysed to calculate mean, range, standard, deviation and 5^{th}, 50^{th} and 95^{th} percentile values. The study found out considerable variation in the body dimensions expressed as the proportions of stature when compared to the proportions for British people given by (Barkla, 1961). They further reported some similarity in the anthropometric dimensions of the agricultural workers and industrial workers.

Mathur (1990) measured six body dimensions of two hundred subjects. It was found that coefficient of variation for stature, shoulder height, waist height and arm reach varied from 3.66 to 4.87 per cent and for body weight it was 11.06 per cent.

Pheasant (1991) suggested three steps for the collection and use of anthropometric data. These were definitions of user population, establishing of design criteria and deciding of the design limits. According to him, the anthropometric design criteria can be grouped into four categories namely those dealing with clearance, reach, posture, and strength. He also mentioned that the design limit should usually be either the 5^{th} or 95^{th} percentile value of the parameter.

Kumar and Paravathi (1998) measured 14 body dimensions of 15 maize sheller operators. The data were analyzed and three subjects having similar anthropometrical parameters related to maize shelling operation were selected to operate three manually operated maize shellers.

Hasiao et al. (2000) analysed the third national health and nutrition examination survey (NHANESIII 1988-94) data to identify differences in various body measurements between occupational groups in the USA. The analysis of the data showed that the body size or body segment measurements of some occupational groups differ significantly. For example, the mean stature of male agriculture workers (173.3 cm) was found to be shortest among the comparison groups and was nearly 2.5 cm shorter than the mean of all occupational groups combined. Among females, agricultural workers were also shorter in stature with a mean height (159.2 cm) that is 2.8 cm less than all workers combined. The average wrist breadth of agricultural workers was found to be wider than that of other workers. Female agricultural workers also showed significantly larger values for elbow breadth and waist circumference and significantly shorter values for upper leg length. When compared to all occupations, those in protective service occupations had tallest mean standing heights among both males and females (177.7 cm and 166.0 cm, respectively), which were 2 cm greater in males and 4 cm greater in females than all occupations combined category for each respective group.

Geetha and Teewari (2000) conducted an anthropometrical survey of the female workers in Southern region of India. Twenty three body dimensions of 137 female workers were measured and compared with other ethnic groups and with male farm workers of the same region as well. The results indicated that Indian female workers were smaller than British, French, Egyptian and Turkish female workers. Further, male body dimensions were higher than that of female workers.

Karthirval and Ananthaskrishan (2000) measured anthropometrical characteristics of male and female agricultural workers. Forty two body dimensions and strength parameters relevant to the machinery design were identified and measured. Mean, standard deviation, 5th and 95th percentile value were computed. The mean statures of male and female agricultural workers were 164.19 and 156.53 cm respectively.

Kumar et al. (2000) collected anthropometrical data of 12 experienced weeder operators using standard measurement procedures. A total of 13 body dimensions related to their study were selected. The data were analyzed and two subjects having distinct anthropometrical characteristics were selected to operate the weeder.

Yadav et al. (2000) reported significant difference in the body dimensions of farm workers of eastern India, south and central India.

Singh et al. (2003) measured 71 body dimensions of forty eight agricultural workers selected randomly from twenty different villages belonging to three districts of Meghalaya state. The aim was to develop an anthropometrical database useful for farm machinery design. The result indicated average weight of female workers to be about 13 per cent lower than male counterpart whereas average stature of male to be nearly 6 per cent higher than the female. Comparison of the other body dimensions showed that all body dimensions of female workers except chest depth and hip breadth were relatively smaller than male agricultural workers of the state. Comparison was also made for agricultural workers of different north eastern and other selected states of the country.

Viren et al. (2003) measured anthropometrical characteristics of 300 female farm workers from Chattisgarh region during the period of 1999-2000. The subjects were in the age group of 21 to 48 years and 99 body dimensions were measured. Results indicated maximum variation in the body weight of the subjects. It was further observed that the mean value of weight and stature were 49.33 Kg and 156.16 cm respectively. The data collected were compared with the available data of other regions of the country.

Yadav et al. (2003) carried out an anthropometric survey of male and female agricultural workers of Gujarat. Seventy five body dimensions including weight in standing and in sitting posture were measured. Mean, standard deviation, 5^{th} and 95^{th} percentile for each body dimension were computed. The average stature of male agricultural workers was found to be 161.64 cm, and 5^{th} and 95^{th} percentiles were 152.65 cm and 170.62 cm respectively. They suggested that the study was useful as a guide in designing and modifying agricultural and industrial equipments.

Karunanidhi et al. (2004) collected anthropometric data of 100 male and 100 female farm workers. Forty six body dimensions were identified and measured. Mean and standard deviation were calculated for each body dimension. The commonality of both the sexes in the design of implements and machinery was assessed. Mathematical modeling of the body dimensions was done and the relation between standing height and other body dimensions were established. Significant relationship existed between the standing height and other body dimensions of the workers viz., crotch height, sitting height, knee height, elbow rest height, shoulder circumference, over head reach, foot length, sitting eye height, forward reach and chest circumference.

Pharade et al. (2005) carried out a study to collect data related to push-pull strength in seated position of Indian agricultural workers (both male and female workers). A strength measurement set up developed at HESA centre of CIAE, Bhopal was used for the purpose. Data were collected on 920 subjects from different parts of Madhya Pradesh State in Central India of which 604 were male subjects and 316 were female subjects. The mean age, weight, stature and sitting height of the male subjects were 29.6±8.9 years, 51.4±6.5kg, 164.6± 5.9 cm and 84.6±3.2 whereas for female subjects the values were 32.6±8.1 years, 45.2± 7.3 kg, 151.2± 5.2cm and 77.4± 2.9 respectively. The mean values for push and pull strength in sitting posture with left hands (horizontal plane) were 89.2±40.2 N and 106.9±50.0 N for male workers and 55.9±15.7 N and 65.7±13.7 N for female workers respectively. The corresponding 5th percentile strength values are for 23.5 N and 25.5 N male workers and 29.4 N and 43.1 N for female workers. These values can be used for design of control lever operated by left hand on vehicles as well as tractor.

Srivastava and Raverkar (2005) measured 89 body dimensions of 22 female agricultural workers in the age group of 19 to 55 years in the Jabalpur region. The measurements were made in standing and sitting posture and data on necessary strength parameters were also collected. The mean stature was observed to be 154.9±5.92 cm compared to 154.6±6.18 cm in case of West Indian female workers.

Yadav (2005) measured strength parameters of 105 agricultural workers (70 male and 35 female) on 'strength measurement set up' with the help of load cell with digital indicator. Parameters measured included push and pull strength with both hands in standing posture; right hand push and pull strength in standing posture; maximum right leg strength in sitting posture; maximum foot strength; torque strength of both hands in standing posture; torque strength of preferred hand in sitting posture; hand grip torque.

The above studies highlight the importance of collecting anthropometric data while designing or testing tools and machines used by workers. The studies show that anthropometric differences exists among people belonging to different ethnic groups, human beings at different stages of life, men and women, people belonging to different occupational groups, people belonging to different geographical locations. This shows that tool or equipment designed for one particular region will not be so useful for the other region. Tools designed keeping in mind the anthropometric characteristics will not be suitable for use with women. It came to the forefront that there was dearth of studies related to the women anthropometry in India. More rigorous studies need to be carried out on women agricultural workers especially belonging to hilly regions as farm mechanization is very low and most of the agricultural is carried by women using age old farm implements causing a lot of drudgery.

2.2 Physiological cost assessment

Various physiological responses like heart rate, oxygen consumption rate, metabolic rate, body temperature, rectal temperature, blood pressure, and cardiac output have been used for evaluation of human efforts for different operations.

Cotton et al. (1935) found that within ten seconds after the cessation of strenuous exercise the rate of fall of heart rate on an average was about 1.0 beats per minute and after that it declined rapidly.

Phillips (1954) estimated energy expenditure of six women with mean body weight of 55kg during grass cutting and hoeing. The mean energy expenditure was found to be 4.3 and 4.4 Kcal/min respectively.

The work and recovery pulse rates of human beings exercising at different levels of activity have been shown to be of value in judging the intensity and duration of work performed. Because of the linear correlation existing between the oxygen consumption and pulse rate, at least at the beginning of the exercise, it is suggested that pulse rate can be used as an indirect measure in calorimetric studies **(LeBlanc, 1957)**. According to him, the main factors involved in muscular activity fatigue are those concerned with the supply of oxygen to the muscles and the dissipation of heat produced. These two factors are dependent on the ability of the circulating system to adapt itself to body requirements. Since the heart is directly affected by these circulatory changes, its use as an index of fatigue resulting from muscular activity is also suggested.

