ASSESSMENT OF WORK RELATED HEALTH HAZARDS OF VEGETABLE CULTIVATORS AND ERGONOMIC DESIGNING OF HAND TOOLS

A dissertation submitted in fulfillment of the requirement for the degree of Doctor of Philosophy (Science) in the Vidyasagar University

By

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Certificate

This is to certify that the thesis entitled **"Assessment of Work Related Health Hazards of Vegetable Cultivators and Ergonomic Designing of Hand Tools"** submitted to the Vidyasagar University by **Amitava Pal** for the award of the degree of Doctor of Philosophy (Science), is a bona fide record of research work carried out by him under my supervision and guidance. Amitava Pal has completed all the prescribed requirements for the award of the degree in accordance with terms and conditions laid down for the Ph.D. examination of Vidyasagar University.

The research report and results embodied in this thesis have not submitted for any other degree or diploma in any other University or Institute.

(P.C. DHARA)

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Declaration

I hereby declared that the research work presented in the thesis entitled "**Assessment of work related health hazards of vegetable cultivators and ergonomic designing of hand tools"**, has been carried out by me in the Ergonomics and Sports Physiology Division of Department of Human Physiology with Community Health, Vidyasagar University, for the fulfillment of the requirement for the degree of Doctor of Philosophy. It is also declared that, the research report and results presented in this investigation is original and has not been submitted in part or full for the award of any Degree or Diploma of any University or Institute.

……………………………..
(Amitava Pal)

Dedicated to

My father

Mr. Mahadeb Pal

&

My mother

Mrs. Gita Rani Pal

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Amitava Pal

CONTANTS

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List of Abbreviations

95% CI	95% Confidence Interval
ANOVA	Analysis of Variance
BF%	Body Fat Percentage
BLA	Blood Lactate Accumulation
BMI	Body Mass Index
CED	Chronic Energy Deficiency
CG	Center of Gravity
CSI	Cardiovascular Stress Index
DBP	Diastolic Blood Pressures
FFM	Fat Free Mass
Hb	Haemoglobin
ICMR	Indian Council of Medical Research
ILO	International Labour Organization
LBM	Lean Body Mass
LH	Left Hand
LUBA	Postural Loading on the Upper Body Assessment
MAP	Mean Artial Pressure
MSDs	Musculoskeletal Disorders
NFHS	National Family Health Survey
NNMB	National Nutrition Monitoring Bureau
OBLA	Onset of Blood Lactate Accumulation
OCR	Oxygen Consumption Rate

OR	Odd Ratio
OWAS	Ovako Working Postures Analysis System
PATH	Posture Activity Tools Handling
QEC	Quick Exposure Checklist
RDA	Recommended Dietary Allowance
REBA	Rapid Entire Body Assessment
RH	Right Hand
RULA	Rapid Upper Limb Assessment
SBP	Systolic Blood Pressures
SD	Standard Deviation
SES	Socio-economic Status
TRAC	Task Recording and Analysis on Computer
TWF	Total Weight of Fat
Vo_2 max	Maximal O_2 Consumption
w.r.t.	with respect to
WHO	World Health Organization
WMSDs	Work-Related Musculoskeletal Disorders

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Abstract

India is an agricultural-based country and agriculture plays an important role in the economic development of the country. A large number of people of different districts of West Bengal state are engaged in agriculture throughout the year. Apart from cereal production (rice, wheat, etc.) agricultural labourers are engaged in different types of vegetable cultivation. In the present investigation potato and ground nut cultivation was taken into consideration.

Potato cultivation is one of the important vegetable cultivation in India. Both male and female workers are involved in this job and expend a great extent of their physiological cost. There are different tasks in potato cultivation, which are performed in different phase viz., planting of seeds, tunneling in the potato field and harvesting of potato. The potato cultivation tasks are repetitive in nature and those are carried out mainly by manual efforts. Most of the tasks of potato cultivation performed by the cultivators are monotonous, strenuous, physiologically demanding as well as time-consuming. They have to face many job related health problems during work. In different phases of potato cultivation tasks different patterns of work are performed. Some of the activities are dominated by static muscular contractions and some other tasks involve repeated dynamic activities. Due to adopting different inappropriate postures whilst performing different potato cultivation tasks, workers are exposed to postural stress and may suffer work related musculoskeletal disorders (WRMSD) in different parts of the body. They may therefore be considered to be suitable for ergonomics intervention.

The farmers were found to use different types of conventional hand tools, viz., plough, yoke, spade, hoe, bucket etc., for performing the different tasks of potato cultivation. An important hand tools, small spade which is frequently use in potato cultivation for tunnelling operation as a part of field preparation. The design of small spade varied from region to region. The existing small spade is designed without

considering the human factors. The workers are compelled to adopt different inappropriate postures during working with this conventional hand tool. As a result they have to face different job related health problems.

The groundnut cultivation is done in different parts of India including the West Bengal state. There are different steps of groundnut cultivation. In the present study ergonomics study has been performed on one of the selected task of groundnut cultivation - the separation of groundnut pods from the plant root after harvesting. The groundnut cultivators required to separate the ground nut from the root of the plant manually by the fingers. This may leads to WRMSD in different segments of the body especially in hand-arm systems during plucking the nut. Ergonomic intervention is required in this field.

In the present investigation different human factors involved in the potato cultivation tasks have been studied. Efforts have been made to evaluate the nutritional status, work related MSDs, work-rest pattern, postural pattern, postural stress, physiological stress of the workers. Attempts had been made to redesign the small spade, one of the most important tools frequently used by the potato cultivators. Efforts had been made to design of a new hand tool, named as nut plucking tool, for separating ground nut from the root of the plant considering the ergonomic principles.

The main aim of the present investigation was the evaluation the occupational stresses of the cultivators engaged in different tasks of potato cultivation job and their relationship with physiological response and nutritional status. Another aim was ergonomic evaluation and redesigning of hand tools used in potato and groundnut cultivation from the viewpoint of ergonomics.

The followings are the objectives of the present investigation:

a) Evaluation of work related musculoskeletal disorders (MSDs) of potato cultivators
b) Evaluation of postural and physiological stress of potato cultivators
c) Ergonomic design of hand tools (small spade and ground nut plucking tool).

The present investigation was carried out on vegetable cultivators only. This study was conducted in 692 participants of whom 353 were male and 339 were female (age range of 18–60 years), selected from different villages of Midnapore (East and West), Bankura and Howrah districts of West Bengal state, India.

The socioeconomic status of workers was evaluated by modified Kuppuswami scale. Anthropometric measurements were taken from the subjects following standard technique and appropriate landmarks. Nutritional status of the participants was evaluated by 24-h recall as well as by the anthropometric method. Blood pressure and hemoglobin status were measured using standard protocols.

Occupational health problems of the participants related to the potato cultivation tasks were evaluated by modified Nordic Musculoskeletal Questionnaire method and perceived discomfort rating in different segments of the body. The work-rest patterns of potato cultivators were determined by directly observing their work as well as by taking interview of the workers. The postural pattern of the workers during performing their jobs was studied by the direct observation method employing video-photography. Working postures were evaluated by standard posture analysis tools, viz., OWAS, REBA, RULA, and QEC. The physiological stress was evaluated by working heart rate, Cardiovascular Stress Index (CSI) and blood lactate during performing different potato cultivation tasks.

For the designing the hand tools some systematic steps were followed. At first, the problems of the conventional tools were evaluated by the subjective assessment as well as by some objective measurements. After identifying the drawbacks of existing tools, design concepts were developed to overcome the problems. According to the design concept some prototype models were made. The prototypes were tested by the psychophysical test like paired comparison test. Design of the tools was made by considering the anthropometric dimension of the users and the results of the paired comparison test. The

effectiveness and acceptability of the modified design of the tools were evaluated. The tests include subjective assessment, discomfort feeling, heart rate and body joint angles.

The result of the socioeconomic status of the cultivators was revealed that the majority of them were belonging to upper lower socioeconomic category (male: 79.61%; female: 87.32%).

From the results of nutritional status it was noted that about 42.71% male and 51.76% female were undernourished. The workers had low hemoglobin concentration and the prevalence of anaemia was 46.62% in males and 66.87% in females, which was more than the global prevalence. Most of the participants were normotensive (male: 67.61%; female: 76%). However, a notable percentage had hypertension (male: 21.86%; female: 15.27%), although the prevalence of hypotension was low (male: 10.53%; female: 8.73%).

It was revealed that the prevalence of MSDs was very high among the workers of both sexes. The lower back problem was highly prevalent (male: 93.25%; female: 92.26%) among the workers which was followed by the problems in upper back (male: 63.8%; female: 65.16%), waist (male: 60.12%; female: 57.42%), shoulder (male: 47.24%; female: 61.94%), hip (male: 44.17%; female: 55.48%) and elbow (male: 46.63%; female: 50.57%). The results indicated that the prevalence of MSDs was comparatively higher in tunnelling task compared to potato harvesting and seed planting operations. However, lower back problem was extremely prevalent in all types of tasks of potato cultivation. It has been noted that the female workers were more likely to have musculoskeletal pain/discomfort compared to the male cultivators. The prevalence of MSDs also exhibited variation in the participants having different work experience.

The work-rest pattern showed that the total working hours was approximately 9 hours including rest pauses. From the results of postural pattern it was revealed that the predominant posture of different potato cultivation tasks were forward bending and squat sitting posture. From different posture analysis methods it was noted that the postures adopted by the workers had risk levels from 'medium' to 'very high' in different tasks of potato cultivation.

The average working heart rate was 105.33±10.77 beats/min in male and 109.97±9.94 beats/min in female and it was found that they were working at about 55% and 58% of their age-predicted maximum heart rate in male and female respectively. Among the different tasks of potato cultivation, the highest mean working heart rate was noted in tunnelling operation compared to potato harvesting and seed planting tasks. According to the classification of physical work in terms of heart rate the seed planting and potato harvesting tasks were considered as the moderate work. But tunnelling task was belonging to the heavy work category. Those workers involved in tunnelling task had a significantly higher Cardiovascular Stress Index (CSI) than that of the potato harvesting and seed planting workers. According to CSI classification, all the tasks of potato cultivation have been classified as stressful category except planting of seed in male. The higher working blood lactate level was noted in tunnelling operation (male: 3.77±0.83 mM/lit; female: 5.20±1.37 mM/lit) compared to seed planting (male: 2.54±0.3 mM/lit; female: 3.22±0.63 mM/lit) and potato harvesting tasks (male: 2.93±0.38 mM/lit; female: 3.33±1.14 mM/lit). In tunnelling operation the blood lactate level of female workers was higher than the point of onset of blood lactate accumulation (OBLA) (4.0 mM/l).

A set of hand dimensions was measured from both male and female participants to make an anthropometric database of the cultivators and those hand dimensions were used for redesigning of hand tools (spade and ground nut plucking tool) which are used in different tasks of vegetable cultivation. Fourteen hand dimensions have been identified which were considered useful for agricultural hand tool design and the measurements were taken from the participants and their percentile values were computed for male and female workers separately as well as for combined population also.

In potato cultivation, the workers are required to use a small spade for tunnelling operation. Such spade is smaller in size than the conventional standard spade. The small spade were made with conventional idea without due consideration of human factors. There were some drawbacks in the design of the small spade from the view point ergonomics. For example, the main problem of this small spade was that the handle length of the spade was short. Therefore, the workers were required to bend too much for a long time while performing tunnelling operation with this tool, which might cause biomechanical stress in different body joints and might produce different segmental pain. The workers reported pain/discomfort at different body segments, viz., lower back, upper back, finger, palm, wrist, etc., i.e., an overall discomfort was prevalent in the hand. Secondly, during summer and hot humid conditions, excessive sweating created problem of gripping the handle.

An attempt has been made to redesign the small spade considering the human factors. Different existing small spade were evaluated and their merits and demerits were identified. A modified design was made by considering several factors. The diameter of the handle of the redesigned small spade was 3.0 cm. The diameter of the handle was made considering 5^{th} percentile value of the hand grip diameter of the users which might be helpful for the proper griping of the handle. The length of the handle of the spade was increased to about 72.5 cm from that of existing length. Such change might improve the postures of the workers when performing the spade operation. The angle between the blade and handle was increased to about 50^o from that of existing models. Such changes in angle might improve the biodynamic parameter of the body (e.g. body joint angles). The length and width of the blade were also increased from that of existing one for improving the surface area of the blade. The weight of the redesigned small spade was 2.0 kg. The weight of the spade was decreased from that of the existing spade. Each of the design criteria were selected by psychophysical analysis of the users employing paired comparison test. To ensure a good grip a rubber pad was pasted on the handle. The final design was settled after a lot of trials and consultations with workers. The redesigned small spade became more comfortable in handling than the existing spade. The prevalence of pain / discomfort in different segments of the body became lowered during use of the redesigned small spade than that of existing spade. The physiological strain of workers was decreased while working with the redesigned spade. There was an increase in productivity by about 11% in male and by about 9% in female workers respectively. The cost of the redesigned small spade was a little higher than existing spade. On the other hand, redesigned small spade lowered the risk of injury among workers and provides better worker comfort.

In addition to the small spade another hand tool was designed which could be used for a specific task in groundnut cultivation. The hand tool was named as groundnut plucking tool, which could be used for detaching groundnut pods from the root of the plant. In usual practice the workers were used to separate the groundnut pods from the root of the plant manually by the fingers. The workers reported discomfort/pain in different body segments, especially in the hands and arms. A large number of workers (89% of male and 92% of female) reported MSDs in finger and more than 75% of male and 80% of female reported problems in the palm and wrist. Besides this, about 66% of male and 71% of female workers were found to have problem in the elbow joint. A nut plucking hand tool was proposed instead of manual plucking. The tool was designed by considering the human factors. The final design was settled after a lot of trials and consultations with workers. In case of designing of nut plucking tool, main emphasis was given on hand–handle interface and plucking interface. A handle was attached to the main body of the

tool and to ensure a good grip a rubber pad was wrapped on the handle. The handle dimension was settled on the basis of percentile values of relevant hand dimensions and other dimensions were fixed by the results of the paired comparison test. For separating the nuts from the plant, sharp finger like projections was made in front edge of the tool. The newly designed nut plucking tool was better than that of conventional system (manual) from the view point of productivity and safety. The prevalence of pain/discomfort in different segments of the body was lower during use of the nut plucking tool than the conventional system. The physiological strain of workers was decreased while working with newly designed nut plucking tool and there was a significant increase in productivity.

It was concluded that the potato cultivators had a number of musculoskeletal disorders in different segments of the body. The lower back problem was highly prevalent among the workers and it was followed by upper back, waist, shoulder, hip and elbow. The higher prevalence of work related MSDs at different body segments of the agricultural workers might be related to their postural pattern, repetitive movements as well as longer duration of exposure in awkward posture. The predominant posture of different potato cultivation tasks were forward bending and squat sitting posture. Adopting these two awkward postures during performing the tasks might be one of the possible causes of back pain among the workers. The female workers were more prone to have MSDs than that of male workers. The female cultivators had to perform household chores including cooking in addition to the occupational work (agricultural activities), the cumulative effects of which might result a higher degree of musculoskeletal problems in comparison to male workers. The WRMSD can be reduced if the workers adopt appropriate posture, as far as practicable, during performing their jobs and follow the rules of manual material handling. The forward bend posture is a very strenuous posture. In case of tunneling task, the workers were spending more than 80% of total work time in forward bending posture. The problems will be reduced if the forward bend posture can be avoided. This may be achieved by using redesigned hand tool (small speed). The workers are required to use a small spade for tunneling operation. The length of the handle of the spade and the angle between the blade and handle were suggested to increase from the existing length. Such change may improve the postures of the workers when performing the spade operation. The musculoskeletal disorders and postural stress could be reduced by modifying the work-rest cycle. In the present study it was observed that the workers took a long duration rest (food break) for about 2½ hours. It may be more helpful if the longer continuous rest period is reduced and more number of short breaks is provided within work shift. According to their work load and energy requirement the 30-minute work and 5 minutes rest will be preferable for long durational potato cultivation jobs. Training and awareness programme are required for educating the workers about the appropriate posture for different tasks and about bad effects of inappropriate posture. Two important hand tools, viz., redesigned small spade for tunnelling operators and newly designed ground nut plucking tools for groundnut cultivators were very simple and low cost. They would be able to improve the productivity and would reduce some of health hazards of the workers. The workers should be encouraged to use the modified tools.

There are further scopes of future studies. The redesigned small spade and newly designed ground nut plucking tools were evaluated for a short period of time. They should be tested for a long time and on a large number of subjects. Efforts may be made for identifying the merits and demerits of the redesigned tools after a long-term use. Further modifications can be incorporated, if required. Efforts may also be made to redesign other tools used by the cultivators. Efforts should also be made to devise new equipment for the workers so that their postural stress could be minimized.

Introduction

Contents

Chapter I

Agricultural work is the most primitive type of employment in the world. The agriculture sector employs about half the world's entire workforce, with an estimate of 1.3 billion workers (ILO, 2003). India is an agriculture-based country and agriculture has plays an important role in the economic development of the country. A large population in India depends for their livelihood on agriculture only.

A census conducted in 2011 in India highlighted that 58.4% of the total population in the country are engaged in agricultural work (Census of India, 2011). According to the Census report it has been found that in West Bengal state about 43.35% of male and 46.3% of the female population are engaged in agricultural work (Census of India, 2011).

A large number of people in India are living with poor health and nutritional status (Pal et al. 2014a). These and other issues such as poor education, violence and unemployment contribute to the burden that workers in India and other developing countries have to deal with on a daily basis. In developing countries the compounding effect of these poverty-related circumstances must ultimately have a negative impact on worker well-being and work performance. A large number of people of this state, especially of Midnapore (East and West), Bankura, Purulia, Howrah district etc. are engaged in agriculture throughout the year. Most of these workers are coming from rural and economically backward areas where employment opportunities are limited. Because of their poverty, farmers are obliged to undertake most agricultural tasks relying solely on their own efforts. Even today, Indian agriculture depends to a very large extent on manual labour although modernization has reached some parts of the subcontinent. Though the agricultural workforce is by far the major work forcing the third world countries, its work organization has not received much attention. Agriculture is one of the three most hazardous sectors in the working world and farmers and farm workers are exposed to a variety of work-related factors, which can affect their safety and health (Lunner-Kolstrup, 2012). Agricultural works are executed by hard manual labour and perhaps more than any other occupational group, agricultural workers are exposed to tremendous variety of environmental hazardous and postural and physiological stresses (Sabharwal and Kaushik, 2011). These manual operations may be physically demanding through their energy requirements and are commonly regarded as source of drudgery that is potentially harmful to their health and well-being (Sabharwal and Kaushik, 2011). They face many job-related health problems during work. A number of national and international studies have shown that farming is a physically demanding occupation with work tasks that can cause musculoskeletal disorders (Holmberg et al. 2002; Gomez et al. 2003; Davis and Kotowski, 2007; Douphrate et al. 2009; Osborne et al. 2010; Pal et al. 2015a). Kar et al. (2012) studied occupational problems of female cultivators and noted that the female agricultural workers had job related problems other than musculoskeletal disorders. Among them fatigue, digestive disorders and headaches were prevalent. They also reported indigestion and pain in the abdomen. Kar et al. (2012) also stated that different types of eye related problems such as pain and burning sensation in the eyes, watering and blurred vision were evident among the women workers engaged in agricultural tasks. They may therefore be considered to be suitable for ergonomics intervention.