Lehmann (1958) considered 5Kcal/min energy expenditure rate including basal metabolism a maximum constant level that a worker should be expected to expend. More rest pauses should be provided if the average level exceeds this value. Variation in basal metabolism rate ranged from 1900 to 2400 Kcal/day.

Brown (1961) reported that body weight of the individual had a linear relationship. In dynamic activity the weight of the body itself was considered to constitute the energy load.

Park and Rodburd (1962) found that the excessive bending of leg and abdominal muscles increased the oxygen consumption resulting in increased energy expenditure.

Andrew (1963) studied the relationship between the energy expenditure rate and heart rate for the limbs involved and the kind of dynamic, static or combination of dynamic and static. Significant relationship was not found between the heart rate and energy expenditure during the static and dynamic work.

Banerjee and Saha (1970) observed that higher physiological cost with increase in body weight was expected due to the movement of heavy body concurrently involving greater muscular efforts and consequently higher energy demand.

Brun(1971) graded agricultural activities by men of 57kg based on energy expenditure as moderate (4.4 to 6.5 kcal/min) or heavy (6.6 to 8.7 kcal/min)

Anonymous (1973) stated that the classification of work of average Indian workers should be done on the basis of energy expenditure per unit area of body weight. Accordingly the EER for light to exceptionally heavy work ranged from 42 to 62 and 33 to 55 Kcal/day per kg body weight for men and women respectively.

Wardle and Gross (1977) experimentally examined the physical work of women for extended periods under a variety of situations and concluded that a woman of average stature and weight can perform many jobs requiring hard physical work. Women should not be compared with men in selection for positions requiring light, moderate, heavy or very heavy work. Rather they should be compared with the occupational demands of the position. Eight female college students with a mean age of 19.6 years worked on a treadmill for a work day consisting of eight partially counterbalanced 45 minute periods (one period of light work, two periods of moderate work, three periods of heavy work)followed by a 15 minute rest period. The results showed that mean heart rate was 119.8 beats/minute for light work, 130.0 beats/ min. for moderate work, 139.8 beats/min for heavy work, and 158.8 beats/ min for very heavy work. Analysis of variance showed that the effect of task order on heart rate was non significant. A correlation coefficient between heart rate and energy expenditure was + 0.52, df=62, which indicated that heart rate and work output were linearly related.

Saha et al. (1979) ascertained acceptable workload for Indian industrial workers for sustained physical activity. They defined 'acceptable workload' (AWL) as that level of physical activity which can be sustained by an individual in an 8h working day in an physiologically steady state and which will not cause fatigue or discomfort and it is generally expressed in terms of relative load (RL) i.e. the percentage of maximum aerobic power (VO_{2max}) spent while performing a given task. In activities requiring heavy manual effort, it may be difficult to sustain this effort for longer periods without affecting the health of the individual. Five physically active young healthy workers, aged 20 - 24 yrs were made to run on a treadmill for 8h at different relative loads (RLs) i.e. the percentage of maximum aerobic power (VO_{2max}), viz. 20, 30,40,50,60 and 70 % in comfortable laboratory conditions. A randomized block design was used for experiments of treadmill running on different rates of work to eliminate the effect of training due to previous work rates on the physiological functions. The findings suggested that 35% of an individual's VO_{2max} (RL) may be considered as an 'acceptable work load' (AWL) for sustained physical activity. Beyond this work rate, the circulatory strain was observed to be out of proportion to metabolic work, indicating a state of disturbed 'work equilibrium' and consequent physiological fatigue. At the RL of 35%, the energy expenditure and the corresponding heart rate was worked out to be 18.0 KJ/min (range: 15.2 to 22.0 KJ/min) and 109 beats/min (range: 109 to 115 beats/min) respectively.

Nag and Dutt (1980) studied the cardio-respiratory performance of five subjects in relation to germinating seedlings and threshing. The usual ways of manual operation of the agricultural jobs were taken for comparison with the machine versions of the seeders and pedal threshers. The work with both the IRRI and CRRI seeders was categorized as extremely heavy. Seeding by IRRI seeder was found to be about 8 times more efficient when compared with the manual transplanting operation but the pulmonary demand was about 2.5 times higher than for the manual transplanting jobs. Relatively less physiological cost was associated with higher work output in the case of the CRRI. The operation with the pedal thresher was considered moderately heavy. Compared to manual threshing it had more output. Comparison of pulse rate and blood pressure responses revealed more static muscular activity in pedal threshing than in manual threshing. It was suggested that pedaling a thresher can be so arranged that the rhythmic pattern of work of both legs is facilitated in both a sitting and standing posture; thereby a part of the postural maintenance reflected in the higher oxygen uptake may be reduced.

Nag et al. (1980) determined the occupational work load of 13 male agricultural workers on the basis of cardio - respiratory responses and individual capacity to perform work. Thirty different agricultural operations were observed during the actual working season in the eastern and western part of India during the summer months of April and May. On the basis of severity of physiological responses, (i.e. pulmonary ventilation, energy expenditure, heart rate and the relative cost of the work as percentage of the maximal oxygen uptake), the operations were graded in sequence. The pulmonary demand due to the operations varied from 14 to 41 litres/minute (BTPS). Only three operations (i.e. water lifting, bund trimming in dry- land and pedal threshing) demanded more than 30 l/min pulmonary demand. The oxygen uptakes varied from 0.37 to 1.407 l/min (STPD). Operations such as laddering (by two men) to level the ploughed ground 7.82 kJ/min, fertilizing (9.7kJ/min) and cutting crops (10.25kJ/min) etc. are the lightest jobs, and ploughing (20.96kJ/min), water lifting (22.05kJ/min) bund trimming (wet land and dry land: 23.11 and 29.54 kJ/min respectively), threshing of paddy pennacles using a pedal thresher (27.56 kJ/min etc. are the heaviest jobs in the agricultural work. Unlike respiratory responses, it has been found that there was not much consistency in average work pulse rate response with the severity of work operations as graded on the basis of respiratory parameters. The average work pulse rate ranged from 108 to 153 beats/min in different agricultural work. However, for a large number of operations cardiac responses were less than 130 beats/ min.

It was suggested that a given percentage of maximal oxygen uptake for the particular job being done should be obtained and that it cannot be assessed in terms of percentage $VO_{2\,max}$ obtained from other kinds of work. Since this type of experimentation is of complex nature and will definitely vary from job to job, it will not always be possible to assess the stress of the job based on time consuming experimentation. For assessment of metabolic needs the technique which is more important (i.e. the amount of oxygen uptake for the job) as compared to the maximum oxygen uptake from standard bicycle ergometry, may be used until a less cumbersome technique is evolved which will account for both static and dynamic components.

Nag and Chatterjee (1981) determined the physiological reactions of eight female workers in agricultural tasks and leisure time activities with a view to standardizing occupational workload in relation to energy expenditure, and individual capacity to perform the job under normal environmental conditions. Eight female agricultural workers from the eastern part of India belonging to low socio-economic status were selected for the study which was conducted during the summer month of April. A month-long observation was undertaken to examine the nature of the work. Seventeen operations were noted and subsequently used to estimate the time requirement in different daily activities. The physiological responses of pulmonary ventilation and the oxygen consumption of the workers were measured during actual work, using the traditional open-circuit method. Results indicated that the majority of the tasks performed by the workers were within 33% of VO_{2max}, but some of the jobs classified as moderate and heavy required 39 to 55% of VO_{2max}. Worker pulse rate for some of the moderate and heavy tasks varied from 130 to 152 beats/min. The whole-day energy expenditure of these workers was estimated to be 1061 MJ or 450 kJ less than their total energy intake. About 52% of this energy expenditure was required for the work day; the remainder was expended for the maintenance of postures and other activities. Average energy expenditure rate over the working hours was 11.11 kJ/min or about 28% of VO_{2max} for longer duration, if an increase in productivity was desired. The study found that activities such as standing rest during working hours, pounding helper, and winnowing (sitting) were categorized as light jobs, and pounding alone and digging dry soil using a spade were categorized as heavy jobs. All other operations like harvesting, transplanting, uprooting, carrying loads, etc., were categorized as moderately heavy. It was found that operations like weeding, uprooting, and transplanting, are performed by hand while sitting with legs flexed at the knee. These operations are also carried out in a bending posture, which demands relatively higher energy output than in sitting posture. Since the workers carry out the jobs haphazardly in any of the postures, a suggestion was made by the authors that when work can be done in sitting posture, a bending posture should be avoided.

Grandjean (1982) opined that increase of 35 work pulses can be taken as the limit for continuous performance of male workers.