In addition to cereal production (rice, wheat, etc.), agricultural labourers also performed different vegetable cultivation. Potato cultivation was one of the important vegetable cultivations in India. Large sections of Indian agricultural workers were involved in vegetable cultivation particularly in West Bengal state. Both male and female workers were involved in this job and expended a great extent of their physiological cost. People are involved in different types of vegetable cultivation. In the present study main emphasis was given on potato cultivation. However, some studies have been made on ground nut cultivation. The potato cultivation is a seasonal work. In many areas of this state, the potato is cultivated in one season (November-March). But in very few areas it is also cultivated in two seasons in one year. Potato cultivation totally depends upon irrigation from rivers, canals and underground water. For good production, the cultivators use organic and chemical fertilizers and they also use pesticides. There are different tasks in potato cultivation, which are performed in different phases. The potato cultivation tasks, viz., planting of seeds, tunneling, and harvesting potatoes are repetitive in nature and are carried out through manual efforts. On the other hand groundnut is cultivated in both 'Rabi' and 'kharif' seasons. Ground nut is the third largest oil seed in the world and second largest in India. It is also cultivated in different districts of west Bengal state.

There are some steps in potato cultivation which were followed by the farmers in this country. After ploughing the land, weeding is performed. The land surface is then levelled after which potato seeds (cut pieces of potato) are sown in rows by making a shallow dig with the hand. During sowing, a regular distance is maintained and the seeds are covered with soil. The seeds are sown in several rows keeping some gaps (40-45 cm) between two rows. After germination, when the saplings have grown, tunnels are made in the gap between the two rows with the help of a small sized spade. These tunnels are used for irrigation purposes. Such tunnels are re-made after every phase of irrigation. After a few months, when the crop is fully grown under the ground, harvesting activities begin. The soil along the rows of plants is dug by with the use of a spade. Care is taken to avoid cutting the potato under the soil. Once the soil beneath the plants becomes loose the potatoes are collected by the hand. The collected potatoes are kept in a sac or a basket.

(a) Making a shallow dig

(b) Plantation of potato seeds

(c) Tunneling

(d) Potato harvesting

(e) Caring of collected potato

(f) Storing of potato

Fig. 1.1: Different steps of potato cultivation

The groundnut cultivation is done in different steps. For the field preparation shallow ploughing is done. Sometimes small cultivators use spade for field preparation. Then groundnut seeds are sown in a definite space in a row in the field. Harvesting of ground nut is done by spade or local plough. The harvested crops are left in small heaps for two to three days for cutting. After curing the pod of the grounds are detached by hands. In West Bengal no device is used for plucking the nuts. In the present study ergonomic intervention has been made for the last step of ground nut cultivation, that is, separation of groundnut seeds (pods). Efforts have been made to design a groundnut plucker for separating the pods from the plant from the view points of ergonomics.

a) Harvested ground nuts b) Separation of pods

Fig. 1.2: Final steps of groundnut cultivation

Occupational health is specifically concerned with safety and well-being of the workers. In normal circumstances, occupational stress appears as an unavoidable part of working life. It is a situation where in the work related factors act together with the human factors in such a way that the individual is diverged from his/her normal functioning. A strong relationship exists between the occupational stress of workers and their productivity (Dall et al. 2013; Summers et al. 2015; Pal et al. 2015b). Occupational stress of the workers results in reduced productivity due to inefficiency of the workers and sickness absenteeism.

Occupational stress is becoming an increasing global phenomenon affecting all countries, all professions and all categories of workers, families and society in general (Bhattacharyya et al. 2011). The working conditions of workers may be hazardous due to various ergonomic risk factors and results in a variety of occupational health problems which include loss of efficiency and onset of early fatigue, discomfort and musculoskeletal problems. The factors that play roles in the process of occupational wellness and stress are body postures, rapid movements, exertion required, environmental factors and poor design of work method/work tools, technical systems, inappropriate relationship between workers performance and their task demands (Bhattacharyya et al. 2011; Goswami et al. 2012; Pal et al. 2015a,b).

Most of the tasks of potato cultivation performed by the cultivators are monotonous, strenuous, physiologically demanding as well as time-consuming (Gangopadhyay et al. 2005; Das and Gangopadhyay, 2012; Pal et al. 2015a). Due to adopting different inappropriate postures whilst performing different potato cultivation tasks, workers are exposed to postural stress and may suffer from pain in different parts of the body. The tasks of potato cultivation are repetitive in nature. In different phases of potato cultivation tasks different patterns of work are performed. Some of the activities are dominated by static muscular contractions and some other tasks involve tasks repeated dynamic activities. Pascal (2003) noted that prolonged static muscle loads have appeared as a major risk factor in the development of load-related illnesses. A constant repetition of movements imposes a cumulative work-load which can cause pain and weakness and impaired function of the muscles and other soft tissues (Gangopadhyay et al. 2007; Girish et al. 2012). The predominant posture of different potato cultivation jobs are the stooping and squat postures. Workers sometimes adopt stooping and twisting postures during tunneling jobs and squatting postures while harvesting of potatoes for long durations. All these postures may produce discomfort in different parts of the body. Olendorf and Drury, (2001); Reneman et al. (2001); Kothiyal and Yuen, (2004) and Chaffin et al. (2006) pointed that bending and twisting of the back impose higher postural strain than the straight back postures which are important risks factor of origin of discomfort. High repetition, excessive forces and awkward postures are major cause of musculoskeletal disorder and complaints in industry and industrializing countries (Westgaard, 2000; Singh, 2010). Prolonged heavy manual works, awkward posture are the encouraging factor and others stress on lower back region (Roffey et al. 2010). According to Caicoyal and Delclos (2010) workers, especially those who carrying heavy weights and perform highly repetitive tasks for longer duration have reported pain at different segments of their body. In potato cultivation jobs, continuous movement of upper limbs also occurs during tunneling jobs. In many parts of the agricultural sector, upper extremity injuries are prevalent and are related to several common risk factors, viz., awkward posture and repetitive movement (Meyers et al. 2000; Struttmann and Reed, 2002; Gomez et al. 2003; Goswami et al. 2012). As the cultivators work in an awkward posture, the center of gravity of the body is also changed. As a result the body becomes unstable and it may be one of the causes of postural stress. Competition and increased work demands have also increased farmers' exposure to risk factors through increased work pace and duration.

Physiological effects of work stress have also been studied by vast researchers. Heart rate is the important determinant factor to estimate the cardiovascular status. Numerous epidemiological studies have reported increases in the daily incidence of cardiovascular mortality and morbidity associated with increase of work stress (Kivimäki et al. 2002). In India, study of occupational cardiovascular stress among the agricultural workers found scanty. The literature survey revealed that there are several risk factors significantly associated with cardiovascular stress. The most important are job strain (Väänänen et al. 2008), job demand (Song et al. 2010), high physical effort (Makowiec-Dabrowska et al. 2007), work place factors like long working hours, psychosocial work stress etc. (Thomas and Power, 2010).

In labour intensive countries like India, studies on agricultural workers are not much available. A few studies (Nag, 2005 and Mohanty et al. 2008) have been reported in maximal oxygen uptake of agricultural men and women in India. Debray et al. (2002) have shown the peak expiratory flow rate and cardio-respiratory fitness of Bengalee workers exposed to dust and plant source particulate matters. Physiological study relating energy metabolism to the work demand of agricultural labours is also scanty in India. Hasalkar et al. (2007) studied on musculoskeletal disorders of the farm women while performing the top dressing of fertilizer activity. Gangopadhyay et al. (2005) also studied on posture related discomfort among preadolescent agricultural workers of West Bengal. Nag and Nag, (2004) also studied on drudgery, accidents and injuries in Indian agricultural worker. Investigation of male subjects predominated; although it is actually women comprise the majority of subsistence farmers in developing countries (F.A.O., 1995; De et al. 2006; Goswami et al. 2012).

The farmers were found to use different types of conventional hand tools, viz., plough, spade, khorpa, sickle, yoke, and bucket etc., for performing the different agricultural tasks. These tools used by the farmers were predominantly designed based on thumb rule without any consideration towards human safety, comfort, etc., while using them. The design of hand tools varied from region to region. The workers adopted different awkward postures during performing different tasks of different vegetable cultivation and they are also compelled to adopt different inappropriate postures during working with conventional hand tools. In that connection, they had to suffer from postural stress and musculoskeletal disorders.

1.1 Problem Statements of the Study

As mentioned earlier, the workers engaged in potato cultivation are economically poor. Due to poor economic constraints they may suffer from nutritional deficiency. On the other hand socioeconomic and nutritional factors may influence the occurrence of musculoskeletal problems. Therefore, efforts should be made to evaluate socioeconomic and nutritional status of the workers.

Potato cultivators may suffer from different work related stresses. There may be some causative factors for the occurrence of work related stresses. Whether the factors like, faulty work method, unusual workload, restricted posture and others involved in the potato cultivation may be studied. The occupational stresses may also have definite effects on the body. One or more of these factors leads to work related musculoskeletal disorders (WRMSD), physiological strain, injuries and accidents. It may leads to disability of the workers. The stresses can be evaluated by assessing physiological and biomechanical parameters. Moreover, ergonomic intervention has definite role to alleviate it.

In some of the cases, traditional work method and poor design of hand tools also impose postural stress which in turn adds to physiological stress. During performing different tasks of potato cultivation they have to adopt different complex postures, ranging from bending, squatting, twisting etc. Some of the postures, which are adopted by them, are very harmful. But they are compelled to adopt those postures during work for a prolonged period of time. Bending and squatting posture leads to postural stress in the body of the workers. In the present study efforts have been made to evaluate postural stress of the workers.

The workers perform repetitive tasks. They are required to use different tools during performing different tasks of potato cultivation for a long time. Hand tools are used to enhance the physical capabilities of workers. However, poor design and excessive use of hand tools may impose biomechanical stress and were found to be the major cause of work-related injuries associated with cumulative trauma disorder (Meena and Dangayach, 2015). To prevent and alleviate cumulative trauma disorder, appropriate tools designed and used for workers and their tasks are needed. In order to design a hand tool, one needs to calculate the necessary dimensions of a hand tool which in turn depend upon comfort conditions for a worker. Anthropometry and biomechanics are applied sciences that study the physiological capabilities and limitation of people in the workplace. Knowledge of body size or anthropometry is essential for designs of industrial or agricultural tools or appliance and work places. These body measurements can then be used to improve the fit of the workplace to the worker.

The potato cultivators commonly use a hand tool, small spade, for preparing the land for sowing the seeds. The said tool is smaller in size than the conventional spade. It is used for making tunnels in the ground. The existing small spade is conventionally designed without considering the human factors. As a result they have to face different job related problems. The hand tool used by the workers should be evaluated from the viewpoints of ergonomics and considering human factors. In the present investigation efforts have been made to evaluate and redesign the spade so that it becomes compatible for the users and may capable of reducing job related hazards and enhancing efficiency of the workers.

The ground nut cultivators required to detach the groundnut (pods) from the root of the plant manually by the hand. This manual process may cause injury to the fingers and other parts of the hand. This may also lead to WRMSDs in different segment of the body especially in hand-arm systems during plucking the nut. Therefore, efforts has been made to design of a hand tool, named as nut plucking tool, considering the ergonomic principles, which may reduce the job related hazards of the workers and may enhanced the productivity.

Review of Literature

Chapter II

Contents

Agriculture plays an important role in economic development of developing countries. The International Labour Organization (ILO) estimated that the agriculture sector employs about 1.3 billion workers worldwide which were about half of the world's entire work force (ILO, 2003). Agricultural sector continues to be an important component of Indian National Economy with a contribution of about 22 percent to the GDP (Kwatra et al. 2010). India is the 2nd largest producer of rice in the world after China and 2nd largest vegetable and 3rd largest fruit producer in the world (Kwatra et al. 2010). In the most recent Census in India, (2011) there were over 144.35 million agriculture workers in India, which was about 58.4% of the total population of the country (Census of India, 2011). Among them the number of male and female agricultural workers was about 82.76 million and 61.59 million respectively. In West Bengal State total agricultural workers was about 1.02 million (Census of India, 2011).

Ergonomics studies on agricultural activities have been made in different countries in the world. In most countries, agriculture is recognized as one of the most hazardous industries (Osborne et al. 2012; Karukunchit et al. 2015). In Asian countries, farming activities are performed manually in extreme environmental conditions. Most tasks involve repetitive motion, awkward postures, heavy lifting, prolonged standing, and control of heavy machinery. Farmers go barefoot when working (Karukunchit et al. 2015). There is a host of injuries and illnesses in agriculture that have been consistently identified through epidemiological and community-based studies as in need for controlling due to their high reporting rates among agricultural workers. These include musculoskeletal disorders (MSDs), respiratory disease; noise induced hearing loss and pesticide-related illnesses (Parekh and Phatak, 2014). However, it has been consistently shown that MSDs are the most common of all occupational non-fatal injuries and illnesses for farm workers, especially those who are involved in labor-intensive practices (Parekh and Phatak, 2014). Ergonomics investigation as well as its application may solve many of the human factor related problems of agricultural workers. In the present study, investigations have been made on the workers who are mainly engaged in vegetable cultivation tasks, especially in potato cultivation and groundnut cultivation. Literature survey revealed that the studies on the above occupation (potato cultivation and groundnut cultivation) are scanty. However, a number of related studies regarding the nutritional and socioeconomic status, occupational health problem of agricultural workers and the design of hand tools have been noted in the literature. Some of the important studies are pointed out here.

2.1 Health Problems of the Agricultural Workers

The problems of agricultural tasks in developing countries like India are somewhat different from that of developed countries. Farmers are at very high risk for fatal and non-fatal injuries; and farming is one of the few industries in which family members (who often share the work and live on the premises) are also at risk for fatal and non-fatal injuries (NIOSH 2013). Farming as an occupation has a number of unique characteristics compared to other occupations, such as worker traits and behavior, the work setting and organizational structure (Cha et al. 2009). It is not an organized sector to provide workers with safety regulations or stable and flexible finances and is subjected to various uncertainties like changing weather, ergonomics stress and viruses associated with weather and new forms of chemical fertilizers and insecticides (Prince, 2006). Environmental and lifestyle factors for disease prevalence among farmers are likely to vary between countries (Cha et al. 2009). As there is a considerable amount of physical labour in agricultural jobs, ergonomic hazards and associated musculoskeletal disorders have become an increasingly recognized occupational challenge in farmers. Thus the health of agricultural worker is always at risk.

A number of studies have suggested a unique pattern of morbidity and mortality among farmers (Fleming et al. 2003; Blair et al. 2005; Cha et al. 2009). Farmers have a remarkable deficit in total mortality, cardiovascular diseases, diabetes mellitus, psychiatric disorders and total cancer compared with the other populations, but appear to have higher prevalence rates of musculoskeletal diseases, respiratory diseases, hearing loss, skin disorders, accidental death and cancer of the skin, stomach, brain, and prostate, as well as the nervous, lymphohematopoietic systems (Fleming et al. 2003; Thelin et al. 2009; Ehlers and Graydon, 2011; Hamid et al. 2014; Samani et al. 2015). Cha et al. (2009) reported that prevalence of chronic lung diseases was higher in farmers than in other occupational groups. A recent case study on adverse health effects of pesticides among occupationally exposed farm sprayers in Bhopal, Madhya Pradesh (Choudhary et al. 2014) showed that the farmers were suffering from burning/stinging of eyes, blurred vision, skin redness/itching, excessive sweating/ shortness of breath, dry sore throat and burning of nose. Behera et al. (2005) studied on the respiratory problem among Indian farmers and noted that about 21.8% of workers had symptoms of chronic bronchitis or bronchial asthma or complained of chest tightness, post nasal drip, dyspnoea and cough. Egharevba and Iweze, (2004) reported that the agricultural workers were suffered from health problems such as muscular fatigues, fever, dermatitis, migraines, respiratory diseases, impaired vision and hearing due to exposure of extreme temperature, use of chemicals, fertilizers, dusts and insect bites. Cha et al. (2009) stated that farmers had higher chronic disease prevalence than other occupational groups. They also reported that arthritis was the most prevalent chronic disease among farmers. Compared with other populations, farmers demonstrated a higher prevalence of arthritis and intervertebral disc disorders. High prevalence of arthritis and intervertebral disc disorders in farmers was consistent with previous studies that had indicated that farmers had higher rates of musculoskeletal diseases than other populations (Davis and Kotowski, 2007). Numerous physical risk factors are integral to farming, such as high workloads, heavy lifting, bending and twisting, exposure to vibration from farm equipment and performing tasks while in awkward postures (Caicoyal and Delclos, 2010; Da-Costa and Vieira, 2010; Das and Gangopadhyay, 2012; Pal et al. 2015a). These have been associated with an increased risk of acquiring musculoskeletal diseases such as osteoarthritis, low back pain and neck and upper limb complaints (Nonnenmann et al. 2008).

2.2 Musculoskeletal Disorders

Musculoskeletal disorders (MSDs) include a range of inflammatory and degenerative conditions that can affect muscles, tendons, ligaments, joints, peripheral nerves, blood vessels, and supporting structures such as cartilage and vertebral discs (Osborne et al. 2012). The term MSDs encompass a variety of conditions, ranging from those that have an acute onset and a short duration to lifelong disorders (Woolf and Pfleger, 2003). MSDs can be caused by wear and tear or damage to the joints and bones but also include autoimmune diseases and genetic diseases. MSDs account for a significant proportion of the disease burden and have considerable economic implications. Work-related MSDs may be caused by, aggravated, or precipitated by intense, repeated, or sustained work activities with insufficient recovery (Yang, 2012). The most frequently affected body regions in the working population tend to be the low back, neck, shoulder, forearm, and hand (Punnett and Wegman, 2004).

Woolf and Pfleger, (2003) reported that the prevalence of MSDs was higher among female than male and shows a steeped increase with age. Indeed, one of the major challenges of an aging population was the increasing burden of MSDs (BMUS, 2008). Along with obesity and the overuse of joints, age was one of the major risk factors for developing an MSD (Yelin et al. 1999). The link between aging and MSDs does not mean that MSDs were not present in or relevant to the working-age population. There were several other conditions that people were likely to experience alongside an MSD. People often do not experience one MSD in isolation, and many will experience multiple MSDs simultaneously (Dall et al. 2013). MSDs can also be linked to mental health conditions, with the presence of an MSD signalling an increased likelihood of experiencing mental illness. Individuals with MSDs were likely to experience pain as part of the condition, and depressive symptoms and conditions were more likely to be found in people living with pain (Reme et al. 2012). Another study found that among individuals with low back and/or neck pain, the following co-morbidities were significantly more likely: respiratory, cardiovascular, gastrointestinal, chronic pain, other musculoskeletal conditions and other chronic conditions (Liao and Solomon, 2013).

MSDs can be linked to lost workdays and wages, reduced productivity, early retirement and unemployment. The consequences of MSDs were significant for the employee who is experiencing an MSD as well as for the employer. MSDs were the greatest single cause of lost workdays and medical bed days in the United States (BMUS, 2008). The U.S. Bureau of Labor Statistics notated that MSDs accounted for 29% of all illnesses and injuries that required days off work (Summers et al. 2015).

2.2.1 Musculoskeletal Disorders in Agriculture

Agriculture is seasonal in nature; in addition, the vast unorganized working sectors are constantly confronted with adverse work environment. Agricultural tasks are carried out mainly through manual efforts and considered one of the most hazardous occupations. Agricultural workers are exposed to many occupational hazardous. Thus the workers engaged in agricultural work are suffering from various kinds occupational health hazards. One of the most common health hazards is work-related musculoskeletal disorders (WRMSDs) risks factors which are associated with different tasks of agricultural work. There are numerous varieties of WRMSDs that are reported in agriculture. These include disorders of the back and neck, nerve entrapment syndromes, musculoskeletal disorders such as tenosynovitis, tendinitis, peritendinitis, epicondylitis and nonspecific muscle and forearm tenderness (NIOSH, 1997; Summers et al. 2015). The majority of the farm workers reported that the MSDs is non-specific and lacks a well-defined clinical diagnosis (NRCIM, 2001). Das et al. (2013) investigated child work in agriculture in West Bengal and reported that the child agricultural workers suffered from pain especially in the low back (98%), knees (88%), hands (82%), shoulder (77%) and neck (68%). They also reported that, among the activities in potato cultivation, the child potato workers felt discomfort during spading (99%), sprinkling water (90%) and picking crops (87%). Nilsson et al. (2009) surveyed injury frequency among the farmers in Sweden and stated that seventy-nine percent of the farmers injured had been severely injured to the point that they had to seek medical help. Agricultural work related injuries among the farmers in West Bengal were studied by Das, (2014a) and he reported that the rate of injuries among male and female agricultural workers were 8.99 per 1000 workers per year and 7.89 per 1000 workers per year respectively. Fingers of both limbs were the most affected parts of the body followed by feet, ankle, hand, wrist and lower back. He reported that the leading external causes of farm injury were hand tools (64.7%) and farm machinery (29.1%). The most frequently involved tools in hand injuries were spade and sickle. MSDs are the most frequent cause of severe long term pain and physical disability (Woolf and

Pfleger, 2003). In addition to causing pain, suffering, illness and injury, they can also result in reduced work ability and, consequently, reduced farm income, poor quality of life such as limited social interaction arising from MSD reduced mobility, and the onset of other health problems such as stress (Whelan et al. 2009; Dall et al. 2013; Summers et al. 2015). Work-related MSDs are not typically the result of an acute or instantaneous event but rather the result of chronic development (Rwamamara et al. 2010).

2.3 Risk Factors for Musculoskeletal Disorders

The origin of MSDs is complex and multi-factorial. Many factors such as heavy lifting, high job demands, awkward postures, prolonged work activity etc have been identified as causes of work related musculoskeletal disorders (Thelin et al. 2009; Das and Gangopadhyay, 2012; Goswami et al. 2012; Pal et al. 2015a). Ergonomic workstation helps in the reduction of work related musculoskeletal disorders and stress as well as throws an opportunity to have better work performance for better and faster production. However, other factors are the sex, age, body mass index (BMI), lifestyle factors etc which influences the musculoskeletal disorders even in a developed ergonomic setup. Woolf and Pfleger, (2003); Sabharwal and Kaushik, (2011) and Das, (2015) reported that the female had a higher prevalence of MSDs compared to the male. Woolf and Pfleger, (2003); Fejer and Ruhe, (2012) and Keller and Engelhardt, (2013) reported that MSDs prevalence was significantly increased with the advancement of age. Overweight/obesity has been shown to increase the risk for musculoskeletal pain (Bihari et al. 2011; Moreira-Silva et al. 2013). Obesity was associated with negative consequences in working populations, including more frequent absenteeism, workplace injury and higher health care costs (Linde et al. 2012).

The farmers are exposed to a variety of physical hazards: lifting and carrying heavy loads, working with the trunk in sustained flexion, repetitive motion, excessive force, awkward and/or sustained postures, prolonged sitting and standing, and exposure to vibration from farm vehicles and power hand tools (Caicoyal and Delclos, 2010; Da-Costa and Vieira, 2010; Pal et al. 2014b; Pal et al. 2015a).Those hazards are the risk factors for the occurrence of MSD. Many farm work tasks were physically very strenuous, and farmers and farm workers were at particular risk of developing MSDs compared with other occupations (Thelin et al. 2009; Das and Gangopadhyay, 2012; Osborne et al. 2012). As the consequences of these problems were of major significance for farmers and farm households, risk factors needed to be identified and assessed if targeted public health campaigns were effective. Punnett and Wegman, (2004) explained that there was near international consensus that MSDs were causally related to occupational ergonomic stressors such as repetitive motions, forceful exertions, nonneutral postures, vibration and so on. Al-Rahamneh et al. (2010) pointed out in their studies that those performing highly repetitive tasks for prolonged period had higher prevalence of pain at different segments of their body. Several studied showed that the prevalence of low back pain in farmers was higher than other manual laborers (Davis and Kotowski, 2007; Cha et al. 2009; Osborne et al. 2012). The risk factors for the occurrence of low back pain as indexed by many researchers are awkward postures, lumbo-spinal strain, high repetition, excessive forces, intense physical work, etc. (Baker et al. 2003; Gallagher et al. 2005; Todd, 2008). Besides the biomechanical risk factors, work-related psychosocial factors were also associated with higher prevalence of WRMSD. Literature survey reported that the associations between MSDs and work-related psychosocial factors such as high work load/demands, high perceived stress levels, low social support, low job control, low job satisfaction and monotonous work (Westgaard, 2000, Caicoyal and Delclos 2010). Gerr et al. (2014) found that psychosocial stress and job change are also predictors of MSDs when personal characteristics and occupational exposure to physical factors are controlled for. In a recent study (Gerr et al. 2014) it was found that when compared with jobs that offered low-demand and high-control working conditions, there was a large increase in the risk of developing hand or arm MSDs for both high-demand/high-control and high-demand/low-control job categories. WRMSD were also influenced by socio economic condition of the workers (Boyer et al. 2009). Working conditions of agricultural works were extremely difficult due to severe environmental conditions, long working hours, strenuous work and the use of improper equipment. The ignorance of the majority of ergonomics principles in the design of agricultural equipment makes the conditions more difficult (Mamansari and Salokhe, 1995). Occupational factors have also been found to improve or delay recovery. Gatchel (2004) reported that a combination of workplace factors (a high-demand and/or low-control working environment, the employee perceiving that the style of management in the workplace was unhelpful, an employee's belief that he or she was working under time pressure and a belief in or actual poor social support from colleagues) contributed to slower recovery rates.

2.3.1 Postural Stress during Work

The human body can adopt various types of postures according to the need of their jobs. The importance of a good working posture has long been recognized for good and healthy life. A good posture becomes even more important when forceful tasks are performed. Posture is as important for the performance of tasks as it is for promoting health and minimizing stress and discomfort during work. Gallagher, (2005) and Gerbaudo and Violante,

(2008) very clearly showed in their studies that the relationship between work posture and the operator's efficiency. They showed how poor working postures lead to postural stress, fatigue and pain, which may in turn force the operator to stop work until the muscles recover. They suggested that pain rather than capacity may often be the limiting factor to performance or productivity in industry. According to Haslegrave (1994), in order to arrive at a definition of a 'good working posture', it is necessary to understand the factors, which will lead a person to choose a posture to perform a particular task. The view put forward by Van-Oostrom et al. (2009) is that a posture is the position adopted because it is appropriate for the task being performed. There was ample evidence showing a strong association between work posture and musculoskeletal disorders. While working farmers are exposed to various potentially poor postures like excessive bending, twisting, kneeling, squatting, static and awkward stoop postures, etc. All these are the predisposing risk factors associated with various musculoskeletal disorders. In a recent study on multiple crop farming (potato, wheat, rice and watermelon) farmers by Gupta and Tarique (2013) it was noted that the farmers who were mainly involved in potato cultivation reported more of knee pain, farmers of wheat and rice crop reported more of lower back pain and farmers of watermelon reported relatively more pain in neck and shoulder region. Gupta and Tarique (2013) explained the possible reason of this variation in discomfort region as per nature of crop was from the difference in nature of posture adapted or repetitive movement done by the farmers. Gupta and Tarique (2013) reported that farmers who do watermelon farming, they need to use spade for preparing land. This involves repetitive shoulder and neck flexion and extension movement. These all could explain the involvement of neck and shoulder joint in these farmers. Farmers who are mainly involved in potato cultivation need to stay in squatting position for most of the time in the fields. This type of posturing puts excessive pressure on knee joints. Activities like squatting involve eccentric contraction of quadriceps muscles group.

2.3.2 Physiological Stress

As the agricultural workers are required to perform strenuous jobs they have to suffer from cardiovascular strain. From the physiological point of view, the job demand or work load refers to the demands placed on the cardio-respiratory system and is determined by the energy cost and cardiac cost of work (Dey et al. 2007). Heart rate acceleration is the main cardiovascular response to demands for the increased oxygen necessary for the performance of physical work, over and above that required at rest. Heart rate increases linearly with the work performed. Kadoya et al. (2010) also explained that increase in heart rate is linear with the increase in the rate of activities. (Kwartra et al. 2010) studied on Indian agricultural operators to assess the occupational workload on the basis of individual capacity to perform work was conducted. A significant reduction of heart rate, energy expenditure rate, total cardiac cost, and total cardiac cost of work was observed by means of using modified method. (Yadav and Pund, 2007; Dewangan, 2007).

Hasalkar et al. (2004) studied to know the workload of agricultural workers in weeding activity. The results revealed that, the total cardiac cost of work while weeding was 6165.87 beats and the physiological cost of work was 14.67 beats/min. The average working heart rate during weeding was observed to be 94.36 beats/min and the average energy expenditure was 6.28 kj/min. Goel et al. (2008) also studied on wedding operation and it was found that the heart rate, oxygen consumption rate and energy consumption rate increases with decrease in soil moisture content for all the treatments. Kishtwaria et al. (2004) study the physiological workload of the workers engaged in plucking tea leaves. The average working heart rate values were up to acceptable limits whereas, the peak heart rate values (HR 25-35 – 110.93; 111.44; HR 35-45 – 106.22, 110.58 beats/min) were beyond acceptable limits. Both average and peak heart rate values were significantly related with elder age group, indicating work to be stressful especially with increase in age. Thus, it is recommended to generate awareness regarding faulty working habits and to develop women friendly technologies to improve efficiency and output of women workers.

In any activity requiring physical effort, work is performed at the expense of energy. The amount of energy spent, however, depends on the level of physical activity. The energy expenditure, a physiological parameter, has been in broad use in the evaluation of muscular effort. The efficiency of any physical activity varies according to the type of activity and manner in which it is performed. Knowledge of physiological cost of work will be of immense use in providing necessary changes required in the work environment, work place and method of performing the task. Nag and Dutta, (1980) conducted an extensive study on Indian agricultural workers to assess the occupational workload on the basis of cardio-respiratory responses and individual capacity to perform work. They classified the work intensity of agricultural operations in terms of ‘light’, ‘moderate’, ‘heavy’ and ‘extremely heavy’ which corresponds to energy cost values and OCR. A linear relationship between heart rate and oxygen consumption rate was also observed and regression equations have been suggested for estimating the oxygen consumption rate of farm workers from their measured heart rate data for agricultural activities (Singh et al. 2008). Generally heart rate is used as an ergonomic measure to evaluate the physiological demands of work on the individual workers (Hasalkar et al. 2004).

2.4 Design of Users Friendly Tools and Equipment

The use of equipment, hand tools and other mechanical aids in agricultural activities may enhance the productivity, ensure safety and lessen the work related health problems. Hand tools are used in most of industrial works to enhance the physical capabilities of workers. However, poor design and excessive use of hand tools were found to be the major cause of work-related injuries associated with cumulative trauma disorder. Higher level of occupational stress some time occurs due to ill design of hand tools. Deteriorate on workers' health and their suffering are inaccessible whilst economic lost from worker remedy and compensation is enormous. To prevent and alleviate cumulative trauma disorder, appropriate tools designed and used for workers and their tasks are needed.

Vyas et al. (2014) investigated on the tools used by the apple cultivators in Himachal Pradesh and recommended that introduction of improved design of horticultural tools could reduce the discomfort feeling of the apple cultivators. Another study was done by Pranav et al. (2014) on orange cultivators and concluded that it was essential to develop a new model of tools for better suitability of the workers based on the problems of the cultivators. Joshi et al. (2014) reported that the improvement and the modification of the existing tools, equipments, machinery and method of work has significant effect in minimizing in human strain and fatigue and increase farm productivity. By developing such small tools, the work and work environment can be improved, physiological workload can be reduced and the efficiency and work out put can be improved significantly. In order to ensure health, safety and well being and there by improving the quality of work life and achieving higher productivity, it is essential that workstation must be designed ergonomically and should be user friendly (Hasalkar et al. 2007).

The goal of ergonomics is to design jobs and tasks around the user's limitations and capabilities. Thus the design of the system must incorporate the worker, equipment and environment as a whole. Task analysis is one of the basic tools that an ergonomist has to design and evaluate systems (NIOSH, 2008). Ergonomically well-designed models and tools which provide comfort to the user, decrease the risk of occupational health problems and increase the job performance (Kuijt-Evers, 2009). Naidoo et al. (2009) reported that ergonomic interventions including improved and adapted work techniques and tools should be considered to reduce the prevalence of pain. A study was performed by Oulakh et al. (2014) on ergonomic evaluation of hand tool (electrical chapatti maker) and they revealed that it was necessary to create awareness among the women for the proper usage of the product.

Literature survey reported that, improving the design of the various hand tools reduces work related problems (Claudon, 2006; Trejo et al. 2007; Bhattacharya et al. 2008; Mukhopadhyay and Srivastava, 2010a). Considering this approach, before the correct model of an ergonomic design, different hypothetical models might be reasonable and consistent with previous knowledge and available data of size, shape, length, diameter, texture etc. Research conducted by different groups of investigators have been reported that factors size, shape, handle length, texture substantiality affect the potential of repetitive use of hand tools for development of WRMSDs (Karwowski et al. 2003a, Kong et al 2008). In order to design a hand tool, one needs to calculate the necessary dimensions of a hand tool which in turn depend upon comfort conditions for a worker. Mismatches between human anthropometric dimensions and equipment dimensions are known to be a contributing factor in decrease productivity, discomfort, accidents, biomechanical stress, fatigue, injuries etc. Finding suitable hand tool models is an important task in ergonomics or biomedical engineering and necessary for better comfort, less prone to WRMSD. As point out Xiao et al. (2005), anthropometric data are essential in order to design safe and efficient workplace, equipment and tools. Anthropometric data is very much useful in design purpose concerning with human. Without such data, the designs cannot fit people who are going to use these. Thus the information about human body dimension is essential to be implemented in the design of various facilities. Tewari et al. (2007) also concluded that anthropometric data would be useful in the design of small farm tools, implements and farm machines. A study was carried out to collect anthropometric data on male and female agricultural workers of Meghalaya belonging to the Khasi, Jaintia and Garo tribal communities with Mongolian origins (Agrawal et al. 2009). The 5th and 95th percentile values of different strength parameters were estimated, which needs to be taken in to consideration while designing the various machinery controls.

From the above discussion it is concluded that few agricultural specific survey has been conducted on Indian vegetable cultivators, especially in West Bengal. There are many lacunae for ergonomic evaluation of different jobs of vegetable cultivation in order to provide safe and comfortable work environments to the workers. Ergonomic intervention on equipment and hand tools of vegetable cultivators is also lacking. So, ergonomic interventions are very much required to assess occupational stress level of vegetable cultivators and also for designing of the hand tool used by the vegetable cultivators from the ergonomic viewpoint. This lacuna inspired us to provide an ergonomic intervention to the vegetable cultivators and agricultural hand tools. In order to fulfill this, in the present investigation, some efforts have been given to evaluate the WRMSD, work-rest schedule analysis, postural stress analysis, hand tool design in Indian context.

Aim & Objectives

Contents

Chapter III

3. Aim and Objectives

Even today, Indian agriculture depends to a very large extent on manual labour, although modernization has reached some parts of the subcontinent. Agricultural works are executed by manual labour and perhaps more than any other occupational group; agricultural workers are exposed to a tremendous variety of postural and physiological stresses. These manual operations may be physically and physiologically demanding and are commonly regarded as a source of the drudgery that is potentially harmful to their health and well being. They may therefore be considered to be suitable for ergonomics intervention.

The aims of this study are to assess the occupational stress of the potato cultivators and to make some ergonomic intervention for reducing the work related stresses of the workers engaged in different jobs of potato cultivation.

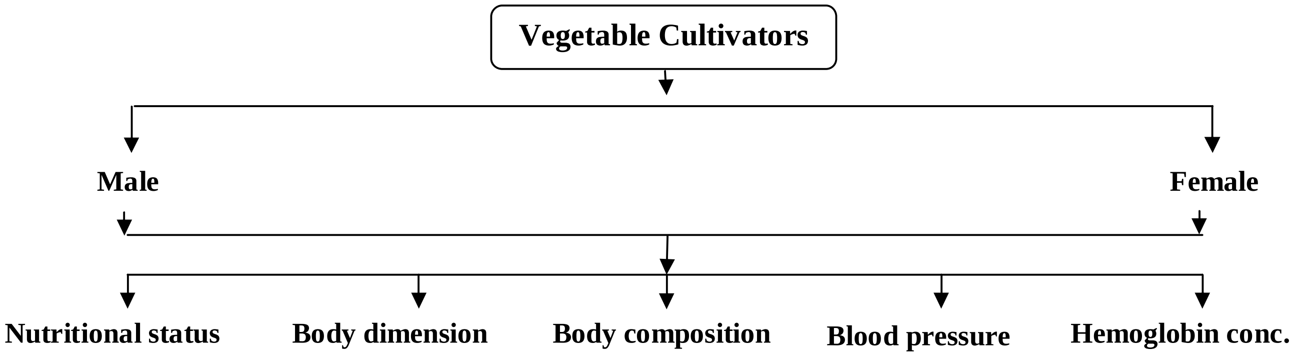
The followings are the objectives of the present investigation:

a) Evaluation of work related musculoskeletal disorders (MSDs) of potato cultivators
b) Evaluation of physiological stress of potato cultivators
c) Evaluation of postural stress of potato cultivators
d) Ergonomic design of hand tools (small spade and ground nut plucking tool).