Pheasant (1991) quoted NIOSH guidelines which stated that the average energy expenditure for continuous work of 8h day should not exceed 33 per cent of the worker's maximum aerobic power. He also mentioned that for men, the mean heart rate during work should not exceed their resting heart rate plus 40 beats per minute.

Tuure (1992) used oxygen consumption, pulse and blood pressure measurement as physiological methods for defining the physical stress imposed by jobs carried out in the farm environment. They selected three jobs viz., making a load of bales, lowering of tomatoes and mechanized loading and transportation of timber. These jobs were selected to represent dynamic loading, static stress and work posture stress. They reported that the stress of dynamic work can be investigated by means of oxygen consumption or heart beat frequency. Furthermore, they opined that static stress also affected heart beat frequency and blood pressure.

Kumar and Parvathi (1998) conducted a study to assess the energy expenditure of women labourers for maize shelling using tubular, modified tubular and operated maize sheller. They compared their ergonomical performance with traditional method of maize shelling. The average energy expenditure for traditional, tubular, modified tubular and hand operated maize sheller was 5.91, 4.97, 6.27 and 5.83 Kcal/min respectively. The work rest analysis showed that the rural woman could effectively for 335 min/day without fatigue using different maize shellers. The work rest ratio was in the range of 2.01 to 3.58.the energy requirement to work with these shellers without fatigue was 2200 Kcal/day.

AICRP Report (1999). It was found that women in different states of India are engaged in various jobs and have to carry the work load ranging from light to very heavy in weight on their head, shoulder, back, hands, etc. They found that in the age group of 21-30 yrs. of age for fetching of water the heart rate increased upto 102.73 beats/ min. For 31-40 yrs. of aged women heart rate increased upto 107.38 beats/min. The energy expenditure was 7.32 KJ/min, 8.41 KJ/min, 11.50 KJ/min, and 12.03 KJ/min respectively. The total cardiac cost of work was 574.43 and 528.80 beats respectively for different age groups.

Aminoff et al. (1999) investigated the physical work load during upper-body occupational work as related to maximal and work task-specific peak values. For this pupose VO_2 and HR measured during work at a conveyor belt in a kitchen were compared to VO_{2max} during two-leg cycling and to VO_2 peak and HR peak during two – arm cranking. The study showed that the relative work intensity is markedly higher when it is expressed relative to the corresponding muscle group's VO_2 peak instead of the VO_{2max}. A similar difference was seen in the HR response. It was suggested that recommendations of acceptable work load.should be adjusted to age, gender and VO_2peak, which determine the amount of active muscle mass, for the particular task rather than to VO_{2max}. When determining the acceptable physical work load, not only the cardio respiratory responses, but also the local effects of dynamic and static postural work must be considered, because in many work tasks the local load on the musculoskeletal system is more harmful than the cardio respiratory one. The study recommended that the physical strain is determined during work by measuring VO_2 and HR simultaneously, and the measured values are related to corresponding peak values.

Bot and Hollander (2000) investigated the validity of the use of HR-response in estimating the VO_2 during non- steady state exercise. A linear relation between HR and VO_2 during both non-steady state leg exercise and non – steady state arm exercise. It was concluded that the estimation of VO_2 by measuring the HR is not limited to steady state exercise. The VO_2 could be estimated from individual HR-VO_2 regression lines during varying non-steady state activities.

Gite and Agarwal (2000) evaluated the ergonomical performance of local and improved sickle for harvesting wheat crop. Six female farm workers participated in the study. Mean value of area harvested per hour were 150.6 m^2 and 158 m^2 for improved and local sickle respectively. The mean ΔHR values were 27 beats/min and 34.3 beats/min for improved and local sickle respectively. The corresponding increase in heart rate per m^2 of area harvested was 11.1 and 13.3 beats/m^2 for local sickle and improved sickle. The difference in mean values of ΔHR/min as well as Δ HR/m^2 of area harvested was significantly lower in case of improved sickle. The data showed that drudgery reduction due to the use of improved sickle was about 16.5 per cent as compared to local sickle.

Karthivel and Ananthakrishan (2000) measured physiological cost of male and female farm workers while performing various rice farming operations. Twenty- four manual rice farming operations were identified. The EER of male workers varied from 2.41Kcal/min. to 4.87 Kcal/min., whereas for female workers it varied from 2.25 Kcal/min. to 3.5 Kcal/min. Most of the rice farming operations performed by the male agricultural workers were graded as "moderately heavy". Male workers consumed 2 to10 per cent more energy for performing the task as compared to female workers.

Kirk and Sullman (2001) examined the physical strain experienced by cable hauler choker setters, and the applicability of heart rate indices for measuring physical strain in commercial forest harvesting operations in New Zealand. The study showed that heart rate indices can be used as an effective means of determining the physiological strain of subjects in applied field situations.

The use of heart rate indices gives the ability to cross- reference results to obtain an overall assessment of the workload of task. The ability to collect real time data from a working subject with minimal personal discomfort or disruption to their normal work routine ensures the collection of accurate and relevant data. The ease and speed of data interpretation ensures that results can be quickly and effectively used to aid decision making.

Wu and Wang (2002) established the relationship between maximum acceptable work time (MAWT) and physical workload. MAWT was defined as the time from the onset of the test until the subject's heart rate (HR) was ten beats/min higher than the steady – state HR during the initial hours of work. Twelve volunteer individuals (six males, six females) were chosen as subjects. They were untrained healthy Taiwanese with ages ranging from 20 to 30 years. They performed cycling tests at six different work rates relative to personal maximum working capacity. The findings showed that MAWT was significantly negatively correlated with the relative aerobic strains (% VO_{2max}, RHR, RVO_2) with an exponentially decreasing relationship. The study suggested following workload limits for 12, 10, 8 and 4h of work.

Table : 2.1 Workload limits (Taiwanese population, mean age 26 years)

Work time (h)	$\%VO_{2max}$	RHR	RVO_2
12	28.5	16	18
10	31	20	21
8	34	24.5	24.5
4	43.5	39	35.5

Hasalkar et al. (2004) analysed ergonomically the workload of the maximum drudgery involved farm activity i.e. weeding through the heart rate method. Thirty healthy rural women performing the weeding activity regularly, not pregnant and mot having any major illness were selected for the study. Every respondent was tied the heart rate monitor and switched on to record the heart rate at every minute. Five minutes rest was given to record the resting heart rate. Then they were asked to do the weeding activity for 20 minutes and then again five minutes rest was given. After a total time of 30 minutes the heart rate monitor was switched off and removed. Two replications of each respondent's weeding activity were taken for the study. Weeding was performed with the traditional weeding tool-kurpi weighing about 250 gms and weeding was dine in squatting position by applying the push-pull pressure by the hand. The average resting heart rate recorded was 80.21 beats per minute, while performing weeding it was 94.36 beats per minute and during recovery period it was 82.27 beats per minute. The average energy expenditure was 4.03 kJ/min, 6.28 kJ/min and kJ/min respectively during rest, weeding and recovery. Total Cardiac Cost of Wok for the whole day (8 hours), for weeding activity was 6162.87 beats and the average Physiological Cost of Work during weeding was 14.67 beats/min. It was concluded that though this activity is performed for maximum number of days in a year, continuously from morning till evening in squatting position women perceived it as light to moderately heavy activity. The heart rate responses showed that the activity is a light activity. Though the activity is light, women feel it as a maximum drudgery prone activity because of its monotony in performance, continuous squatting posture and performing it for a longer period of time.

Singh et al. (2004) evaluated a commercially available fertilizer broadcaster with eleven farm women workers to assess its suitability for farm women. It was found from the ergonomical study that the mean work heart rate and ΔHR was 146.7±13.3 beats/minute and 65.4±18.8 beats/minute, respectively with its full hopper capacity (9 kg urea). Higher work rate and ΔHR indicated the need of refinement in the present fertilizer broadcaster to make suitable for farm women. The effective field capacity of the broadcaster was found to be 1.15ha/h. based on the ergonomical study, anthropometric data and feedback received from the subjects, the refinement in the hopper capacity, total height of broadcaster, height of crank handle, cushioning on back portion etc, was proposed.