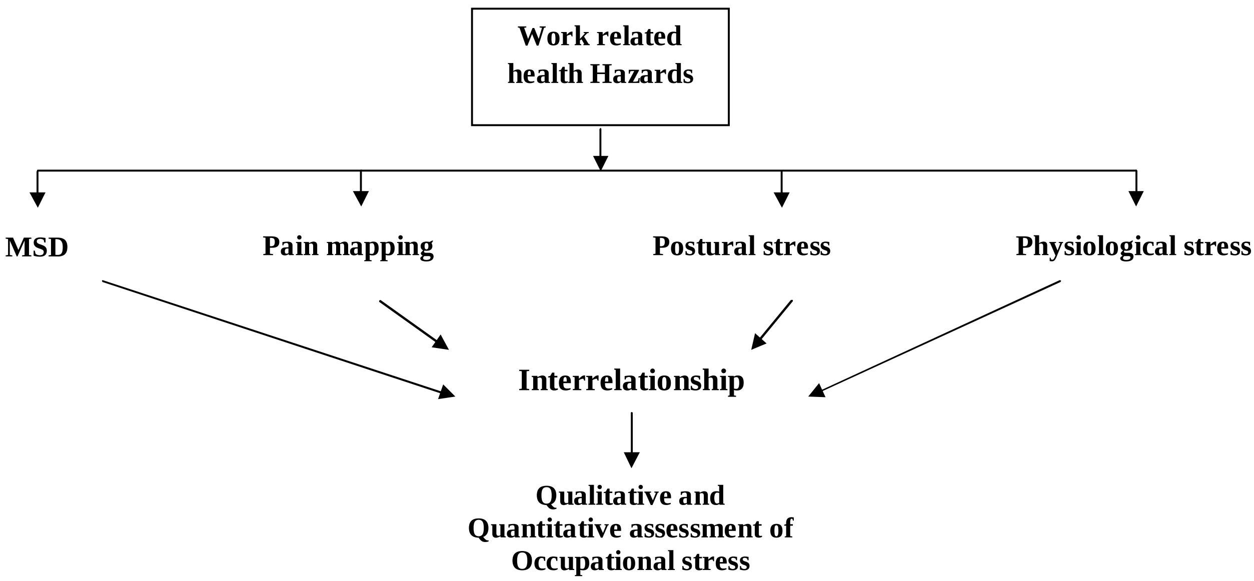
3.1 Experimental Design

To fulfill the above objectives the experiments was done in different phases. For each phase separate experimental design was made. Experimental designs are as follows:

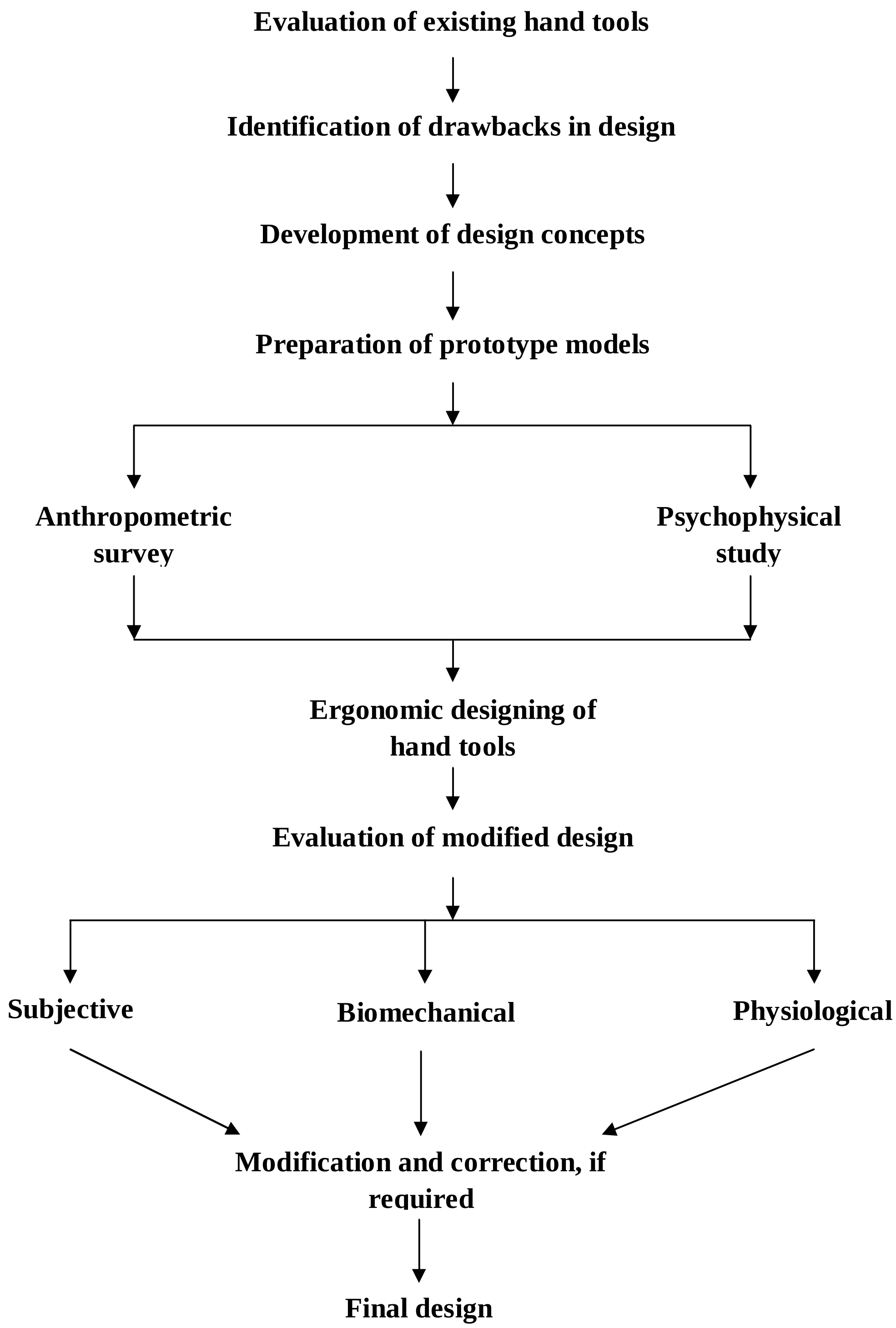
Phase-1: Assessment of general health status: In this phase, nutritional status, body dimensional and physiological parameters of vegetable cultivators were evaluated.



Phase-2: **Evaluation of work related health hazards**: In this phase, MSD, pain mapping, postural stress and physiological stress of vegetable cultivators were evaluated.



Phase **- 3: Designing of hand tools-** In this phase two hand tools (small spade and ground nut plucking tool) were designed by using anthropometric data of the user population and considering psychophysical responses of the users. This newly designed hand tools were tested again to evaluate its suitability and acceptability of the users.



Methodology

Chapter IV

Contents

4.1 Selection of Site and Subjects

The present investigation was carried out on vegetable cultivators only. The participants were selected from different villages of Midnapore (East and West), Bankura and Howrah districts of West Bengal state, India. A total number of 692 participants were included in this study. Among them, 353 were male and 339 were female. The age range of the participants was 18–60 years. Ethical approval and prior permission was obtained from the institutional Ethics Committee before commencement of the study and the experiment was performed in accordance with the ethical standards of the committee and with the Helsinki Declaration. Prior to the experimental trial, the protocol was explained verbally in local language (Bengali) and informed consent was obtained from the participants. They were measured on the same day or another as per their agreement by fixing prior appointments. Some of the parameters were studied on the total number of selected participants. However, in case of a few parameters like, cardiovascular stress, blood lactate, postural analysis and tests included in the designing of hand tools were studied in lesser number of participants, as mentioned in respective chapters and tables.

4.1.1 Inclusion Criteria

The eligibility criteria for recruitment of the participants for the study were age 18 to 60 years, having at least one year experience in performing potato cultivation job, apparently healthy, not suffering from any acute illness, not having any physical deformity and who were self satisfied with their normal day-to-day work schedule at the time of measurements were enrolled as participants in the study.

4.1.2 Exclusion Criteria

Participants with background of heart disease, chronic hypertension, diabetes mellitus, respiratory diseases, orthopedically challenged or accident affecting musculoskeletal system were excluded from the study. Pregnant and lactating women were also excluded from the study.

4.2 Study of Socioeconomic Status

The socioeconomic status of workers was evaluated by modified Kuppuswami scale (Kumar et al. 2013). The educational level of the participants was evaluated by questionnaire technique. The participants were grouped to illiterate, primary educated, upper primary educated, secondary educated, etc. From the response of the participants, total monthly income of the family was noted. The socioeconomic status of the workers was determined by the scores suggested in this scale. The score obtains by each participants in education, occupation and income were added to get the final score and accordingly the participants were categorized. Five different categories from the lower to upper have been suggested in this scale. The questionnaire of the modified Kuppuswami scale of socioeconomic status has been given in Appendix-I.

4.3 Measurement of Body Dimensions

Different anthropometric measurements of the cultivators were taken by adopting proper land mark definition (Ermakova et al. 1985) and standard measuring techniques (Weiner and Lourie, 1969; Stewart et al. 2011). Fourteen hand dimensions which were considered useful for agricultural hand tools designing, were measured from both male and female participants. The equipment consisted of an anthropometer (Holtain), sliding caliper (Holtain), steel tapes and portable weighing machine (Libra). Internal diameter of hand grip was measured using a wooden cone.

All participants were wearing light clothes and were bare footed during measurements. The anthropometric definitions used in this investigation are summarized below.

1. Weight: The body weight of the participant was measured by a portable weighing machine with an accuracy of 0.1 kg.
2. Stature: The vertical distance from floor to the vertex. The head is oriented in the eye-ear plane.
3. Arm length: Have the participant stand with his arms straight at his side with his hands and fingers in line with the forearm. The measurement is taken from the acromion to the dactylion III.
4. Upper arm length: Have the participant stand with the right upper arm hanging at the side and the elbow flexed at 90 degrees. Make sure the hand is straight and the palm is facing in. Follow the scapula out to the shoulder. Mark the outermost point, which is the acromion process. The olecranon process is the tip of the elbow when it is flexed at 90 degrees. While standing behind the participant, measure the distance from the acromion to rediale.
5. Forearm length: Have the participant stand with his arms straight at his side with his hands and fingers in line with the forearm. The measurement is taken from the radiale (identified as the bony process on the outside of the elbow) to the stylion landmark (the bone on the thumb side of the wrist).
6. Hand length: The straight distance between root of the palm and tip of the middle finger.
7. Palm length: The straight distance between root of the palm and root of the middle finger.
8. Digit lengths: Participant was asked to stretch the fingers. Then the length of each finger was measured by a sliding caliper from the fold of the skin at the end of the palm to the tip of the fingers.

9. Hand breadth: The breadth of the palm measured at the level of the maximum bulge of the palm excluding thumb.
10. Maximum hand breadth: The breadth of the hand measured at the level of the maximum bulge of the palm including the thumb.
11. Hand grip circumference (inner): Maximum inner curvature of the hand at the touching level between tip of the middle finger and thumb.
12. Fist girth: Fist girth was measured by wrapping the steel tape around the hand when the hand was closed with the thumb.

4.4 Nutritional Status

Nutritional status of the participants had been assessed by the two methods:

4.4.1 Nutritional Assessment

Nutritional status of the participants evaluated by questionnaire method. For this purpose 24 hours recall method was employed (Swaminathan, 1999). From the quantity of the food consumed by the participants, the amounts of energy, carbohydrate, protein, fat, minerals and vitamins were calculated by using ICMR (ICMR, 2009) food composition table.

4.4.2 Anthropometric Index [Body Mass Index (BMI)]

Anthropometric measurements are the useful tools for the nutritional assessment, particularly in the field condition where it is difficult to conduct clinical and laboratory test (Johnston, 1981). Weight and stature are the two basic measurements used for assessing nutritional status (WHO, 1986). Though the pattern of growth and physical state of a subject is mostly genetically determined and affected by other factors such as frequent illness due to infection or infestation, but it can also be said that diet and nutrition have also profound influence on the growth of the subject. From this viewpoint, anthropometric measurements are the useful parameters for assessing nutritional status.

In the present study, from measures of height and weight of the male and female workers, the body mass index (BMI) was computed by the following formula (Park, 2005).

BMI = Weight (kg) / Height^2 (mt)

4.5 Body Composition

The body composition of the participiants was determined by measuring the skin-fold thickness. The chest, abdomen and thigh skin folds were measured in male participiants, whereas triceps, suprailium and thigh skin folds were taken from female participiants. The skin fold caliper (Holtain) was used for these measurements. The measurements were taken under standardized condition and using proper landmarks (Jhonson and Nelson, 1986).

The anatomic sites that were used for skin fold measurements are as follows:

1. **Chest:** Midway between the anterior fold of the axilla and the nipple.
2. **Triceps:** On the back of the arm midway between the acromion process and the olecranon process. The skin-fold was taken parallel to the long axis of the arm.
3. **Abdomen:** A vertical fold about 1cm to the right of the umbilicus.
4. **Suprailium:** Just above the crest of the ilium at the midaxillary line. The fold was lifted diagonally, following the natural line of the iliac crest.
5. **Thigh:** With the subject weight on the left foot, a vertical fold on the front of the right thigh halfway between the hip and the knee.

From the skin fold data, total weight of body fat and lean body weight were determined by the calculating the body density (Jackson and Pollok, 1978; Jackson et al. 1980) and percentage of body fat (Siri, 1956). The following formulae were used:

(a) Body density (gm/cc) for men = 1.10938 – 0.0008276 (sum of chest, abdomen and thigh skin folds in mm) + 0.0000016 (sum of the same three skin folds in mm)^2 – 0.0002574 (age in years)

(b) Body density (gm/cc) for women = 1.0994921 – 0.0009929 (sum of triceps, supraillium and thigh skin folds in mm) + 0.0000023 (sum of the same three skin folds in mm)^2 – 0.0001392 (age in years)

(c) Percentage of fat = {(4.95 ÷ Body density) – 4.50} ×100

(d) Total weight of fat = (Weight in kg × Percentage of fat) ÷ 100

(e) Lean body weight = Total weight (kg) – Total weight of fat (kg)

4.6 General Health Status

4.6.1 Hemoglobin Concentration

The hemoglobin (Hb) status was measured with a fingerprick sample of capillary blood and analyzed immediately using a hemoglobinometer (STAT-Site M Hemoglobin Analyzer, USA). Both male and female participants were classified as mildly, moderately or severely anemic based upon their hemoglobin status following international reference (WHO, 2011). Anemia was defined as Hb of <13g/dl in male and Hb of <12g/dl in female. Mild anemia was defined as Hb of 10-12.9 g/dl in male, Hb of 10 –11.9 g/dl in female. Moderate anemia was defined as Hb of 7-9.9 g/dl and severe anemia as an Hb of < 7 g/dl in both male and female.

4.6.2 Blood Pressure

Blood pressure was measured by auscultatory method, with the help of a sphygmomanometer (mercury type) and a stethoscope (Weiner and Lourie, 1981; Chobanian et al. 2003; Tesfaye et al. 2007). Resting systolic and diastolic blood pressures of the participiants was measured after taking a rest in a sitting position for at least 15 min prior to measurement and again at least 10 min after the first reading. The mean values of three measures were used in analyses. The participiants was classified as normotensive, hypotensive and hypertensive according to the guidelines of the US Seventh Joint National Committee on Detection, Evaluation, and Treatment of Hypertension (JNC VII) (Chobanian et al. 2003).

Normotensive: SBP <120 mm Hg and DBP <80 mm Hg
Hypertensive: SBP ≥ 140 mmHg and DBP ≥ 90 mmHg
Hypotensive: SBP ≤ 90 mmHg and DBP ≤ 60 mmHg

4.7 Occupational Health Hazards

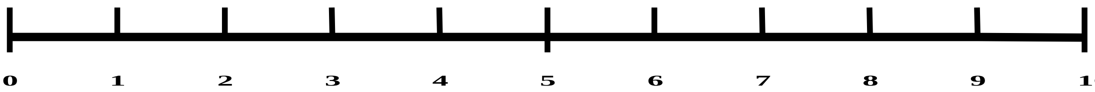
4.7.1 Musculoskeletal Disorder

The musculoskeletal disorders (MSDs) of the potato cultivators were evaluated by using modified Nordic Questionnaire technique (Kuorinka et al. 1987) during performing different tasks of potato cultivation, viz., planting of seeds, tunneling and potato harvesting.

4.7.2 Discomfort Rating

To evaluate the segmental pain, the subjective assessment was employed. Often the assessment of discomfort is administered together with body mapping a method where the perceived discomfort is referred to a part of the body. A 10-point scale was used for this purpose. The scale consisted of marks from 1 to 10 and ranges from just noticeable discomfort to intolerable discomfort. A '0' in the scale meant no discomfort at all and '10' in the scale indicated intolerable discomfort. The mean value of scores (perceived rating of discomfort) of all segments was taken as the overall discomfort rating of the workers. It was a modified pain mapping scale of Corlett and Bishop (1976) as shown in Fig 4.1. The human body was divided into 12 segments (Fig.4.2).

The participiants was asked if he/she experiences discomfort / pain in any part of the body. If so, the participiants was asked to mention discomfort rating, starting zero (no pain) to 10 (intolerable pain) as shown in Fig. 4.1.



The 10 point scale:

0 : No pain	6 : Moderate pain
1 : Discomfortness	7 : Severe pain
2 : Very mild pain	8 : Very much severe pain
3 : Mild pain	9 : Very very much severe pain
4 : Numbness	10 : Intolerable
5 : Average pain	

Fig 4.1: Modified ten point scales to rate the discomfort experienced by the workers

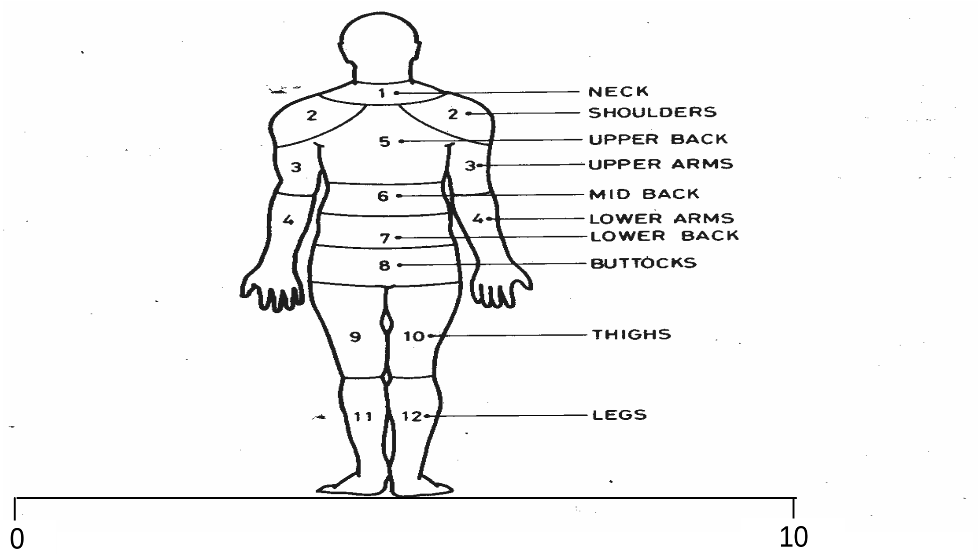


Fig. 4.2: Different segments of the body

According to the degree of severity, the perceived rating of discomfort score of the 10-point scale were divided into three subgroups (Dutta and Dhara 2012), as shown below:

i) Mild pain : Grade 1 to 4

ii) Moderate pain : Grade >4 to 7

iii) Severe pain : Grade > 7

4.8 Evaluation of Work-Rest Cycle

The work-rest patterns of potato cultivators were determined by directly observing their work as well as by taking interviews of the workers (Wilson and Corlett, 1985). The work-rest cycle of different tasks of potato cultivation was studied by noting the actual work time and rest time. The total work shift was divided into work cycle and rest cycle. The rest period is the sum of prescribed rest pause (rest for food break) and job related rest pause (rest taken by the worker for self requirement / or during working hour). The actual work time was calculated by subtracting the actual rest pause from total work time. It was recorded carefully from beginning to end of the work by direct observation method employing video-photography on the job. For this purpose, whole day task performance of the workers were recorded in DVD mode and the recorded DVD run in by media player (XingMPEG player, version 3.30) in the computer after setting a time. After a careful and repeated observation, the whole day work was evaluated and the duration of work time and different rest pauses of the workers were noted.

4.9 Study of Postural Stress

In different phases of potato cultivation tasks, workers were adopted different postures during work. Some of the works are dominated by static muscular contraction and some other works are involved with repeated dynamic activities. Thus, they had to change their posture in different phases of their work, which may lead to different type of postural stress. Thus ergonomics assessment of work postures is one of the starting points to address the problem of work related body pain as the risk of musculoskeletal injury associated with the posture. Researcher proposed different methods for ergonomic assessment of working posture and quantification of ergonomic risk factors. In the present study various techniques have been applied for postural analyses to identify the stress of different phases of potato cultivation.

The postures were chosen from the working images recorded with a camera (Sony Handycam and Nikon SLR) based on posture held for the greatest amount of the work cycle or where highest loads occur. When taking pictures of working postures, the camera was positioned at an angle to the operator so that different dimensional working postures could be identified during playback.

4.9.1 Study of Postural Pattern

The postures adopted in different tasks, viz. planting of seeds, tunneling and potato harvesting were evaluated by direct observation method and video photographic technique mentioned earlier. The duration of different major postures adopted by the workers was recorded minute by minute from the beginning to end of the work. The duration of having food break was excluded from the recording. Proper care had been taken through repeated observation to minimize errors. Afterwards the postural changes were analyzed by using the software Xing MPEG player (Version 3.30). From the above data total duration of adopting a particular posture was calculated.

4.9.2 Postural analysis

Researcher proposed different methods for ergonomic assessment of working posture and quantification of ergonomic risk factors. Ergonomic assessment of work postures is one of the starting points to address the problem of work related body pain as the risk of musculoskeletal injury associated with the posture (Kee and Karwowski, 2007). So, various techniques have been applied for postural analysis to identify the stress of different phases of work. Working postures were evaluated using the OVAKO Working Postures Analysis System (OWAS) method (Heinsalmi, 1986). Although the OWAS method has a wide range of use, the results can be poor in detail (Hignett and McAtamney, 2000). Therefore, the Rapid Entire Body Assessment (REBA) method (Hignett and McAtamney, 2000), Rapid Upper Limb Assessment (RULA) method (McAtamney and Corlett, 1993) and Quick Exposure Checklist (QEC) method (Li and Buckle, 1999) were also applied for analysis work postures of the workers. Researchers (Sahu and Sett, 2010; Mukhopadhyay and Srivastava, 2010b) used several posture analysis methods viz. OWAS, RULA, REBA etc. simultaneously for posture analysis. This was the reason for applying four methods for posture analysis. In all the jobs of potato cultivation continuous movement of upper limb was noted. Thus, the RULA method was applied for posture analysis.

4.9.2.1 OWAS

The OVAKO working postures analysis system (OWAS) was developed in the Finnish steel industry (OVAKO) during 1974-1978 (Heinsalmi, 1986). OWAS identifies four work postures for the back, three for the arms, seven for the lower limbs and three categories for the weight of load handles or the amount of force used. The technique classifies combinations of these four categories by the degree of their impact on the musculoskeletal system for all posture combinations. The degrees of the assessed harmfulness of these posture–load combinations are grouped into four action categories, which indicate the urgency for the required workplace interventions.

- Action category 1: No corrective measures
- Action category 2: Corrective measures in the near future
- Action category 3: Corrective measures as soon as possible
- Action category 4: Corrective measures immediately

The worksheet for OWAS method has been given in Appendix-II.

4.9.2.2 RULA

The RULA technique (Rapid Upper Limb Assessment) was proposed to provide a quick assessment of the loading on the musculoskeletal system due to postures of the neck, trunk and upper limbs, muscle function and the external loads exerted (McAtamney and Coriett, 1993). Based on the grand score of its coding system, four action levels, which indicate the level of intervention required to reduce the risks of injury due to physical loading on the worker, were suggested:

- Action level 1: Posture is acceptable
- Action level 2: Further investigation is needed and changes may be needed

- Action level 3: Investigation and changes are required soon
- Action level 4: Investigation and changes are required immediately

The worksheet for RULA method has been given in Appendix-III.

4.9.2.3 REBA

The REBA technique (Rapid Entire Body Assessment) is a postural analysis system sensitive to musculoskeletal risks in a variety of tasks, especially for assessment of working postures (Hignett and McAtamney, 2000). The posture classification system, which includes the upper arms, lower arms, wrist, trunk, neck and legs is based on body part diagrams. The method reflects the extent of external load/forces exerted, muscle activity caused by static, dynamic, rapidly changing or unstable postures and the coupling effect. Unlike OWAS and RULA, this technique provides five action levels for evaluating the level of corrective actions:

- Action level 1: Corrective action including further assessment is not necessary
- Action level 2: Corrective action including further assessment may be necessary
- Action level 3: Corrective action including further assessment is necessary
- Action level 4: Corrective action including further assessment is necessary soon
- Action level 5: Corrective action including further assessment is necessary now

The worksheet for REBA method has been given in Appendix-IV.

4.9.2.4 QEC

Quick Exposure Checklist (QEC) is an observational method that was developed by Li and Buckle (1998) and enhanced by David et al. (2008). QEC is used to assess the level of exposure to ergonomic risks. The method includes the assessment of the back, shoulder/upper arm, wrist/hand and neck, with respect to their postures and repetitive movement. Information about time spent on task, level of hand force, visual demand of the task and difficulties to sustain with the work as well as the stressfulness of the work are also obtained from the worker. The ratings are weighted into scores and added up to summary scores for different body parts and other items like work pace, and stress. The

QEC checklist/assessment sheet includes questions that need to be answered by the user. These questions are designed to quantify the exposure risk for the four main areas of the body (back, shoulder /arm, wrist, and neck).

The worksheet for QEC method has been given in Appendix-V.

4.9.3 Analysis of Center of Gravity

The location of the center of gravity (CG) in the human body is extremely important in determining the state of equilibrium at any moment. The CG is the point where the sum of all the forces and force moments acting on the body is zero. It is the equilibrium point. So, the location of CG of workers in action requires the use of a good method and a highly useful procedure is one called segmental method (Page, 1978). This technique makes use of a photograph of the participant and involves finding the location of the center of gravity of each of the body segments, the position of these individual gravity points with respect to an arbitrarily placed X and Y axis and knowledge of the ratio between the individual segment weight and the total body weight. With the information on the proportionate mass of body segments and the location of the CG of each segment, the CG of the whole body may now be determined by making use of a principle of moments. The sum of the moments of the individual segments about arbitrarily placed X and Y-axis was produce the location of the Center of Gravity of the whole body with respect to the X and Y-axes. That is, the total body weight acting at the center of mass is the resultant of the combined segment weights acting in their mass centers. The resultant moment of the total body weights about the X, Y-axis is the sum of the individual segment moments about the same axis.

The whole body center of gravity (CG) of the workers was determined in different working postures. The CG of the workers was determined under rest (normal erect posture) and during different work activities. The segmental CG as well as whole body

CG of the workers was determined and the location of the CG was expressed as the percentage of total body length.

The percentage of the location of the whole body center of gravity was determined by the following formula taking ground as the reference:

$$\text{Percentage of location of whole body CG} = \frac{\text{Length of the CG from the ground}}{\text{Length of the whole body}} \times 100$$

The worksheet for CG analysis has been given in Appendix-VI.

4.10 Study of Physiological Stress

Different physiological responses of male and female cultivators were evaluated during performing different potato cultivation jobs. The parameters were discussed below.

4.10.1 Heart Rate

The heart rate of the workers was taken in resting as well as throughout the working period. The heart rate monitor (Polar S610i) was used to determine the resting heart rate as well as a change of heart rate during working condition. The data were transferred to a computer and analyzed by the Polar Precision Performance software.

4.10.2 Cardiovascular Stress Index (CSI)

An index, termed as cardiovascular index, was used to evaluate the degree of cardiovascular stress of the workers. From measured values of both resting and working heart rate of the workers, the Cardiovascular Stress Index (CSI) was determined by the following formula (Trites et al. 1993).

$$\text{CSI} = \frac{100\ (\text{Heart rate during work} - \text{Heart rate during rest})}{\text{Heart rate maximum} - \text{Heart rate at rest}}$$

Where, Heart rate max = 220 – Age (years).

4.10.3 Blood Lactate Level

The blood lactate accumulation (BLA) of the participants was measured in resting as well as in the working periods with the help of a digital blood lactate analyzer (EKF-Diagnostic GmbH, Germany). Before drawing blood from the finger tip, the workers were asked to wash their hands with soap and their hands were dry. A test strip was inserted into the strip inlet. A drop of blood was collected with the help of a lancing device. The blood was drawn automatically into the strip's reaction space and the reading was recorded.

4.11 Designing of Different Hand Tools

4.11.1 Design Principle

The cultivators use different types of agricultural hand tools, viz., plough, spade, khorpa, sickle, yoke and bucket etc., for performing various tasks of vegetable cultivation. These tools used by the farmers were predominantly designed based on the thumb rule without any consideration towards human safety, comfort, etc., while using them. The design of hand tools varied from region to region. The workers adopted different awkward postures during performing different tasks of different vegetable cultivation and they are also compelled to adopt different inappropriate postures during working with conventional hand tools. In that connection, they had to suffer from postural stress and musculoskeletal disorders. Poorly designed hand tools may be too heavy, poorly balanced, have a grip that is too large, the wrong shape or slippery. Any of these factors can lead to injuries of the hand, wrist, forearm, shoulder, and/or neck (Khidiya and Bhardwaj, 2010). A main basis of tool design was specialization, using the right tool for a specific job.

During designing of different hand tools it will be considered that the body dimensions of the users are essential and also remembered that the percentile values are important for design principle. Clearance values are essential for comfortable handling of different tools. In general cases, a designer will specify an artifact's dimension so that the handle length of hand tools accommodates the size of the large hand, knowing that this accommodation will also accommodate the size of a small hand. Usually, dimensions using this principle will base upon the dimensions of a 95th percentile value.

Adjustability is a very important principle for hand tool design. This principle, which is frequently applied to maintain the height of agricultural appliance, allows the small user or large user to make dimensional adjustments to suit his/her own needs related to fit. This adjustability range will serve approximately 95% of all who might use the instrument.

Considering different principle of ergonomic design, it is generally an accepted fact that an optimal "fit" of human and tools, furniture, equipment, appliances will minimize error in use and minimize biomechanical stresses. These minimizations, in turn, will lead to a) greater productivity, b) greater efficiency, c) fewer mishaps leading to injury and property damage and d) fewer musculoskeletal diseases and other diseases as well.

In the present investigation two important hand tools, e.g., small spade and nut plucking tool were taken in to account for designing. Small spades were frequently used in different phases of potato cultivation, was selected for the evaluation and redesigning considering human factors. On the other hand there was no special tools for plucking groundnut. Efforts have been made to design for making a suitable tool for plucking groundnut. The methodology adopted for this purpose is discussed below:

4.11.2 Evaluation of Existing Hand Tools

Different type of existing model of hand tool, i.e. small spade, were collected and evaluated from the viewpoints of ergonomics. Different general characteristics of of the existing small spade were assessed by questionnaire technique and video graphic observation. The following parameters were considered in the evaluation of existing hand tools.

4.11.2.1 Subjective Evaluation

The subjective evaluation regarding feeling of comfort or discomfort of workers during the use of the existing tools was studied by frequent interviewing the subjects. The questions were also asked about the advantages and disadvantages during operation of the tools. The tool operators were directed to give answers to all questions in questionnaire cautiously and carefully. The questionnaire for evaluation of physical dimension and subjective feeling during operation of tools has been given in Appendix-VII.

4.11.2.2 Study of Mode of Operation

The mode of operation of the existing hand tools was studied by video photographic method. After the study of the mode of operation of existing hand tools the drawbacks of the design were identified.

4.11.2.3 Physical Dimension

To get an idea about the shape and size of the existing hand tools, those were used by the farmers, different models of the hand tools were collected from the users. Different dimensions of the collected hand tools, e.g., weight, length, breadth, diameter etc. were measured. The angle between blade and handle of spade was also measured. The shape of blade and shape of cutting end of the blade were also measured.

4.11.3 Evaluation of Drawbacks of Existing Tools

After the study of the mode of operation and subjective evaluation of existing hand tools the drawbacks of the design were identified. The problems were listed after repeated watching of the operations of the tools and observing the relative positions of different body parts of workers with the hand tool. The participants were frequently interviewed about their advantages and disadvantages during operation of the tools.

It may be mentioned that the above steps were not followed in case of designing groundnut plucking device because there is no such existing device in the local area or in the state. However, subjective evaluation of the problems of ground nut plucking was made.

4.11.4 Redesigning of Hand Tools

After identifying the drawbacks of existing tools, efforts have been made to redesign the hand tools on the basis of the user’s preference score as well as body dimensions of the workers. Different design concepts were developed for improving the hand tools. A final selection of different design criteria was made by a psychophysical test, which indicated the preference of the users. For this purpose paired comparison test (discussed later) was performed.

4.11.4.1 Formation of Anthropometric Database

A set of body dimensions, which are relevant for hand tool design, was taken from both male and female subjects following standard technique and appropriate landmarks (Ermakova et al. 1985; Stewart et al. 2011). All dimensions were taken from left and right sides of the body. The percentile values (either 5^{th} or 95^{th}) of the measures were determined which were used for the determining the different dimensions of hand tools. Clearance values were added to the selected values of dimensions whenever required.

4.11.4.2 Development of Design Concept

Considering different human factors, including body dimension of the users, mode of operation of the hand tools and user preferences, some design concept were developed. Some of the physical dimensions and characteristic features of the hand tools were changed in the new design concepts. Some new criteria were incorporated in the new design concepts (discussed detail in the Chapter V).

4.11.4.3 Preparation of Prototypes

According to the design concepts some prototypes were prepared. In most of the cases, modified models of the hand tools were fabricated and their merits and demerits were evaluated by psycho-physical analysis.

4.11.4.4 Psycho-physical Analysis

The behavioral pattern of the workers during using the different prototype models of the hand tool were studied by paired comparison tests (Hunns, 1982; Dhara et al. 2015). Different samples of the hand tools, having variations in their dimensions / characteristics, were selected for the test.

The paired comparison was using a 11 point subjective scale ranging from -5 (at left hand) to +5 (at the right hand) with zero mark in the middle (Ebe and Griffin, 2001) (Fig 4.3).

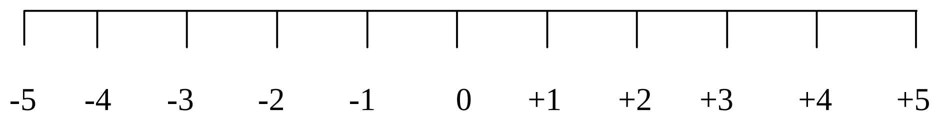


Fig. 4.3: Subjective scale asked for paired comparison test

The subjective impression of each of the points on the scale was expressed as follows:

+5 : 1^{st} very very much more comfort than the 2^{nd}
+4 : 1^{st} very much more comfort than the 2^{nd}
+3 : 1^{st} definitely more comfort than the 2^{nd}
+2 : 1^{st} moderately more comfort than the 2^{nd}
+1 : 1^{st} slightly more comfort than the 2^{nd}
0 : 1^{st} same comfort as the 2^{nd}
-1 : 1^{st} slightly less comfort than the 2^{nd}
-2 : 1^{st} moderately less comfort than the 2^{nd}
-3 : 1^{st} definitely less comfort than the 2^{nd}
-4 : 1^{st} very much less comfort than the 2^{nd}
-5 : 1^{st} very very much less comfort than the 2^{nd}

The subjects were provided with different pairs of the model / product (stimulus) to be tested (e.g., 1:2, 1:3 , 1:4 2:3 2:4, 3:4 etc). The subjects were asked to judge relative impression of the second stimulus in respect to first one and they were allowed to answer by words. The answers were tabulated in a table with respective signs.The average value given by the subjects for each pair of stimulus was computed. From each of the mean scores individual scores for each model (stimulus) was separated with its respective sign and separately added. This sum with its respective sign was divided by the total number of times it was compared. This obtained value was scaled along the category subjective scale. The relative position of the computed score (stimuli) indicated the best and worst characteristics of models chosen by the population.