Vinay and Sharma (2004) studied the physiological workload of farm women while performing selected home, farm, and allied activities. Thirty farmwomen belonging to Tarai and Bhabhar agroclimatic zones of Udham Singh Nagar district of Uttaranchal state were selected for the study. The activities were fetching fuel, collecting fodder, milking, weeding, and fetching water. The study concluded that all these activities are heavy and induce fatigue in some or the other way. The results revealed the average heart rate while fetching fuel, collecting fodder, milking, weeding and fetching water to be 140.34, 118.71, 108.16, 103.57 and 96.25 beats/min respectively. The corresponding energy values were13.58, 10.1, 8.2, 7.74, and 6.58 kJ/min for the respective activities. The measures suggested to reduce drudgery included the introduction of suitable tools for the operations demanding high energy to enhance human comfort, effectiveness, increase in production and quality of life, the introduction of a revolving stool for milking the animal designed and developed by AICRP-FRM, G.B.Pant University of Agriculture &Technology, Pantnagar, use of water trolley for fetching water, and a work rest schedule to reduce fatigue.

Wu et al. (2005) investigated complete recovery time (CRT) after exhaustion in high intensity work. High intensity work was defined as any physical activity that mobilizes contraction of large muscle groups and requires oxygen uptake (VO_2) of at least 50% of the maximum oxygen uptake (VO_{2max}). The complete recovery time was defined as the rest period that makes an individual no longer perceive fatigue or to allow VO_2 and HR return to their resting levels (baselines), whichever is longer. Twenty four untrained healthy young volunteers (with a mean age of 23 years), 12 males and 12 females were recruited. They were divided into two groups based on the cardio respiratory capability index, which was measured in a maximum capacity test. Each subject then performed two cycling tests (at 60% and 70% maximum working capacity). The subject continued cycling until exhaustion in each test and then sat recovering until he she no longer felt fatigue of until the oxygen uptake (VO_2) and heart rate (HR) returned to their baselines, whichever was longer. The experimental results indicated that heart rate (HR) recovery time (about 28 min) was significantly greater than VO_2 recovery time (about 17 min). Since HR recovered most slowly after exhaustion in high – intensity work, it was considered as the CRT. The CRT was significantly correlated with the cardio respiratory capability index and the relative workload indices: RVO_2 and RHR. The RVO_2 was the average elevation in VO_2 during work from the resting level as a percentage of maximum VO_2 reserve. The RHR's definition was similar to that of RVO_2. two functions for predicting the CRT with RVO_2 and RHR – based prediction model, the CRT for a high- cardio respiratory – capability person as 20.8, 22.1, 23.4 and 24.7 min at 50,60, 70 and 80% levels, respectively. For a low- cardio – respiratory capability person, it was suggested to keep CRT greater (about 10 min. more) than that for a high - cardio respiratory - capability person. These results are convenient and useful in determining sufficient recovery time after exhaustion for a high intensity work task including mainly lower limb muscular efforts such as rapid and prolonged walking of climbing stairs.

Hasalkar et al. (2005) assessed the workload of women during groundnut decortication using traditional method and two new groundnut decorticators. The one was sitting type developed by CIAE Bhopal. And the other was standing type developed by TNAU and modified by UAS Dharwad. Ten healthy women between the age group of 25-45 years, without any cardio-respiratory problems were selected for the study. Heart rate was measured to estimate the physiological workload of the farmwomen. The experiment was designed for 20 minutes and 30 minutes duration. Two replications were made. It was found that the average working heart rate in both the improved technologies was higher compared to the existing method of decortications. The comparison between 20 minutes and 30 minutes of decortication activity showed that the average working heart rate for 30 minutes duration to be significantly higher and above the acceptable working heart rate limits compared to the average working heart rate for 20 minutes duration. The work output of the standing type model was observed to be highest among all the three experiments. In all the three methods of groundnut decortication, the work output for 30 minutes activity was lower compared to the 20 minutes of activity. It was therefore recommended that the standing type groundnut decorticators can be used for decortication work with five minutes rest period after ten minutes of activity, and it gives maximum output in lesser time.

Mohanty and Satapathy (2005) studied manual threshing operations of paddy in Orissa. Fifteen female subjects in the age group of 18 to 45 years in OUAT central farm were selected on the basis of the anthropometrics data.

Their heart rate, blood pressure, maximum aerobic power and oxygen consumption were measured in the laboratory at rest and work. Maximum aerobic power of the selected female subjects was observed to be in the range of 1.56 to 1.81l min^{-1}, which decreases with the increase in age of the subjects. Body mass index was observed to be in the range of 18.4 to 22.4kg/m^2. Oxygen consumption rate at rest was in the range of 0.16 to 0.23 l min^{-1} which also decreases as the age of the subject increases. Average working oxygen consumption rate was noticed to be in the range of 0.86 to 0.91 l $min^{-1}$for all workers. The corresponding average working heart was found to be in the range of 123 to 139 bpm for female workers. The work pulse was found to be in the range of 52.0 to 66.7 bpm for above female agricultural workers. Maximum continuous working time for female agricultural workers observed to be 49 minutes operated by double workers against 34 minutes by single worker. Number of strokes per minute for female worker was noticed in the range of 95 to 104. The output of the thresher was observed to be 32 to 40 kg/hr.

Gandhi et al. (2005) designed and tested cot bag for cotton picking activity in order to prevent musculoskeletal disorders which occur due to the traditional method of cotton picking. The cot bag was further modified for picking of other crops also and was named as pick bag. Pick bag was tested on 30 women respondents for 60 min of cotton picking activity. During experiment time and activity profile, physiological stress and biochemical stress were studied. Pick bag resulted in 20.4 per cent more cotton picked. Hence production per minute was more with pick bag (96.6gm) than existing cot bag (78.3gm). Pickbag reduced the physiological stress as peak heart rate recorded was lesser by 2.2 per cent than the existing cot bag, consequently, resulting in decrease in energy expenditure (2.6%),TCCW and PCW (2.8% each).

Satapathy et al. (2005) evaluated three makes of self propelled reapers in Central farm of Orissa University of Agriculture and Technology, Bhubaneswar with male and six female subjects in the age group of 20- 40 yrs. Their heart rate, oxygen consumption, body parts discomfort score were measured and actual field capacity, grain loss percentage and cost of operation were computed for selecting the best reaper. Safety during operation involving fear during operation, noise due to machine during operation and unbearable vibration of the machine were compared by opinion survey. Heart rate of male operators varied in the range of 125.6 beats per minute to 137.6 beats per minute in comparison to female subjects having 122.6 bpm to 135.6 bpm. Oxygen consumption of female operators varied from 0.7 ltr/min to 0.87 ltr/min as compared to male operators in the range of 0.8 ltr/min to 1.03 ltr/min. body part discomfort score varied from 66.0 to 81.0 for male subjects and from 63.0 to 77.0 in case of female subjects respectively. Actual field capacity varied from 0.15 ha/hr to 0.24 ha/hr for male subjects and female subjects could not complete operation. Cost of operation varied from Rs. 678/- to Rs. 1017/- for three different reapers against Rs.1590/- /ha in manual harvesting of rice crops.

Singh et al. (2005) carried out ergonomical evaluation of sowing of maize crop by the traditional method and with seed drill was carried out to evaluate the energy expenditure, cardiovascular load and cardio-respiratory stress in its use. Four subjects were selected for the study. The energy expenditure rate due the conventional method and using seed drill were 11.15±1.90 and 21.19±2.42 kJ/min, respectively. The relative cost (%VO_{2max}) of conventional and seed drill method was 27.8±0.048 and 53.05±0.060%, respectively. Sowing with both the methods was categorized as moderately heavy. The mean output in case of conventional method was 0.065kg/1000 beats where as under sowing with seed drill was 0.309 kg/1000 beats. The average of 485% increase in productivity over conventional method was achieved by using maize seed drill. Thus under hill condition seed drill proved to be superior to conventional method for sowing of maize in respect of physiological cost of operation.

Posture stress

According to **Kendall (1993)**, in 1947 the American Academy of Orthopaedic surgeons defined poor posture as "a faulty relationship of the various parts of the body which produces increased strain on the supporting structures and in which there is less efficient balance of the body over its base of support." In

1949 they defined good posture as "that state of muscular and skeletal balance which protects the supporting structures of the body against injury or progressive deformity irrespective of the attitude (erect, lying, squatting, and stooping) in which these structures are working or resting. Under such conditions the muscles will function most efficiently and optimum positions are afforded for the thoracic and abdominal organs" (cited in Allen, 2000).

According to **Grieve and Pheasant (1982)**, postural stress is the term used to denote the mechanical load on the body by virtue of its posture. Posture may be defined as the average orientation of the body parts, with respect to each other, over a period of time. Under the influence of gravity, postural stress becomes an important part of the total mechanical stress. In order for the body to be stable, the combined center of gravity (COG) of the various body parts must fall within a base of support (the contact areas between the body and the supporting surface). When one is standing, the weight of the body must be transmitted to the floor through the base of support described by the position of the feet. The alignment of the body parts must be maintained to ensure continuing stability, and it is the maintenance of posture that much stress arises.