4.11.5 Design and Fabrication

From the results of paired comparison tests and the computed anthropometric dimensions of the users the design characteristics of the hand tools were finalized.

4.11.6 Evaluation of Redesigned Hand Tools

After ergonomic modification of different hand tools, the effectiveness of the redesigned hand tools was evaluated by the following parameters.

4.11.6.1 Subjective Evaluation

It was made by questionnaire method. The feeling of comfort and discomfort were evaluated while using hand tools. It was made when the workers used existing and different modified models. The results of the modified models were compared with that of existing model.

4.11.6.2 Heart Rate Study

The working heart rate was measured during working with different modified models of small spade and nut plucking tools, and the results were compared with that of existing one.

4.11.6.3 Joint Angle Study

During use of the different existing and modified models of small spade and nut plucking tools, the different body joint angles, viz., shoulder, elbow, wrist etc. were measured. The deviations of different joint angles from the normal erect posture were calculated in all the cases. The joint angles were measured by means of a goniometer.

a) **Shoulder joint angle:** The angle at acromial joint region between the vertical trunk (lateral) line and the upper arm (as shown in fig. 4.4a). The line was drawn at the back where one arm was fixed along the bodyline and the other line was drawn along the mid line of the upper arm.

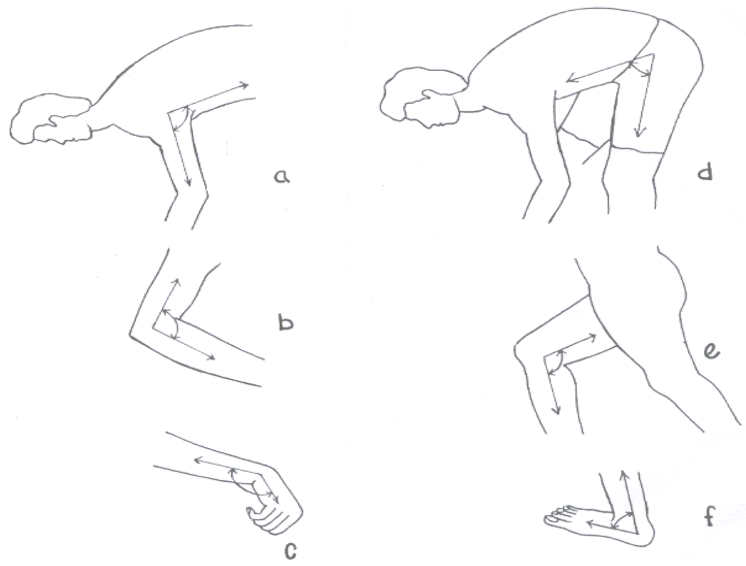
b) **Elbow joint angle:** The angle at elbow joint region between upper arm and lower arm (fig 4.4b). The line was drawn on the elbow joint where one of the arms of it was fixed in the mid line of the upper arm and the other one was drawn at the mid line of the lower arm.

c) **Wrist joint angle:** The angle at wrist joint region between lower arm and hand (fig. 4.4c). The line was drawn on the wrist joint; one of the arms of the instrument was fixed in the midline of lower arm of the subject and the other line was drawn at the midline of the backside of the palm.

d) **Hip joint angle:** The angle at hip region is the angle between trunk and thigh (fig. 4.4d). The line was drawn on the waist line; one line of it was drawn on the vertical trunk (lateral) line and another one was at the mid line of the thigh.

e) **Knee joint angle:** The angle knee joint region between thigh and lower leg (fig. 4.4e). The lines were drawn on the knee joint; one line of it was drawn on the midline of the thigh and other on the midline of the lower leg.

f) **Ankle joint angle:** The angle at ankle joint region between lower leg and foot (fig.4.4f). The lines were drawn on the ankle joint between the midline of the lower leg and the midline (lateral side) of the foot.



a) Shoulder angle b) Elbow angle c) Wrist angle

d) Waist angle e) Knee angle f) Ankle angle

Fig 4.4: Different joint angles of upper and lower extremities

4.11.6.4 Productivity Study

The productivity study was made while the workers had been performing their job with different models of existing and modified hand tools. The productivity during the use of hand tools was determined either by determining the time for unit production or by counting the products for a specific time. The participants were asked to do the task and the required time was noted by a stopwatch.

4.12 Analysis of Data

Descriptive characteristics of the participants were presented as means and standard deviation and percentages. ‘t’-test and correlation of parameters between different groups had also been made. χ^2 test was performed to compare groups for categorical variables. Multiple means were compared with the one-way ANOVA. The data were analyzed for statistical significance by using the statistical package of social science (SPSS 20.0) software. A *p* value below 0.05 was denoted as significant.

Results & Discussions

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5.1 Socioeconomic Status

Assessment of socioeconomic status (SES) of a person or a population is an important aspect in community based studies because it is an important determinant of health and nutrition of an individual. Assessment of SES of a family would mean categorization of the family in respect of different variables such as, education, occupation, economic status, etc.

The educational status of the vegetable cultivators has been shown in Table 5.1. From the results it was noted that the educational level of both male and female cultivators were very poor. About 44% male and 50% female were illiterate. The rest of them were literate but only 13.59% male and 12.09% female had secondary level or above education. The results also indicated that the females were educationally poorer than the male cultivators. The cause of low literacy level of the cultivators might be related to the poor economic condition of their family and lack of awareness about the benefit of education.

Table 5.1: Frequency and percentage (%) of educational status of the vegetable cultivators

		Illiterate	Literate			
			Primary level	**Upper primary level**	**Secondary level**	**Above secondary level**
Male (n=353)	f	154	102	49	38	10
	%	43.63	28.89	13.88	10.76	2.83
Female (n=339)	f	168	90	40	30	11
	%	49.56	26.55	11.8	8.85	3.24

From the socioeconomic score (Table 5.2) it was noted that the majority of the cultivators were belonging to upper lower socioeconomic category (male: 79.61%; female: 87.32%). A notable percentage of the cultivators were in the lower middle category (male: 20.39%; female: 12.68%). The low socioeconomic status of the agricultural workers might be related to their health and nutrition. This might be one of the reasons for the occurrence of occupational hazards also (Sec. 5.5).

Table 5.2: Socioeconomic status of vegetable cultivators according to the modified Kuppuswami Scale (Values showing the percentage of total subjects)

Total Score	Socioeconomic Status Scale	Male (n=353)	Female (n=339)	All together (n=692)
26-29	Class I (Upper)	-	-	-
16-25	Class II (Upper middle)	-	-	-
11-15	Class III (Lower middle)	20.39%	12.68%	16.62%
5-10	Class IV (Upper lower)	79.61%	87.32%	83.38%
<5	Class V (Lower)	-	-	-

5.2 Body Dimensions

Human body dimensions may be used for assessing body composition, nutritional status as well as for ergonomic designing of equipment and furniture. Mismatches between human anthropometric measures and equipment dimensions were known to be a contributing factor in discomfort, accidents, biomechanical stress, fatigue, injuries, cumulative traumas and decrease productivity. As pointed out by many investigators (Xiao et al. 2005; Dewangan et al. 2008; Mandahawi et al. 2008; Imrhan et al. 2009) anthropometric data were essential for designing safe and efficient workplace, equipment and tools. Without such data, the designs could not be fit to the people who were going to use this. Thus the information about human body dimension was essential for implementation of various facilities in the design. Hand anthropometry is also very important in designing tools which dealing with human hands. Hand dimension, relevant to the design of hand tools and other manual devices have been published for various nationalities such as Western Nigerian rural farm workers (Okunribido, 2000), Maxicans (Imrhan and Contreras, 2005), Bangladeshi (Imrhan et al. 2009), Filipian manufacturing workers (Del Prodo-Lu, 2007).

In India, some anthropometric data on agricultural workers were collected (Yadav et al. 1997; Karunanithi, 2001; Nag et al. 2003; Kar et al. 2003) which could be useful in farm machinery and agricultural hand tools designing. India is a vast country with a large population and there are multi-racial, multi-ethnic and multi-cultural populations and they having their own variations. The body dimensions may be different in different part of India. There may be inter-racial and inter-geographical differences in body dimensions. Dewangan et al. (2005) measured few hand dimensions from the north eastern region of India and compared these to central, eastern, southern and western region of the country and demonstrated that there was significant differences in hand dimension exist between groups within a nation. Okunribido, (2000) and Kar et al. (2003) also pointed out that significant differences in hand anthropometry existed compared to other nationalities. Therefore, in the present study the hand dimensions were measured from both male and female participants to make an anthropometric database of the cultivators and those hand dimensions were used for redesigning of hand tools (spade and ground nut plucking tool) which are used in different tasks of vegetable cultivation. Fourteen hand dimensions have been identified which were considered useful for agricultural hand tool design and the measurements taken from 468 participants of which 226 were males and 242 were females.

The mean and standard deviation for each hand dimension of both male and female workers have been shown in Table 5.3. All hand dimensions were significantly larger ($P<0.01$) in male than female, in general, was not unexpected. The 't' value was computed and it was noted that there was no significant difference in hand dimensions between right and left hand of both sexes, and the percentage difference between right and left hand was also small and it ranged from 0.1% to 1.57% in male and 0.00% to 0.87% in female respectively.

Table 5.3: Mean ± SD and percentage difference of hand dimensions of agricultural workers (all dimension in cm)

Dimensions	Male (n=226)			Female (n =242)			%diff. between Male & Female	
	RH	LH	% diff.	RH	LH	% diff.	RH	LH
Total arm length	71.34 ±4.93	71.26 ±4.95	0.11	66.81* ±3.77	66.72* ±3.81	0.13	6.35	6.37
Upper arm length	28.38 ±3.54	28.35 ±3.54	0.11	26.71* ±2.53	26.71* ±2.57	0.0	5.88	5.78
Lower arm length	25.34 ±2.21	25.24 ±2.24	0.39	23.65* ±1.73	23.57* ±1.77	0.34	6.67	6.62
Hand length	17.62 ±1.01	17.68 ±1.0	0.34	16.53* ±0.96	16.54* ±0.96	0.06	6.19	6.45
Palm length	9.98 ±0.7	9.97 ±0.67	0.1	9.3* ±0.6	9.29* ±0.62	0.11	6.81	6.82
Hand breadth	7.89 ±0.51	7.87± 0.53	0.25	7.14* ±0.4	7.1* ±0.41	0.56	9.51	9.78
Max. hand breadth	9.82 ±0.68	9.78 ±0.7	0.41	8.58* ±0.59	8.56* ±0.64	0.35	12.63	12.58
1st digit length	6.41 ±0.56	6.42 ±0.57	0.16	5.79* ±0.53	5.81* ±0.53	0.35	9.67	9.5
2nd digit length	6.93 ±0.52	6.97 ±0.52	0.58	6.61* ±0.54	6.6* ±0.54	0.15	4.62	5.31
3rd digit length	7.64 ±0.49	7.71 ±0.52	0.92	7.23* ±0.51	7.25* ±0.51	0.28	5.37	5.97
4th digit length	7.09 ±0.5	7.1 ±0.5	0.14	6.69* ±0.57	6.66* ±0.57	0.45	5.64	6.2
5th digit length	5.74 ±0.55	5.81 ±0.514	1.22	5.42* ±0.49	5.4* ±0.49	0.37	5.57	7.06
Hand grip circumference	16.3 ±1.35	16.48 ±1.38	1.1	15.29* ±1.32	15.29* ±1.34	0.0	6.2	7.22
Hand grip diameter	5.18 ±0.43	5.24 ±0.44	1.16	4.86 ±0.42	4.86* ±0.43	0.0	6.18	7.25
Fist girth	25.48 ±2.0	25.33 ±1.92	0.59	22.9* ±1.99	22.7* ±1.81	0.87	10.13	10.38

RH-Right Hand; LH-Left Hand w.r.t. male *$p<0.001$

The 't' test was computed between male and female participants and it was noted that there was a significant difference in different hand dimensions between the sexes. The percentage difference between male and female was noted and it ranged from 5.05% to 12.53% for right hand and 5.6% to 12.47% for left hand respectively.

Table 5.4 shows the percentile values (5^{th}, 50^{th} and 95^{th}) for each hand dimensions (right and left) of male and female separately, which should be interest of designer of tools since they influence fit and comfort. The data of male and female participants may also be used separately for designing of hand tools for them. However, in India, rural farming tools and implements are generally made by members of tool-making families who very on their knowledge and personal experience of the tasks to be performed in fabricating the different tools. That was presently a major problem for females, particularly those with small hands, as the tools are likely to be oversized and difficult to handle in the face of excess tool weight. Lin et al. (2004); Kamarul and Ahmad, (2006); Mandahawi et al. (2008) also reported that the male has large physical dimensions and ability than the female. From the result (Table 5.3) it was also be noted that the male had relatively larger hand dimensions than females, which indicated some tools fit to male hand but may not fit to female hand comfortably. For designing such hand tools for common practice, the hand dimension were also computed considering male and female together. The results have been presented in Table 5.5. The percentile values of those hand dimensions (male and female combined) may be required for designing of common equipment like, spade, nut plucking tool, sickle, paddy pullar, straw pullar, hoe, hand power tiller etc for both male and female workers. When a number of workers use common equipment, computation of population data is essential because people differ significantly in their anthropometric characteristics (Okunribido, 2000). Al-Haboubi, (1999); Kar et al. (2003); Ismaila et al. (2013); Qutubuddin et al. (2013) collected common data for designing of industrial workstation and equipment.

Table 5.4: Percentile values of different hand dimensions of the cultivators (Male: 226; Female: 242) (all dimension in cm)

Dimensions	5th				50th				95th			
	Male		Female		Male		Female		Male		Female	
	RH	LH	RH	LH	RH	LH	RH	LH	RH	LH	RH	LH
Arm length	63.28	63.2	61.33	61.5	71.5	71.4	66.3	66.35	79.35	79.13	74.18	73.2
Upper arm length	22.63	22.48	23.31	23.1	28.45	28.3	26.5	26.5	34.6	34.8	31.39	31.49
Lower arm length	22.1	22.0	21.3	21.0	25.2	25.1	23.6	23.4	29.5	29.5	26.8	26.6
Hand length	16.0	15.8	14.9	14.8	17.6	17.8	16.5	16.55	19.1	19.2	18.0	18.0
Palm length	8.73	8.6	8.3	8.21	10.0	10.0	9.3	9.3	11.08	10.9	10.3	10.3
Hand breadth	7.2	7.0	6.5	6.41	7.8	7.8	7.2	7.1	8.7	8.7	7.8	7.7
Max hand breadth	8.8	8.6	7.6	7.6	9.8	9.8	8.5	8.5	10.7	10.68	9.5	9.7
1st digit length	5.4	5.3	5.0	5.1	6.4	6.4	5.8	5.8	7.4	7.3	6.6	6.6
2nd digit length	6.1	6.2	5.8	5.8	7.0	7.0	6.6	6.5	7.7	7.7	7.3	7.4
3rd digit length	6.8	6.9	6.4	6.4	7.7	7.7	7.2	7.2	8.48	8.6	7.9	7.9
4th digit length	6.3	6.3	5.8	5.8	7.1	7.1	6.7	6.6	7.9	7.9	7.5	7.5
5th digit length	5.0	5.1	4.6	4.6	5.7	5.8	5.4	5.4	6.6	6.7	6.2	6.2
Hand grip circumference	14.23	14.4	12.91	13.0	16.4	16.6	15.4	15.4	18.0	18.28	17.0	17.0
Hand grip diameter	4.53	4.58	4.11	4.14	5.22	5.28	4.9	4.9	5.73	5.81	5.41	5.41
Fist girth	21.85	22.2	20.2	20.01	25.6	25.5	22.95	22.7	28.35	28.2	25.9	25.39

RH-Right Hand; LH-Left Hand

Table 5.5: Mean ± SD, range and percentile values of different hand dimensions of the cultivators (male and female combined) (all dimension in cm)

Dimensions	Mean ± SD (n=468)		% diff	Percentile values					
				5th		50th		95th	
	RH	LH		RH	LH	RH	LH	RH	LH
Arm length	69.0±4.91	68.91±4.94	0.13	62.1	62.0	68.5	68.5	77.8	78.2
Upper arm length	27.52±2.78	27.49±2.74	0.11	23.4	23.4	27.2	27.4	32.0	31.8
Lower arm length	24.47±2.14	24.38±2.17	0.37	21.4	21.2	24.3	24.2	28.1	28.2
Hand length	17.06±1.12	17.09±1.13	0.18	15.1	15.1	17.1	17.2	18.9	18.8
Palm length	9.63±0.73	9.62±0.73	0.1	8.5	8.5	9.6	9.6	10.8	10.8
Hand breadth	7.5±0.59	7.47±0.61	0.4	6.6	6.5	7.4	7.4	8.6	8.5
Max hand breadth	9.18±0.89	9.14±0.91	0.44	7.8	7.8	9.2	9.2	10.5	10.5
1st digit length	6.09±0.63	6.1±0.62	0.16	5.1	5.2	6.1	6.2	7.2	7.2
2nd digit length	6.76±0.55	6.78±0.55	0.3	5.9	5.9	6.8	6.8	7.6	7.7
3rd digit length	7.43±0.54	7.47±0.56	0.54	6.5	6.5	7.4	7.4	8.3	8.4
4th digit length	6.88±0.57	6.87±0.58	0.15	6.0	6.0	6.9	6.9	7.8	7.7
5th digit length	5.57±0.54	5.6±0.55	0.54	4.7	4.6	5.6	5.5	6.5	6.5
Hand grip circumference	15.77±1.42	15.86±1.48	0.57	13.3	13.2	16.0	16.1	17.8	18.0
Hand grip diameter	5.02±0.45	5.05±0.47	0.6	4.2	4.2	5.1	5.1	5.7	5.7
Fist girth	23.22±3.79	23.05±3.68	0.73	14.7	14.8	24.1	23.8	27.6	27.3

The hand dimensions of male and female workers in the present study were compared with other studies (Table 5.6 and Table 5.7) and it was observed that there were variations between different populations, indicating the significant difference in specific dimension and country. Such regional variation in anthropometric dimensions also observed in other countries [Nigeran female- Okunribido, (2000), Indian agricultural workers –Kar et al. (2003); Dewangan et al. (2005)]. Sacngchaiya and Bunterngchit, (2004) reported in their study that the variation in anthropometric dimensions existed between different populations.

Table 5.6: Comparison of hand dimensions of male participants in the present study with earlier studies

Body Dimensions	Present study	Indian (a)	% diff	Jordanian (b)	% diff	Malaysian (c)	% diff	Bangladeshi (d)	% diff
Total arm length	71.34 ±4.93	74.39 ±5.12***	4.28	-	-	72.3* ±3.7	1.35	-	-
Upper arm length	28.38 ±3.54	30.2 ±7.95***	6.19	-	-	-	-	-	-
Forearm length	25.34 ±2.21	26.16 ±6.28**	3.24	-	-	-	-	-	-
Hand length	17.62 ±1.01	18.03 ±9.77	2.56	19.12*** ±1.02	8.51	17.8 ±1.2	1.02	17.31* ±0.83	1.76
Palm length	9.98 ±0.7	-	-	-	-	10.3*** ±1.0	3.21	-	-
Hand breadth	7.89 ±0.51	-	-	8.77*** ±0.48	11.15	8.6*** ±0.5	9.00	7.93 ±0.71	0.51
Max hand breadth	9.82 ±0.68	-	-	10.42*** ±1.09	6.11	-	-	9.83 ±0.96	0.10
3rd digit length	7.64 ±0.49	-	-	8.12*** ±0.71	6.28	-	-	7.58 ±0.33	0.79
5th digit length	5.74 ±0.55	-	-	6.11*** ±0.46	6.45	-	-	5.78 ±0.38	0.70

w.r.t. present study * $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$
a) Ghosh and Malik, 2007 b) Mandahawi et al. 2008 c) Rosnah et al. 2009
d) Imrhan et al. 2009

Difference in the hand dimension of Nigerian female with foreign population also been reported by Okunribido, (2000). Similar findings were also found in four ethnic groups, Chinese, Japanese, Korean and Taiwanese (Lin et al. 2004). They also reported that ethnic differences in body dimensions are affected by heredity, economic development, social environment, type of work and labour structure (Lin et al. 2004; Sanli et al. 2005; Rastogi and Nagesh, 2008; Zaher et al. 2011). The differences found in the hand dimensions of different population emphasized the usefulness of this study in the implication of design and evaluation of hand tools for the Indian population. Most of the agricultural tools and machinery used in India are designed based on the body dimensions of the foreign population. Chakrabarti, (1997) and Dewangan et al. (2008) also reported that in India, while designing of the tools the body dimensions of the British population are followed. This implied that the anthropometric database of the present study should be used for suitable modification of hand tools before introducing these to the Indian agricultural workers.

Table 5.7: Comparison of hand dimensions of female participants in the present study with earlier studies

Body Dimensions	Present study	Indian (a)	% diff	Thailand (b)	% diff	Bangladesh (c)	% diff	Jordanian (d)	% diff
Total arm length	66.81 ±3.77	68.55*** ±4.2	2.60	68.6*** ±1.92	2.68	-	-	-	-
Hand length	16.46 ±0.98	16.964*** ±0.9	3.04	17.7*** ±0.7	7.53	16.74 ±1.14	1.70	17.78*** ±0.74	8.02
Palm length	9.2 ±0.56	9.35 ±0.79	1.63	-	-	-	-	-	-
Hand breadth	7.14 ±0.4	6.8*** ±0.51	4.76	7.01*** ±0.32	1.82	7.41*** ±0.4	3.78	7.78*** ±0.39	8.96
Max hand breadth	8.59 ±0.6	-	-	8.99*** ±0.4	4.66	8.86** ±0.56	3.14	9.39*** ±0.56	9.31
1 st digit length	5.83 ±0.53	6.41*** ±0.63	9.95	-	-	-	-	-	-
2 nd digit length	6.58 ±0.52	6.92*** ±0.55	5.17	-	-	-	-	-	-
3 rd digit length	7.26 ±0.54	7.6* ±0.57	4.68	7.67*** ±0.32	5.65	7.29 ±0.37	0.40	7.51*** ±0.36	3.44
4 st digit length	6.69 ±0.58	7.02*** ±0.54	4.93	-	-	-	-	-	
5 st digit length	5.4 ±0.49	5.63*** ±0.54	4.26	5.58*** ±0.33	3.33	5.19** ±0.41	3.89	5.66*** ±0.34	4.81
Fist girth	22.9 ±1.99	23.51*** ±1.23	2.66	-	-	-	-	-	-

w.r.t. present study * P <0.05 ** P <0.01 *** P <0.001

a) Nag et al. 2003 b) Sacngchaiya and Bunterngchit, 2004 c) Imrhan et al. 2009
d) Mandahawi et al. 2008

5.3 Nutritional Status

Nutritional status of the vegetable cultivators was carried out by studying nutrient intake. Besides this, to support the findings of the nutritional status, anthropometric indices like the Body Mass Index (BMI) was also evaluated.

5.3.1 Nutritional Assessment

Average one day food consumption of the workers of both sexes was taken by 24 hour recall method and the results have been presented in Table 5.8 and Table 5.9. The foodstuffs were divided into ten categories. From the study of working heart rate, it has been revealed that both the male and female cultivators were categorized as moderate worker; it has been discussed later in this chapter (Sec. 5.8.1). The daily food intake of the workers was compared with the Recommended Dietary Allowance (RDA) made for the adult moderate worker (low cost balanced diet) by ICMR Expert Group (ICMR, 2009). It was noted that the amount of intake of different foodstuffs by the agricultural workers were less than the RDA value, except cereals, roots and tubers and other vegetables of both sexes. The average cereal intake was 552.35g/day in male and 483.65 g/day in female, which were more (6% in male and 10% in female) than the RDA. They consumed rice three to four times in a day at breakfast, lunch and dinner either as boiled rice or puffed rice or wet rice (boiled rice in water for the duration of overnight). The average consumption of pulses of both male and female workers was very low, which was less than half of the RDA (male: 40.9% of RDA; female: 36.84% of RDA). They generally consumed lentil and sometimes Bengal gram (dhal) among the pulses. Some workers consumed ready to cook soyabean once in a week. Usually they consumed pulses, which were cooked in liquid form (“dal”). The workers consumed wet rice 1-2 times in a day and they did not take liquid pulse preparation (“dal”) with it. That might be the cause of lower consumption of pulses. The amount of daily intake of roots and tubers was much higher than

RDA (male: 131.58% of RDA; female: 136.7% of RDA). The amount of daily intake other vegetables was also higher than RDA (male: 106.26% of RDA; female: 119.20% of RDA). The agricultural workers consumed vegetables like, brinjal, cauliflower, cucumber, dramstick, ladies fingers, onion stalks, papaya (green), pumpkin (fruit), ridged gourd, snake gourd etc. These vegetables were easily available in the village garden and village market also. They also grew those vegetables in spaces around their homes. But the most notable feature was that the amount of daily intake of green leafy vegetable was much lower than the RDA (male: 34.2% of RDA; female: 53.79% of RDA). However, they compensated it by taking other vegetable, as reported by them. The fats and oils consumption by the workers was low, which was about 58% in male and 79.5% in female of recommended value. As the worker did not consumed sugar or jaggery in their regular diet and most of the workers were not habituated to take tea regularly, the consumption of sugar or jaggery of the workers was lower than the RDA. The intake of milk and milk product was remarkably low among the workers. The intake of those items was about 71.67% of RDA in male and 15.56% of RDA in female respectively. The milk products were costly items. The economically weak agricultural workers tried to avoid for purchasing such food items. In rural areas, people would try to keep at least one cow or buffalo as a pet. However, in most of the cases the agricultural workers would sell the milk to get some money instated of consuming it. The consumption of fish and other flesh foods was also very low. The average fish and other flesh food intake were 19.59 g/day in male and 16.97 g/day in female. The agricultural workers were habituated to take different types of locally available fishes like, ‘Bhola’, ‘Boal’, ‘Folui’, ‘Kui’, ‘Lata’, ‘Magur’, ‘Mrigal’, ‘Punti’, ‘Sol’, etc. They purchase these fishes from the local market and sometimes they catch fishes from the ponds, tanks, canals and even from the rice fields especially in rainy season. They usually could not consumed fishes every day in a weak due to their low economic condition. They consumed meat or egg irregularly, once in 15 days or more.

Table 5.8: Average daily intake (gm) of different food groups in male and female workers

Food Groups	Male (n=148)			Female (n=163)		
	Mean±SD	RDA	% of RDA	Mean±SD	RDA	% of RDA
Cereals	552.35±96.38	520	106.22	483.65±89.67*	440	109.92
Pulses	20.45±8.69	50	40.90	16.58±7.68*	45	36.84
Roots and Tubers	78.95±52.35	60	131.58	68.35±48.39	50	136.7
Other-Vegetables	74.38±35.69	70	106.26	47.68±29.34*	40	119.2
Green-Leafy Vegetables	68.39±36.35	200	34.20	53.79±34.68*	100	53.79
Fat and Oil	23.15±5.63	40	57.88	19.89±5.16*	25	79.56
Meat, Fish and Egg	19.59±26.38	-	-	16.97±22.38	-	-
Sugar/ Jaggery	8.23±24.12	35	23.51	6.52±17.92	20	32.6
Milk and milk product	32.25±21.29	45	71.67	23.34±15.37*	150	15.56

w.r.t. male*p<0.001 RDA given by ICMR, (2009)

The average nutrient and energy consumption of agricultural workers, along with the recommended allowance has been given in Table 5.9. There were significant differences in consumption of different nutrients between male and female workers. The average calorie consumption by the male and female workers was 2612.29 Kcal/day and 2184.02 kcal/day respectively. There was wide variation in calorie intake among the workers. The calorie consumption of both male and female workers was a little lower than the RDA recommended value (ICMR, 2009). The consumption of calorie by the male and female workers was 95.69% and 97.94% of the RDA respectively. The result also indicated that the female workers had significantly lower ($p<0.001$) intake of calorie than that the male workers. The result showed that the carbohydrate intake by the male workers was significantly higher ($p<0.001$) than that of the female. The mean protein intake was close to the value of RDA. Generally it was revealed that protein requirement was met mostly from intake of pulses, egg, fish and flesh foods. But the present study showed that the consumption of the above food items was low. So the excess protein might be met from consumption of cereals. Investigations suggested that a variety of grains, legumes, seeds and vegetables are the good sources of amino acid and proteins to make up the deficit (Mangels et al. 2003; USDA, 2005). The intake of protein by the female workers was significantly ($p<0.001$) lower than that of the male. The average intake of fat was very close to the value to RDA. From the results it has been revealed that the average intake of iron was close to the value of RDA. The consumption of iron was significantly ($p<0.001$) lower in female than that of male. However, both male and female workers were suffering from anemia, which has been discussed later in this chapter (Sec. 5.4.1). This can be attributed to the fact that the bioavailability of iron is poor owing to the presence of phytates, oxalates, carbonates, phosphates and dietary fibre which interferes with iron absorption. Indian diet, predominantly vegetarian food, contains large amounts of inhibitors like phytates in bran, tannin in tea, oxalates in vegetables and phosphates in egg yolk, interfering with iron absorption, this may lead to a higher prevalence of anemia (Nair and Iyengar, 2009; Pal et al. 2014a). They consumed comparatively lower amount of calcium in respect to RDA value. The observed deficiencies might be due to less consumption of calcium containing vegetables. Not only vegetables, but also the lesser consumption of fish which might be another cause of calcium deficiency. Small fish with bones are extremely calcium rich (Miura et al. 2009). They also had Vitamin A deficiency. The consumption of Vit B1 was higher than the RDA value.

Table 5.9: Average daily nutrient intake by male and female agricultural workers
(The values in parenthesis indicate the range of food intake)

Nutrients		Male (n=148)			Female (n=163)		
		Mean±SD	**RDA**	**% of RDA**	**Mean±SD**	**RDA**	**% of RDA**
Energy (Kcal)		2612.29±460.81 (3999.90-1398.00)	2730	95.69	2184.02±641.21* (3542.80-861.85)	2230	97.94
Carbohydrate (gm)		517.21±104.42 (729.82-292.00)	-	-	464.59±144.21* (763.75-160.30)	-	-
Protein (gm)		69.29±18.78 (137.99-27.80)	60	115.48	54.19±20.28* (136.14-15.09)	55	98.53
Fat (gm)		31.47±14.38 (101.45-3.70)	30	104.90	27.23±9.98** (65.36-12.82)	25	108.92
Iron (mg)		23.06±7.24 (49.55-6.67)	17	135.65	21.23±15.25 (87.74-2.88)	21	101.10
Calcium (mg)		551.65±284.81 (1426.00-140.00)	600	91.94	506.71±356.87 (1789.05-43.90)	600	84.45
Vit-A (µg)		948.78±1852.15 (11282.00-24.00)	4800	19.77	760.53±1567.66* (7474.50-27.00)	4800	15.84
Vit-B1 (mg)		1.80±0.43 (2.89-0.93)	1.4	128.57	1.44±0.51* (2.68-0.56)	1.1	130.91
Vit-B2 (mg)		0.69±0.26 (1.84-0.22)	1.6	43.13	0.52±0.23* (1.39-0.08)	1.3	40.00
Niacin (mg)		26.14±5.81 (46.25-14.62)	18	145.22	21.37±7.21* (41.95-5.91)	14	152.64
Vit-B6 (mg)		0.98±0.31 (1.43-0.01)	2.0	49.00	0.84±0.31* (1.69-0.01)	2.0	42.00
Folic Acid (mg)	Free	73.13±31.26 (216.80-11.90)	-	-	56.59±25.69* (152.10-11.15)	-	-
	Total	135.84±56.36 (327.00-47.00)	200	67.92	108.80±47.95* (264.80-16.25)	200	54.40
Vit C (mg)		97.79±75.58 (333.50-4.00)	40	244.48	88.55±72.78 (325.00-5.00)	40	221.38
Choline (mg)		546.17±328.77 (1318.50-0.01)	-	-	519.84±337.09 (1633.25-75.00)	-	-

w.r.t. male *p<0.001, **p<0.01 RDA given by ICMR (2009

Generally it has been found that, in a lunch or dinner dish, rice or chapatti has to be supplemented with pulses, vegetables, fish or egg or meat and milk or milk product to make the diet more balanced and adequate in all nutrients. But in the present assessment it was noted that, the workers could not purchase such supplementary foodstuffs, which might be due to low economic condition.

The gender difference in nutrient and energy consumption might be due to the fact that the female had to do the household works after finishing the agricultural work and in most of the cases, they were used to take lunch or dinner after taking foods by all other members of the family (children, husband, in-laws etc.). As they had to take lunch or dinner last of all, sometimes they would not get sufficient amount of food. Thus the gender bias in intra-household food sharing might be another reason for this difference. In various societies of India, large-scale sex discrimination exists in sharing of food (Basu et al.1986; Khan et al.1995; Bharati et al. 2004). So, due to low socioeconomic status, their diet was inadequate with respect to energy and nutrients including micro nutrients like Vit. A, Vit. B2, Vit. B5 and calcium, etc. (Gopalan et al. 2002).

The average dietary and nutritional intake in the present study was also compared with the survey report of the National Nutrition Monitoring Bureau (NNMB) and the results have been presented in Table 5.10 and 5.11 (NNMB, 2002). The National Nutrition Monitoring Bureau (NNMB) carried out a survey over the past decade in rural and urban areas of 10 states of the country have brought out this fact clearly. The present study compared with the one part (dietary daily intake of rural poor people) of the NNMB survey report. It was observed that the consumption of pulses, milk and milk products, fruits and sugar/jaggery by the participants of the present study were lower than that the NNMB survey report (Table 5.10). However, the intake of cereals, root and tubers, vegetables, fat and oil and fish and egg were higher than that the survey report.

Table 5.10: Comparison of average daily intake of food (gm) between present study with the survey report of National Nutrition Monitoring Bureau (NNMB)

Food Groups	Male			Female		
	Mean±SD	**NNMB 2002**	**Mean diff.**	**Mean±SD**	**NNMB 2002**	**Mean diff.**
Cereals	552.35±96.38	494	58.35	483.65±89.67	410	73.65
Pulses	20.45±8.69	31	-10.55	16.58±7.68	27	-10.42
Roots and Tubers	78.95±52.35	65	13.95	68.35±48.39	46	22.35
Other-Vegetables	74.38±35.69	56	18.38	47.68±29.34	41	6.68
Green-Leafy Vegetables	68.39±36.35	18	50.39	53.79±34.68	14	39.79
Fat and Oil	23.15±5.63	15	8.15	19.89±5.16	13	6.89
Meat, Fish and Egg	19.59±26.38	12	7.59	16.97±22.38	4	12.97
Sugar/ Jaggery	8.23±24.12	13	-4.77	6.52±17.92	14	-7.48
Milk and milk product	32.25±21.29	77	-44.75	23.34±15.37	66	-42.66
Fruits	18.34±24.65	27	-8.66	14.39±23.67	24	-9.61

Table 5.11: Comparison of average consumption of nutrients between present study with the survey report of National Nutrition Monitoring Bureau (NNMB)

Nutrients		Male			Female		
		Mean±SD	**NNMB 2002**	**Mean diff.**	**Mean±SD**	**NNMB 2002**	**Mean diff.**
Energy (Kcal)		2612.29±460.81	2184	428.29	2184.02±641.21	1808	376.02
Protein (gm)		69.29±18.78	58.6	10.69	54.19±20.28	48.8	5.39
Fat (gm)		31.47±14.38	22.6	8.87	27.23±9.98	18.9	8.33
Iron (mg)		23.06±7.24	18.1	4.96	21.23±15.25	15.2	6.03
Calcium (mg)		551.65±284.81	468	83.65	506.71±356.87	383	123.71
Vit-A (μg)		948.78±1852.15	267	681.78	760.53±1567.66	234	526.53
Vit-B1 (mg)		1.80±0.43	1.5	0.3	1.44±0.51	1.2	0.24
Vit-B2 (mg)		0.69±0.26	0.8	-0.11	0.52±0.23	0.6	-0.08
Niacin (mg)		26.14±5.81	17.8	8.34	21.37±7.21	13.9	7.47
Folic Acid (mg)	Free	73.13±31.26	62.2	10.93	56.59±25.69	50.4	6.19
	Total	135.84±56.36	-	-	108.80±47.95	-	-
Vit C (mg)		97.79±75.58	48	49.79	88.55±72.78	37	51.55

The nutrients consumption of the cultivators was also compared with the NNMB (2002) survey report (Table 5.11). From the comparison of the data it has been revealed that both the male and female workers consumed comparatively higher amount nutrients and energy than the NNMB survey report of rural people.

5.3.2 Body Composition

BMI is promulgated by the World Health Organization (WHO) as the most useful epidemiological measure of overall obesity (Kopelman, 2000; WHO, 2012). It is nevertheless a crude index, has advantages in clinical and epidemiological practice – as a non-invasive and low-cost method. BMI is the simple, safe, inexpensive method (Banik, 2009; Pal et al. 2013) and best indicator tool for the nutritional assessment (Lee and Nieman, 2003; Das and Bose, 2010), particularly in the field condition where it is difficult to conduct clinical and laboratory test (Vasudev et al. 2004; Ranasinghe et al. 2013). Not only the nutritional status, but also BMI is considered as a good indicator of the socioeconomic condition of a population, especially adult populations of developing countries (Khongsdier, 2002; Mosha, 2003; Venkatramana et al. 2005). The health risk has been shown to increase in a graded fashion when moving from the lower to higher BMI categories (Brown et al. 2000; Kesavachandran et al. 2012). In Caucasian populations, a strong association has been depicted between BMI and mortality (Wen et al. 2009). A similar association has also been demonstrated among Asian populations (Weng et al. 2006; Pal et al. 2014c).