Orthopaedic research on sitting posture has revealed the valuable information of possible relations between frequent complaint of pains and pathological degeneration of the discs in the spine. According to **Nachemson and Elfstrom (1970), Anderson and Ortengren (1974), and Nachemson (1974)** the pressure on the discs is considerably increased when the trunk is bent forward when compared with standing in an upright position. Further, it was noted that the intradiscal pressure is higher in the sitting than in the standing posture. In their opinion this is certainly due to the turning mechanism of the hips in the sitting position, which produces a kyphosis in the lumbar region of the spine. Therefore, the increase in intradiscal pressure must be considered as an unnecessary load and strain on the disc promoting pathological changes when the knees are straight and the back bent. The intradiscal pressure is about three times as high when compared with the correct way of lifting a load i.e., by keeping knees bent and the spine straight. The pressure in the discs in various sitting postures is low in a relaxed position. Also, in the writing position, with the arms lying on the table, pressure is lower than in the typing position where arms have no support. The highest disc pressure is recorded when a load is held with outstretched arm.

Gary, Hansen and Jones (1966) found that small changes in sitting and standing posture have a significant effect on neck muscle tension. Three postural images viz., most comfortable, best and greatest height were measured in terms of changes in angles between head and trunk and in the differentiated activity in the muscles of stern mastoid and upper trapezius. These postures were distinguished from each other with a high degree of statistical significance.

Gschwend (1969) and Schoberth (1962) opined that the final shape of the spinal column depends on the aggregate of all the postures during its growth. They considered that, sitting for long periods deprives the body of the alternation of stress and relaxation, and as a result the correcting forces remain undeveloped. The authors suggest that it is not so much the postures themselves as the lack of corrective movements that leads to chronic defects.

Astrand and Rodahl (1970) have pointed out that the return of the venous blood to heart is reduced in a bending posture. Consequently the cardiac output decreases and there is and increase in the heart rate.

Brantingham, et al. (1970) reported that the primary occupational symptoms and diseases related to prolonged constrained standing are pain, discomfort, fatigue, swelling of the lower extremities and foot, due to blood pooling and varicosities of the lower extremities.

Corlett(1981) showed adoption of poor working postures in order to perform tasks could lead to postural stress, fatigue and pain, which may in turn force the operator to stop work until the muscles recover.

Westguard and Aaras (1984) studied that posture is important to the comfort of all people at work. A poor posture becomes a hazard to health and safety in two main situations: in tasks, which are static in nature and involve maintaining the posture for relatively long periods; and in tasks, which involve the exertion of force. In the first situation, the postural loads on muscles and joints can lead to muscular fatigue, pain and in long term to cumulative physiological changes and injury. **(cited in Haselgrave,1994)**.

Astrand and Rodahl(1986) stated that the feeling of fatigue is also a physiological warning signal and neglecting this signal may have harmful consequences for the muscles.

According to **Gallagher and Bobick (1986)** in kneeling postures lower back strength reduces because the strong leg muscles could not be used to aid the back muscles (**cited in Haselgrave, 1994).**

Giland and Kerschenbaum(1988) investigated back pain across a spectrum of jobs. More back pain was found in groups who worked in unusual body positions or with the trunk flexed laterally or forward in standing of sitting.

Varghese et al. (1989) reported that a good working posture reduces the physiological cost of work and fatigue to the minimum, whereas static muscular efforts and incorrect postures for long periods during household activities can damage the inter-vertebral discs. They also reported that since the standing type of kitchen are common in urban homes, it is recommended that if a combination of sitting, squatting and standing postures are adopted for some of the selected activities like chopping, grinding etc, work and energy cost could be minimized to a great extent.

Green, Briggs and Wrigley (1991) reported that elevation of the shoulders in occupational tasks is sure to cause pain in the neck and shoulder. So, the authors have opined that the position of the upper limbs is also important in any analysis of the working posture.

Haselgrave(1994) reported that posture is as important for the performance of tasks as it is for promoting health and minimizing stress and discomfort during work. He also states that posture therefore arises from the functional demands of vision, reach, manipulation, strength and endurance and is constrained by the geometric relationship between the person's own anthropometry and the layout of the workplace. **Haslegrave(1994)** also reported that the geometrical or anatomical measures which can be used to record posture, and which define posture parameters, are suitable for the analysis of workspaces and of biomechanical loading under postural and external forces. However, the functional and geometrical aspects than need to be combined when designing the layout of work places or assessing the appropriateness of postures adopted during work tasks.

De looze et al. (1994) reported that different aspects of working body posture are considered to be related to specific injuries:for instance, the need to bend the torso is generally considered to be and important factor in low back pain(Tannii et al.,1985; Troup 1984), repetitive of prolonged elevation of the arms above the shoulders is thought to be related to shoulder injuries (Hagberg,1982), knee injuries could be related repeated or prolonged knee flexion(Bejjani et al, 1984). If such injuries are to be prevented, these particular postures should be avoided as much as possible. To this end the frequency of their occurrence should be assessed in normal tasks (Colombini, 1985).

Kuorinka et al. (1994) reported that the prevention of low back pain is an important task from the standpoint in economics and individual suffering (Kelsey and golden, 1988). Although no philosopher's stone has been found to prevent back disorders in the working environment, it seems that ergonomic improvement (Snook, 1988) and the involvement of the affected individual (Nachenson, 1983) are useful elements in the prevention of LBP and in minimizing the negative consequences. These elements call for the application of the principle of participatory ergonomics.
Methods for recording postures:

Murali et al. (2004) assessed the angle of postural deviation of body of 30 women while performing the selected farm activities using traditional methods and improved tools. A sample of 30 healthy women was randomly selected from 6 villages of Parbhani district for the study. Slight variation in the angle of body bend at cervical and lumber region of women while performing the selected activities using traditional and improved tools was found. However, the correlation between angle of body bends and heart rate and perceived exertion was non-significant for most of the activities except the activities of seed treatment, chaff cutting, decorticating and stripping of groundnut.

According to **Poddar et al. (2004)** the discomfort has got direct effect on the postural sway of a person. The variation of postural sway can be identified by measuring the displacement of center of pressure (COP) of a person. The COP actually reflects the position of center of gravity (COG) within a plane parallel to the support surface. An important understanding of postural sway follows from the interpretation of COP fluctuations. Ten subjects volunteered in the study. Kistler force platform & 4 infra-red cameras were used for the experiment. Each subject was asked to sit bare foot on a chair placed on the platform adopting different postures with their eyes open & eyes closed condition. The observation revealed that there was significant change in the COP motion in different sitting postures. As the postural sway is controlled by the central and peripheral nervous system, a difference in COP during eyes open &eyes closed condition during the person adopting same sitting posture.

Chantia (2005) revealed the correlation between work posture and health. Forty one lady teachers of SJNPG College, Lucknow were interviewed ethno methodologically to know their health problems. The study exhibited an idea about difference between male and female postural problem which can be improved by ergonomics.

Bhattacharyya et al. (2005) assessed the postures assumed by workers in tea cultivation in Assam. A total of 120 (60 male and 60 female) workers were selected. Majority of the respondents found the postures uncomfortable while performing pruning (95%) and digging (93.33%). Cent per cent females found the postures uncomfortable while performing manuring and pruning. The most comfortable posture reported by female workers was squatting on pidra while doing stalk picking (92.85%) and sorting activity (86.71%). The angle of deviation from the normal posture was found to be highest in manuring and digging for both male and female workers. A negative correlation was found between the body mass index and the severity of the musculoskeletal problems and the perceived exertion as well. It was thus concluded that higher the age of the respondents higher the perceived exertion and the severity of the musculoskeletal problems faced.

An analytical approach using artificial neural network was developed by **Tewari et al. (2005)** developed to predict comfort to the operators of self-propelled rice transplanter. Vibration intensity of the rice transplanter and oxygen consumption rate of the operator was undertaken as input parameters for the model. Work related body discomfort scores of the operators were taken to validate the output of developed model. An experiment was conducted to generate input parameters in actual field at Indian institute of Technology, Kharagpur, India. The study showed that the extent of discomfort could be represented at four different levels where a certain index is utilized or defined to give a range of the amount of discomfort felt. With a certain training data, the level of discomfort could be predicted for a physical parameter without knowing the exact relationship between them, with an error of 4%.

Sandhu et al. (2005) recommended that woman of 35-45 years weighing between 52-57 kg, having physiological parameters within permissible limits and average fitness level can lift weight safely 12±2 kg while standing. If she has to work in sitting posture then she can only only lift upto 3 kg ± 0.75kg safely without exposing herself to any extent to any health hazard.

Kuijt- Evers et al. (2005) identified groups of descriptors that predict comfort and discomfort in using hand tools. The comfort questionnaire for hand tools (CQH) was developed on the basis of the results of previous study by kuijt – Evers et al. 2004, where a list of descriptors that hand tool users associate with comfort and discomfort was defined. A convenience sample of twenty healthy volunteers, who were frequent users of screwdrivers, was obtained by approaching visitors of a do-it- yourself (DIY) shop and employers of TNO work and employment. Four screwdrivers were evaluated on comfort (expected comfort at first sight and comfort after short time use) using the CQH and discomfort (local perceived discomfort. The results of the study showed that comfort in hand tools can partly be predicted from adverse body effects which determine discomfort but the best predictors of comfort are descriptors of functionality and physical interaction. Therefore, when hand tools are evaluated on comfort, not only discomfort should be measured, but also aspects of functionality and physical interaction should be taken into account. The study further suggested that in order to design hand tools that provide more comfort, designers have to focus on functionality and physical interaction and avoiding discomfort. Aesthetics is especially important to expected comfort and can play a major role in product- buying decision. A comfortable screwdriver should be easy to use and functional. Additionally the handle should feel comfortable and should provide a low grip force supply.

2.4 Muscular stress

Nag et al. (1980) studied thirty agricultural operations on 13 agricultural workers and observed that much of the agricultural work involved varying degrees of static components in dynamic work. Static components were involved in grasping and holding tools and in postural control of trunk and head in work in awkward postures. Work with a mixture of static–dynamic components yielded a disproportionately high heart rate response in contrast to other physiological responses, such as pulmonary ventilation and oxen uptake, which are more related to the rhythmic component of work.

Grandjean (1982) stated that muscular effort produces a troublesome fatigue in the muscles concerned. This could build an intolerable pain. According to him, when the muscular effort is less than 15-20 per cent of the maximum, blood flow is normal but gets contracted in proportion to the force exerted, thereby causing muscular discomfort.

Sakai et al (1993) reported that agricultural work has resulted in an increase in size of female labour forces making it more than 60% of the population engaged in agriculture. There is a considerable muscular work load in women's job and this causes various health problems of the women farmers. Results of the study also showed that backache was prevalent among most of these women.

Xianing et al (1999) found that back pain is an occupational health problem among farmers on small operations of family farms. A total of 194 farmers (26.20 per cent) reported to have at least one episode of back pain lasting for one week or more. Lower back pain was the predominantly affected part of the body in 45.40 per cent of males and 43.90 per cent of females. Back pain was brought on by repeated activities.

AICRP (2001) conducted a study on dibbling activity. Muscular stress (grip fatigue) of the respondents of two ages groups i.e. 25-35 years and 36-45 years and were measured. Findings of the study indicated that average grip strength of the respondents during dibbling was highest amongst younger age group as compared to older age group. Percentage change in grip strength (muscular stress) after dibbling was higher among older women. These changes were higher during the work performed by left hand than right hand of the older women.

Kugler et al. (2001) concluded that walking, a higher degree of muscle activity and greater muscle enhance venous emptying if the healthy human leg. Conversely, impairment of joint mobility reduces the efficacy of the muscle - vein pump. They opined that body height and weight significantly influence venous pressure physiology under both resting and activity related conditions.

Oberoi et al. (2006) assessed the muscular stress of rural women while performing different household, allied and farm activities with the use of traditional as well as improved tools. The selected drudgery prone activities were cleaning of animal shed, mud plastering of house, milking of animals and weeding. The muscular stress was measured in terms of four parameters i.e. frequency of postural change, decrease in grip strength, angle of deviation of backbone and the incidence of musculoskeletal problems of farm women while performing the selected activities.

Authors observed that with the use of improved tools for performing the selected activities there was a significant reduction in the angle of deviation for milking of animals as well as for mud plastering of house. Angle of deviation was also reduced for cleaning animal shed while using selected improved tools as well as weeding with the use of weeder. Data indicated that the use of improved tools for performing the selected activities reduce the angle of deviation of the back and minimize the muscular efforts to perform the task. Lower muscular efforts lead to lower muscular fatigue.

Grip fatigue for the selected activities was measured in terms of percentage reduction in grip strength. More the reduction in the grip strength, more was taken as the grip fatigue for the selected activities. The decrease in grip strength was less with the use of improved tools as compared to traditional tools in all the activities except weeding with the use of weeder. The grip fatigue with the use of weeder was found more because of its uncomfortable handles and inappropriate handle dimensions.

It was further found that with the use of improved tools pain was reduced in neck, shoulder, upper back, elbow, upper arm, knees, wrist/hands, calf muscles etc except with the use of weeder and improved tools for cleaning animal sheds which increased the pain in shoulder, upper back, elbow, wrist, hands and lower arms. It was concluded that use of the improved tools is beneficial and more and more women should be motivated to use these improved tools for reducing their drudgeries in work.

Hasalkar et al. (2007) investigated the postural stress and musculo-skeletal problems of the farm women while performing top dressing of fertilizer activity. This activity is performed in standing posture for the field crops like wheat, paddy etc, where the fertilizer is broadcasted by hand. Women carry the fertilizer either in iron/plastic baskets or tie the fertilizer filled cloth bag to waist and apply the fertilizer near the root of the each plant in bending posture in commercial crops like chilli, Tomato, cotton etc. An improved technology for performing this activity was introduced and both the methods were ergonomically evaluated. AICRP-FRM of UAS, Dharwad has developed a handy trolley to carry the fertilizer for top dressing of fertilizer to the root of the crop in the field. The trolley has three wheels and weighs 5.00 kg. It has a circular stand at the top to hold the fertilizer basket. It can be easily pulled with the chain in the field while performing the activity. The trolley can carry about 10 kgs of fertilizer at a time. Thirty subjects with normal health, without any major illness or cardio-vascular problems were selected for the study. Pain in musculo-skeletal system was recorded by showing the Corlett and Bishop (1976) body map to the subjects and asking them to identify the region of any pains/aches in the body parts after the performance of the activity by traditional and improved methods. Five point scale ranging from very mild pain (1) and very severe pain (5) was used to quantify the stress on muscles used in work. Grip dynamometer was used to measure the strength of grip muscles before and after performance of the activity. It was measured separately both for the right and left hand and the percentage change in grip strength was calculated. The decrease in percentage of women (91.42%) complaining the shoulder joint was observed when top dressing of fertilizer activity was performed with the improved technique as the fertilizer load was shifted from shoulders to the trolley. Similarly 75 per cent, 47.83 per cent, 72.72 per cent and 68.85 per cent decrease in percentage of farm women experiencing pain in upper arm, low back, wrist/hands and knees respectively was found when they performed the top dressing of fertilizer activity in improved method compared to traditional method. The percentage reduction in grip strength was observed to be lower in improved method compared to traditional method.

2.5 Body discomfort

Van Wely (1969) discussed the relationship between inadequate work postures and pain. He postulated 11 commandments for a better equipment design; he suggested that dynamic forces should be kept less than 30 per cent of the maximum force.

Chaffin (1971) reviewed the problem associated with either sustained or often repeated contractions of specific muscle according to him, sustained muscle exertion can lead to discomfort and thereby decrease the performance.

Corlett and Bishop (1976) defined the overall level of discomfort felt by women as a summation of all individual sensation via the various sense channels and suggested a technique to quantify the discomfort.

Agrawal et al. (2005) studied pedal operated paddy thresher to describe the effects of workstation adjustment (pedal movement) with respect to the working posture. In pedal operated paddy thresher, widely used in eastern India for threshing activity, operator needs to pedal at 75-80 cycle per minute to keep cylinder rotating and simultaneously feed the crop for threshing. The pedal positions and its range of movement in the fore/aft direction affect the possibility of standing nearer to or farther from the thresher thereby affecting the posture. The various body joints and their movement with respect to the thresher at different range of pedal movement was recorded using digital camera. The body joint movements were recorded using seven joints marked on human body in saggital plane and was analyzed by segregating the frames of the continuous video stream. The body dimensions of subjects and range of pedal movement were found to have considerable effect on the joint movement pattern and angular displacement of limbs of various subjects. Highest body joint movement was observed at knee joint and ankle joints since the implement is leg operated.

Electromyography (EMG) was recorded for the workers involved in lifting wheat bundles and bhusa by **Singh and Maheshwari (2005)**. Dynograph recorder was used to record EMG signals from the four different muscles selected i.e. neck, right deltoid, left trapezoid and right erector spinae. These muscles are mainly involved in the process of load carrying. The muscles were selected by activating them. The subjects were then prepared for EMG.

The desired muscles were first identified over the skin surface by developing the contracture and were marked by sketch pens. Muscles with an inter electrode spacing of 1-2cms. The signals stored in the tape recorder was later on analysed for the root mean square values by using logic signal analyzer. Acceptable loads were then determined for both the activities, 5 subjects of wheat lifting and 5 subjects of bhusa lifting were brought to the lab. General information regarding B.P., hemoglobin content, weight, height etc. were recorded. Walking speed was simulated by the treadmill. The subjects were asked to carry loads of different amount starting from 0, 15, 25,35,45,55 kg. for light weight evaluation of 20 minutes work was done. Heart rate and O_2 consumption was taken for each worker after every 5^{th} minute. The workers then were asked to lift loads of their choice for one hour duration for determining finally the acceptable load. For different loads, the EMG values of these selected muscles with different loads were carried. In general it was observed that the RMS values increased gradually with the increase in load.
Nag and Pradhan (1992) evaluated biomechanical strains during hoeing operation. Hoeing speeds in low lift (LL) and high lift (HL) work were optimized. The result showed that, hoe with blade- handle angle of 65° was less strenuous in LL, while hoe with blade – handle angle of 87° was better for HL work. They suggested that the farmers should adopt the LL mode of hoeing. A hoe, weighing about 2 kg, with blade-handle angle ranging from 65 to 70°, blade length from 25 to 30 cm, blade width from 22 to 24 cm, handle length from 70 to 75 cm, and handle diameter from 3 to 4 cm was found suitable.

Colan et al. (1995) conducted an investigation to evaluate lower back stress during the citrus harvesting operation. They identified the activities, which induce excessive lower back stresses on citrus workers. This was evaluated under static conditions for three commonly positions viz., descending the citrus ladder, walking with a full citrus bag and bending over to pick citrus from the ground. Sensitivity analysis was performed to determine the effect of citrus bag weight, abdominal pressure, height, weight, and physical size of the worker on lower back stress. They concluded that present citrus harvesting system should be redesigned to reduce physical stress encountered by citrus pickers.

Gite (1996) stated that the body discomfort may be due to two factors viz., awkward posture and excessive stress on muscles. He opined that subjective rating appeared to be valid method for its assessment. Further, in many of the situations, though the work may be well within the physiological cost criteria, the body discomfort may restrict the duration of work depending upon the static loading component in it.

Balasankri et al. (2003) conducted a study to assess overall discomfort rating and body discomfort of the tractor operators. The overall discomfort rating (ODR) and body part discomfort score (BPDS) ranged from 4.05 to 7.21, 1.67to 4.80, and 6.08 to 9.12 and 54.57 to 96.89, 45.67 to 94.25 to 138.11 for disc ploughing, cultivator operation and transportation respectively. The corresponding discomfort scale was moderate, light, and very comfortable. The body part discomfort was localized at lower back, buttocks and mid back regions of the body. With increase in tractor forward speed the BPDS and ODR values increased for all three operations. They further found that BPDS and ODR were highest for transporting the tractor with empty trailer on road. They opined that this may be due to vibration and noise.

Kathirvel et al. (2003) assessed the operator's body discomfort for paddy seeder. They found that the ODR was 7.67 and the corresponding discomfort scale rating was "very uncomfortable". The BDPS was 56.57 and the majority of discomfort was experienced in the left shoulder, right shoulder, left leg, right leg, left knee and right knee for all the subjects. The discomfort experienced by the subjects was mainly due to walking in the puddle soil and pulling the seeder with both hands. The force required for pulling the direct paddy seeder was 196.96 N.

Kathirvel et al. (2003) evaluated self propelled paddy harvester for the discomfort experienced by the operators. The study indicated that the majority of discomfort was experienced in the left arm, right arm, left leg, right leg and shoulder region for all the subjects.

Kathirvel et al. (2003) assessed body discomfort and force requirement for operating the manual paddy transplanter. They found that ODR was 6.50 and the corresponding discomfort rating scale was "more than moderate discomfort". The BPDS was 64.53 and the majority of discomfort was experienced in the left shoulder, right shoulder, left arm, right arm, left fore arm, right fore arm, left leg, and right leg for all the subjects. The force required for pushing the handle to pick the seedling and planting, force in pulling the plate back from the soil to the next planting position and the force in pulling the implement in forward direction was 102, 94 and 129 N respectively.

Tewari and Gite (2003) studied the influence of four work-rest schedules on physical workload during power tiller operation. Psycho-physical measurement technique was used to quantify the overall discomfort as well as body part discomfort. The study indicated that the work - rest schedules influenced the physiological and postural workload. They suggested that this was due to increase in heart rate and postural discomfort.

Rahi (2003) studied 50 male and 50 female agricultural workers of Rajasthan for ergonomical studies and found that mean ODR and BPDS for male and female subjects during weeding with 2-tyne cultivator was 15.2, 4.8 and 14.9, 20.3 per cent higher than kudali respectively.

Solomonow (2004) reported on ligaments as a source of work- related musculoskeletal disorders. This research work was supported by grants from the National Institute of Occupational Safety and Health, and by an Occupational Medical Research Center grant from the Louisiana Board of Regents. The article describes the role of ligaments in maintaining joint stability by increasing their tension, as may be necessary, as the joints go through their range of motion, with or without mechanical load. It also describes the mechanical properties of ligaments and their general response to stretch or tension, which is rather complex and non-linear, and when subjected to several phenomena which are time- dependent, such as creep, tension-relaxation, and hysteresis. The role of ligaments that connect the vertebrae is especially critical when the spine is in a fully flexed position, such as when bending at the waist with the hands near the ground. In this posture the ligaments receive little assistance from the back muscles in supporting the load on the spine and maintaining joint stability.

Dr. Solomonow states. 'Static or repetitive loading of a ligament, within its physiological limits, when extended over a period of time result in creep, which is an expression of a micro-damage within the collagen fibers structure of the tissue. The micro-damage triggers inflammatory responses as well." He further states, "Repetitive exposure to physical activity and reloading of the ligament over prolonged periods without sufficient rest and recovery represent cumulative micro-trauma. The resulting chronic inflammation is associated with atrophy and degeneration of the collagen matrix leaving a permanently damaged, weak and non-functional ligament. The dangerous aspect of a chronic inflammation is the fact that it builds up silently over many weeks. months or years (dependent on a presently unknown dose-duration levels of the stressors) and appears one day as a permanent disability associated with pain, limited motion, weakness and other disorders. Rest and recovery allow only partial resolution of the disability. Full recovery was never reported."

'Workers engaged in daily performance of static or repetitive activities over periods of weeks or months will exhibit first hypertrophy of the ligaments, but still subjected to creep, tension- relaxation and hysteresis. The ligament becomes lax over a day's work and cannot exert sufficient tension to maintain the motion of the bones on track and maintain even pressure distribution on the cartilage surface, while supporting the same external loads. Such degradation of function can cause increased exposure to injury as the workday progresses, while at the same time causing gradual degeneration of the articulating' surfaces of the joint, leading to osteoarthritis. The development of cumulative creep in the ligament may build up at some point to trigger sufficient micro-damage in the collagen fibers with the acute inflammation becoming chronic and consequently degeneration of the ligament and permanent disability."

Research has demonstrated that bad posture will lead to alteration in bone and soft tissues bone spurs intervertebral disc damage and fibro tic scar tissue. Evidence exists that some postural positions can compromise neural tissue by changing blood flow to the spinal cord itself. Connective tissues undergo plastic changes that can become permanent. This is probably why many individuals who exhibit the postural abnormalities cannot be placed into proper postural alignment with short- term methods (cited in **Allen, 1997**).

Sirisha et al. (2005) carried out the ergonomic evaluation of groundnut stripper, and fertilizer broadcaster was carried out with ten female subjects varied in age from28 to 35 years. The parameters used for the ergonomical evaluation of all the selected implements include heart rate and oxygen consumption, energy cost of operation, acceptable work load, work pulse, overall discomfort rating, body part discomfort score and force measurement for manually operated implements. The energy cost of groundnut stripper & fertilizer broadcaster was 7.02 and 13.55 kJ/min respectively. The overall discomfort rating (ODR) showed a range of 45 to 63 by the Corlett and Bishop (1976) technique. The Body Part Discomfort Score (BPDS) was maximum for broadcasting the fertilizer with fertilizer broadcaster (62.107) followed by stripping with groundnut stripper (58.3).

2.6 Weeding

This section presents studies related to the evaluation of weeding devices.

A laboratory study was carried out by **Gite and Yadav (1990)** at the central institute of agricultural engineering (CIAE) Bhopal to find out the optimum handle height for a push pull type manually - operated dryland weeder from ergonomic considerations. Four handle heights, i.e.0.6, 0.7, 0.8 and 0.9 of shoulder height (SH) were compared with eight subjects in a laboratory set up which involved an application of 98 N horizontal push for operating the weeder. The observations made during the experiment were heart rate, ventilation rate, energy expenditure and rating of perceived exertion. Based on the results of the experiment it was concluded that for operating a push-pull type weeder, the handle height should be within 0.7 and 0.8 of shoulder height to have minimal physiological and muscular fatigue. Considering this range and the available anthropometric data, a handle height of 100 cm was recommended for Indian workers.

Rana et al. (1994) studied an improved, wheel mounted hoe for women. Specifications for two models, an improved version and a light weight version, were given in comparison with existing local hoes. Field trials involving 40 women in 4 villages were undertaken. The lightweight hoe was judged the best by the women for improving the quality of life. In producing a lightweight hoe the cost was reduced.

Singh et al. (1999) conducted experiments on energy efficiency of different weeding methods in wheat crop in Punjab. The methods used included weeding by (1) khurpa (a short handle tool used in squatting posture),(2) kasola (a long handle tool used in standing posture), (3) wheel hand hoe, (4) chemicals. These four methods were in practice there. Results indicated that weeding by khurpa, kasola and wheel hand hoe requires 105, 75, and 24 man hours/hectares respectively. Thus weeding by wheel hand hoe can save 72, 61 and 67 per cent of energy over weeding by khurpa, kasola and chemicals respectively without significant effect on yield. There is also a saving of 28 to 86 per cent of operational time in weeding by kasola, wheel hand hoe and chemical as compared to khurpa.

Vatsa and Singh (2000) compared the performance of four different types of wheel hoes and the traditional khuntee with respect to the following paramerers viz.,effective field capacity (ha/h), field efficiency (%), labor requirement(man hour/hectare) and cost of operation (Rs/ha). The wheel hoes manufacture by CIAE, Sherpur,and HPKV were used for the study. Three women subjects operated the weeders for two hours with a rest of 10 minutes after every half an hour. Results of the study have been depicted in the table given below.

Table : Comparative performance of the various weeders for interculture operation in wheat crop.

Parameter	W1	W2	W3	W4	W5
	CIAE(small)	CIAE(Big)	Sherpur	HPKV	Local
Effective field capacity.ha/h	0.026	0.024	0.022	0.023	0.008
Field efficiency, %	72.3	70.5	70.2	73.6	81.5
Weed intensity, g/metre square	60.5	63.4	68.2	65.3	58.2
Weeding efficiency, %	85.4	87.4	82.3	78.2	80.5
Labor requirement, man hour/ha	38	42	46	43	125
Cost of operation,Rs,ha	230	254	278	260	750

Results indicated that the area covered with conventional (khuntee) was about one fifth as compared to both wheel hoes. All the subjects felt more discomfort and tiredness with wheel hoe (sweep type) followed by wheel hoe (tine type) and manual khuntee. It was also observed that the area covered decreased as time increased with all the implements. The body part discomfort ranking used for various weeders shows hat seven body parts experienced extreme discomfort. The discomfort body parts were in order of left shoulder, right shoulder, left arm, right arm, lower back, left wrist and right wrist with all the wheel hoes. However, the subjects complained serious discomfort in right wrist with khuntee.

Alexandrou and Coffing (2001) carried evaluation of four different implements for weed control at three growth stages, between and within rows, at two different speeds and two different crops. Canola was chosen as theweed and cultivation took place at 2-lear, 5-leaf and 8-leaf stage of growth. Of the four weeding mechanisms assessed on the corn and soybean fields, sweep and roe cultivators were the most effective in reducing the number of canola plants between rows. The tine weeder was effective only during the 2-

lear stage of the canola growth for both fields. The rotary hoe gave disappointing results. Velocity does not show statistically significant differences with the exception of the rotary hoe at the 5-leaf stage on the corn field, where low velocity gave best results. Within the row, the tine weeder when used at 2-leaf stage was the most effective implement in both velocities and fields.

Hagmann (2002) under The Agritex- GTZ Conservation Tillage (Con Till) Project in Zimbabwe developed a low- cost, light-draft (single donkey) toolframe with attachable tools for weeding, ridge-tying and opening planting furrows. The toolframe was the outcome of the ideas generated by the farmers which were taken up by the researchers who added basic engineering knowledge and, in collaboration with a local engineering workshop, made a prototype. The prototype was given to male and female farmers who tested it and suggested numerous modifications in terms of dimensions, working angles and ergonomics. After incorporating these suggestions, the implement was tested again by farmers, who came up with another innovation as they fitted other tools to the frame instead of the tying blade: a sweep tine for weeding widely spaced crops; a duckfoot tine for weeding groundnuts; and a cultivator tine for opening shallow furrows for planting small grains, cotton and sunflowers. Farmers shared ideas and came up with suggestions for the design of additional tools. The new designs were tested, improved and refined. A breakage – test and draft power tests followed to ensure technical viability. In a breakage test, the lower end of the toolframe started bending at a draft force of about 3.1kN and remained permanently bent at 3.5 kN which is far above the draft force a donkey can produce. The draft requirements of all tools mounted on the tool frame were below 200N, which is well within the draft capability of a single donkey. The low weight made it particularly attractive for women.

Mbanje et al. (2002) evaluated animal drawn weeders for smallholder maize production in Zimbabwe. Comparable results were obtained in terms of weeding efficiency for the ox-drawn cultivators, but the light three-tined cultivator had a lower work rate and was more difficult to control on heavier soils than the traditional five tined cultivators. In sandy soils the duck foot tines performed better than the reversible tines in terms of yield responses, and vice versa for the heavier clay loam soils. The single animal- drawn tool- bar had the second lowest weeding efficiency and returns to hours spent weeding, post –emergent ridge weeding out performed all of the other weeding treatments. It was recommended that for heavier soils, farmers should use the reversible tines that are sold with most cultivators, whilst, on lighter sandy soils, farmers would be wise to use the ducks foot tines. However farmers who do not own a cultivator and draught animals are not a constraint should practice post emergent – ridge weeding with the mouldboard plough, as it not only gives good weed control, but also enhances crop yields.

Nadre and Yeole (2004) compared Krishiratna hoe, a wheel type hand hoe developed by Tyne Tiller & Company with local hand tool khurpi. The different sizes of blades are provided with the implement to suit the different row spacing of crops. Both the implements were tested in the instructional farm of college of Agricultural Engineering MAU Parbhani for weeding in cotton crop. For the testing cotton crop having row to row spacing 45 cm was selected and a krishiratna hoe with 38 cm blade was found suitable and hence compared with khurpi. The time required to cover an area of 100 m^2 for the krishiratna hoe was 29 minutes and the same area covered by khurpi was 2 hrs 19 minutes. Field capacity was also more than khurpi. Cost of weeding with krishiratna hoe was Rs.158/hectare and with khurpi Rs 590/hectare.Weeding one hectare area with khurpi required 30 women days whereas with krishiratna hoe 7 women days were required to cover an area of one hectare. The daily earning of farmwomen labour increased by Rs.65 with this hoe.

Badiger et al. (2005) analyzed the workload of farm women while weeding with three different weeders namely khurpi (traditional tool), twin wheel hoe and grubber weeder. Ten healthy women farmers performed the experiments. The physiological cost of work was observed to be less with the improved twin wheel hoe (13.15 beats/min). Maximum work output was observed with grubber weeder i.e. 147 metre followed by twin wheel hoe. The farm women perceived twin wheel hoe to be very light while performing weeding.

Zend et al. (2005) carried out ergonomical evaluation of weeder designed by AICRP (Family Resource Management) component, Parbhani by comparing the physiological cost of using newly developed weeder with the cost of traditional weeder & Saral khurpi (designed by Dharwad centre). The sample comprised 30 farmwomen belonging to age group of 20-45 years. All the parameters selected for determining physiological workload indicated that physiological cost of work of weeding increased over traditional method by 39 per cent when it was performed by using newly developed weeder & reduced to 21 per cent when it was performed by using Saral khurpi. The output (coverage of land) under improved weeder & saral khurpi was 64 & 41 per cent respectively which was more than traditional khurpi. Weeding efficiency of traditional & saral khurpi was 95 per cent & that of newly developed weeder was 88 per cent. It was further found that the work with newly developed weeder required standing position which eliminated postural stress by reducing the angle of deviation. Field trials revealed that newly developed weeder functions efficiently with highest coverage of land. Hence newly developed weeder was recommended for weeding efficiently.

This shows that a number of weeders have been have been manufactured but in relation to hill agriculture no new technology is devised.