Stature and weight of the workers were measured and BMI was calculated from the stature and weight and the results have been presented in Table 5.12. It was observed that the mean values of BMI of both sexes were low and falling under the 'lower weight' category (Table 5.13). Ideal weight for height was calculated following standard equation: 22 x height $(m)^2$ (Tokunaga et al. 1991). The results indicated that the actual weight of both male and female were significantly ($p<0.001$) lower than the estimated ideal weight. The studies of

BMI support the observed result of nutritional assessment of diet survey method as mentioned earlier (Sec. 5.3.1). Low socioeconomic status of the cultivators might be one of the reasons of low BMI (Table 5.2). From the study of the Bose et al. (2007) and Chakraborty et al. (2007) it has been revealed that the monthly family income significantly and positively correlated with BMI. According to them the lowest family income group had the lowest mean BMI.

Table 5.12: The physical characteristics of the cultivators

Variables	Men (n=295)	Women (n=284)
Age (years)	38.66±12.87	38.33±13.09
True Body Weight (kg)	52.17±8.75	44.17±10.01 **
Stature (cm)	162.22±5.67	151.25±6.43 **
BMI (kg/m^2)	19.80±3.02	19.23±3.70 *
Ideal Body Weight (kg)	57.96±4.04 $	50.42±4.24 **$

w.r.t male *p<0.05, ** P<0.001 w.r.t True Body Weight $ p<0.001

Several groups of researchers were using WHO proposed BMI cutoff points to classify subjects to underweight or overweight (WHO, 1995, 2000, 2004). Whereas another group of researchers using Ferro-Luzzi et al. (1992) proposed BMI cutoff points to classify subjects to nutritional grade. However, in both these cases, a cutoff point for BMI of 18.5 kg/m^2 has been taken in most cases in the literature for chronic energy deficiency (CED) (Bailey and Ferro-Luzzi, 1995; Khongsdier, 2005) as well as underweight (WHO, 2000, 2004) classification. Thereby for screening of the CED grades of the cultivators, the value of 18.5 was taken as the cutoff point. Table 5.13 represents the percentage distribution of cultivators of present study according to BMI. CED was prevalent (male: 42.71%; female: 51.76%) among the cultivators. About 52.20% of male and 38.39% of female were normal while a low percentage (male: 5.09%; female: 9.86%) of them were overweight/obese.

The World Health Organization's classification (WHO, 1995) of the public health problem of low BMI based on adult populations worldwide, was followed.

This classification categorizes prevalence according to a percentage of a population with BMI<18·5 kg/m^2.

- Low (5–9%): warning sign, monitoring required
- Medium (10–19%): poor situation
- High (20–39%): serious situation
- Very high (≥40%): critical situation

Table 5.13: Prevalence of Chronic Energy Deficiency (CED) according to BMI of the cultivators (Male: 295, Female: 284)

BMI Value	Underweight/ Overweight Classification[1]		CED Classification[2]	Frequency (percentage) of the cultivators	
	Classification	Sub class		Male	Female
<16.00	Under weight	Severe thinness	CED Grade III (Severe)	18 (6.1%)	45 (15.85%)
16.00 - 16.99		Moderate thinness	CED Grade II (Moderate)	24 (8.14%)	40 (14.08%)
17.00 - 18.49		Mild thinness	CED Grade I (Mild)	84 (28.47%)	62 (21.83%)
18.50 - 20.00	Normal range		Low weight normal	49 (16.61%)	45 (15.85%)
20.01 - 24.99			Normal	105 (35.59%)	64 (22.54%)
25.00 - 29.99	Overweight		Obese	13 (4.41%)	24 (8.45%)
≥30.00	Obese			2 (0.68%)	4 (1.41%)

[1]WHO Classification (WHO, 1995) [2]Ferro-Luzzi Classification (Ferro-Luzzi et al. 1992)

Based on the WHO (1995) classification, it was revealed that prevalence of CED was very high among both male and female cultivators and thus the situation was critical among them. This indicated that most of the workers were suffering from nutritional deficiencies which strongly supported the observed results by diet survey schedule (Section 5.3.1). Such nutritional deficiency might be the possible cause of CED among the cultivators. Low BMI and high levels of undernutrition were a major public health problem, especially among rural underprivileged adults in developing countries (WHO, 1995). Investigations were carried out by different groups of researchers and revealed that the adult Indian rural population were suffering from some grade of CED (Bose et al. 2007; Chakraborty et al. 2007; Pal et al. 2014a,c).

The BMI of both male and female workers was compared with other groups of workers (Table 5.14; Table 5.15). In case of male, the results indicated that BMI of the present study was significantly lower than that of forestry stackers ($P<0.001$). However, there was no significant difference in BMI between the present study and prawn seed collectors as well as brick kiln worker. The results also indicated that BMI of the present study was significantly higher than tea factory worker ($P<0.001$). But it was observed that other than tea factory worker, all the groups were within normal range (18.5-24.99 kg/m^2). In case of females, BMI of the present study was significantly lower than forestry stackers ($P<0.001$). The BMI value of the subjects of present study had no significant difference with that of textile factory worker, prawn seed collectors and brick kiln worker. The results also indicated that the BMI value of all the occupational groups except brick kiln worker were within normal range (18.5-24.99 kg/m^2). The workers of the present study had to perform continuous physical activity which might lead to low fat deposition and low body weight; this might be the causal factor of lowered BMI value. It is well known that various lifestyle factors and socioeconomic inequalities affect BMI of industrial workers (Yajnik, 2002; Wadden et al. 2012; Eckel et al. 2014). Physical activity might be an important factor in preventing obesity and improving the fat distribution of the upper body (Misra et al. 2009; Lee et al. 2012; Wadden et al. 2012).

Table 5.14: Comparison of BMI of male subjects among earlier survey and present study

Workers Group	**n**	**Age**	**Height**	**Weight**	**BMI**
Potato cultivators (Present Study)	295	38.66 ±12.87	162.22 ±5.67	52.17 ±8.75	19.8 ±3.02
Tea factory worker (a)	15	20.1 ±1.73	163.8 ± 7.5	46.3* ±3.04	17.1** ±2.4
Prawn seed collectors (b)	21	31 ±12.19	161.9 ±6.13	50.6 ±6.37	19.3 ±2.06
Forestry stackers (c)	23	35.5 ± 8.7	172.2* ± 5.5	66.2* ± 5.3	22.4* ± 1.8
Brick kiln worker (d)	92	33.5 ±6.2	169.2* ±4.1	55.2 ±6.2	18.8 ±1.8

w.r.t. present study * P<0.001, ** P<0.01
a. Sengupta and Sahoo, 2012 b. Gangopadhyay et al. 2008 c. Scott and Christie 2004
d. Das, 2014b

Table 5.15: Comparison of BMI of female subjects among earlier survey and present study

Workers Group	**n**	**Age**	**Height**	**Weight**	**BMI**
Potato cultivators (Present Study)	284	38.33 ±13.09	151.25 ±6.43	44.17 ±10.01	19.23 ±3.7
Textile factory worker (a)	32	35.06 ±4.53	149.0 ±7.0	44.11 ±5.74	19.2 ±2.16
Prawn seed collectors (b)	25	35.6 ±11.78	150.3 ±6.17	43.3 ±5.98	19.2 ±1.96
Factory worker (c)	1612	30.1 ±8.1	153.1* ± 5.5	56.8* ± 13.2	24.2* ± 5.4
Brick kiln worker (d)	144	22.3 ± 3.13	144.15* ±5.67	40.83*** ±4.9	18.43 ±1.33

w.r.t. present study * P<0.001, *** p<0.05
a. Metgud et al. 2008. b. Gangopadhyay et al. 2008 c. Chee et al.2004 d. Sahu and Sett, 2010

The definitions of overweight and obesity in adult individuals have been varied over time. The BMI is the most commonly used as an indicator to evaluate excess body fat. Although this index has advantages in clinical and epidemiological practice – as a non-invasive and low-cost method but its predictive value for chronic diseases has been questioned, especially it does not take into account the distribution of body fat, proportions of muscle and other tissues that make up a person's total body weight, resulting in variability in different individuals and populations (Hiza et al. 2000; WHO, 2002; Flegal et al. 2009; Pal et al. 2013). Therefore, the determination of body fat percentage (BF%), lean body mass (LBM) and fat free mass (FFM) was very much essential. Different skin fold measurements of male and female workers were taken and body composition parameters were also calculated.

Tables 5.16 and Table 5.17 show different skin fold thickness and body composition parameters by gender. The body fat percentage (BF%), total body fat and BF% and BMI ratio in the female were significantly ($p<0.001$) higher than that of male. By contrast, the lean body mass was significantly ($p<0.001$) higher in male than that in female. According to the finding of the Shah et al. (2005) and Pal et al. (2013; 2014c), it has been revealed that Indian female had comparatively low BMI and high BF% than that of the male.

In comparison with other countries, people of African descent had greater bone and muscle mass at a given BMI (Wagner and Heyward, 2000), conversely, in male of Indian subcontinent descent, body fat content was higher (and fat free mass was lower) than for South African Black or white Americans at any given level of BMI (Rush et al. 2007). Asians have a higher total body fat as well as a higher amount of abdominal and visceral fat at a given BMI compared with other races and ethnicities (Wang et al. 1994; Deurenberg et al. 2002; Lear et al. 2007).

Table 5.16: Different skin folds thickness (Mean±SD) of male and female workers (all measurements in mm)

Variables	Male (n=295)	Female (n=284)
Chest skin fold	15.43±5.8	-
Abdomen skin fold	15.84±5.1	-
Thigh skin fold	17.48±6.04	17.11±8.96
Triceps skin fold	-	14.61±8.91
Supra-iliac skin fold	-	14.23±8.73

Table 5.17: Different body composition parameters of workers

Variables	Male (n=295)	Female (n=284)
Body density (gm/cc.)	1.06±0.01	1.05±0.02**
Body fat percentage (BF %)	15.60±4.35	19.38±8.67 **
Total body fat (Kg)	8.38±3.4	9.25±6.24*
Lean body mass (kg)	43.78±6.11	34.91±4.82 **
BF%:BMI	0.78±0.16	0.98±0.31 **

*p<0.05, ** P<0.001

Table 5.18: Correlation coefficients between BMI and BF % and between BMI and lean body mass by sex and age groups

Age Groups (years)	BMI - BF%	BMI – LBM
Male		
All respondents	0.721*	0.816*
18–29.9	0.733*	0.855*
30-39.9	0.669*	0.806*
40-49.9	0.743*	0.833*
50-60	0.760*	0.804*
Female		
All respondents	0.836*	0.735*
18–29.9	0.788*	0.744*
30-39.9	0.791*	0.641*
40-49.9	0.875*	0.767*
50-60	0.877*	0.793*

* P<0.001 BF% - body fat percentage, LBM- lean body mass
BMI- Body Mass Index

The Correlation cofficients of BMI with BF% and lean body mass by sex and age groups have been presented in Table 5.18. Correlation analysis demonstrated that BMI was positively and significantly correlated with BF% and lean body mass in both sexes and in all age groups. It was also noted that the correlation coefficient between BMI and BF% had a tendency to be increased with the advancement age in both the sexes. Kesavachandran et al. (2012) studied in urban Indian population and concluded that BMI was positively associated with BF%. According to Ranasinghe et al. (2013) there was a significant correlation between BF% and BMI of Sri Lankan adults.

5.4 General Health Status

5.4.1 Hemoglobin Concentration

The hemoglobin content of the participants was measured and it was noted that the average blood hemoglobin values of both male and female cultivators were below the normal range (Table 5.19). Especially, its value in the female workers was very low and significantly ($P<0.001$) lower than the male.

Both male and female cultivators were classified as mild, moderate or severe anemia based upon their hemoglobin status following international reference (WHO, 2011) and have been presented in Table 5.20. In the study population, the prevalence of anemia was 46.62% in males and 66.87% in females, which was more than the global prevalence (Worldwide prevalence of anemia, 1993–2005; De Mayer and Tegman, 1998). Among of them 29.73% male and 34.97% female had mild, 12.16% male and 14.11% female had moderate and 4.73% male and 9.2% female had severe anemia. The exact figures for the prevalence of anemia vary from study to study, but there is no doubt that anemia is an extremely serious public health problem in India, especially among the rural population. But females have a higher percentage of anemia and lower hemoglobin content than the males. The gender difference in anemia might be due to the fact that adult females experienced regular blood loss due to menstruation as well as repeated delivery. The added burden of intra-household food allocation precipitates the crisis too often. In a family with limited resources, the female is more likely to be neglected (Siddharam et al. 2011). Several studies on intra-household food allocation showed that women got less food than men relative to their nutritional needs (Bharati et al. 2004; Siddharam et al. 2011). Unequal access to food, heavy work demands, nutritional deficiencies including iron, made Indian women susceptible to illness, and anaemia (Seshadri, 1997; Gupta et al. 2011). While malnutrition in India is prevalent among all segments of the population, poor nutrition among women begins in infancy and continues throughout their lifetime (Siddharam et al. 2011). As stated earlier, female members in a family typically, are the last to eat. Thus, if there is not enough food they are the ones to suffer most (Bharati et al. 2004). Nutritional assessment of the participants also supports such gender bias in food sharing (Section 5.3.1). In various societies of India, large-scale sex discrimination exists in sharing of food (Basu et al. 1986; Khan et al. 1995; Bentley and Griffiths, 2003).

Table 5.19: Mean± SD of hemoglobin content (g/dl) among male and female cultivators

Parameter	**Mean±SD**
Male (n=148)	12.19±2.27
Female (n=163)	10.26±2.13*

*p<0.001

According to the WHO classification of anemia as a problem of public health significance at community levels, the prevalence of anemia which was > 40% was considered to be a severe public health problem, that which was between 20.0 to 39.9% to be a moderate public health problem, that which was between 5.0 to 19.9% to be a mild public health problem and that which was <4.9% not to be a public health problem (WHO, 2001). As the prevalence of anemia among the study population of both sexes was greater than 40%, it was considered as a severe public health problem. The present study thus brings out the fact that the problem of anemia was related to a wider population than the traditionally considered groups of the pregnant and lactating females and children. The adult male population was also equally susceptible in rural areas of West Bengal.

Table 5.20: Prevalence **(**Frequency (f) and percentage (%)) of different categories of anemia among male and female cultivators

Anemia classification	Frequency (f)		Percentage (%)	
	Male	Female	Male	Female
Mild (Male- Hb.10-12.9 g/dl; Female- Hb.10 –11.9 g/dl)	44	59	29.73	36.2
Moderate (Hb.7-9.9 g/dl)	18	32	12.16	19.63
Severe (Hb.< 7 g/dl)	7	18	4.73	11.04
All category (Male- Hb.<13g/dl; Female- Hb.<12g/dl)	69	109	46.62	66.87

Again the participants were divided into anemic and non-anemic groups with the cutoff value of hemoglobin (anemia < 13.0 g/dl for male and < 12.0 g/dl for female) and the mean values of BMI and resting heart rate were compared between those groups (Table 5.21). The results indicated that the mean value of BMI was significantly lower among anemic individuals than the non-anemic individuals of both sexes. However, the mean value of resting heart rate was significantly higher in anemic groups than that of non-anemic groups. Many studies have reported such differences between anaemic and non-anaemic individuals (Ickx et al. 2000; Weiskopf et al. 2003; Pal et al. 2014a). Ickx et al. (2000) studied on a group of 20 conscious patients and found that their heart rate increased by mean value of 2.2 beats per minute per g hemoglobin decrease when their hemoglobin concentration was reduced from 13.7 g/dl to 8.6 g/dl. Weiskopf et al. (2003) also pointed out that the heart rate increased 4 beats per minute for each g per dl decrease of hemoglobin concentration. Severe anaemia might compromise the ability to supply amounts of oxygen sufficient to meet the needs of the increased myocardial oxygen consumption caused by increased heart rate (Weiskopf et al. 2003).

Table 5.21: Comparison of BMI and heart rate between anemic and non anemic subjects

Parameters	**Male**		**Female**	
	Non anemic (n=79)	**Anemic (n=69)**	**Non anemic (n=79)**	**Anemic (n=69)**
Age (years)	37.52±12.62	40.03±14.65	37.83±12.36	32.71±15.42*
BMI (kg/m^2)	22.0±3.16	20.28±2.67***	20.52±4.16	18.98±3.13*
Heart rate (beats/min)	75.67±7.88	87.25±9.44***	73.37±9.14	84.74±11.71**

w.r.t. Non anemic *$p<0.05$, ***$p<0.001$

The dietary habits of the anemic and non-anemic subjects were also compared (Table 5.22) and it was revealed that the anemic individuals had significantly poor consumption of energy, carbohydrate and protein than that the non-anemic individuals. The vitamin and mineral intake of the anemic individuls were also significantly lower than that of non-anemic individuals of both sexes. This might be a possible reason for higher rate of anemia in the study population as there was poor bio-availability of iron in the Indian diets (Desai and Chaudhry, 1993). As stated earlier, in developing countries such as India, low dietary intake, poor iron and folic acid intake, poor bioavailability of iron in phytate fibre-rich Indian diet, were a major etiological factor for anemia (Kaur et al. 2006). In India, the rural population are mostly subjected to low bioavailability of iron because of the cereal based diet and chronic blood loss from hookworm infestations which results in anaemia (Bentley and Griffiths, 2003;

Nair and Iyengar, 2009). Although iron intake by the poor in India comes from staple foods such as rice, contamination iron from pots, small quantities from green and yellow vegetables and animal products, the phytate content of the meal is typically high (Nair and Iyengar, 2009; Gupta et al. 2011). Moreover, it was likely that the rural populations have taken a nutritionally deficient diet and are also exposed to diseases due to the unsanitary conditions; they have to wash utensils and clothing in the polluted pond water which may have been more susceptible to parasitic infestations and other chronic infections, thus leading to a higher prevalence of anemia (Seshadri, 1997; Gupta et al. 2011).

Table 5.22: Comparison of nutrient intake between non anemic and anemic subjects

Nutrients		**Male**		**Female**	
		Non anemic (n=79)	**Anemic (n=69)**	**Non anemic (n=74)**	**Anemic (n=88)**
Energy (Kcal)		2773.55±467.44	2427.67±376.09*	2537.96±495.11	2003.08±632.76*
Carbohydrate (gm)		551.18±102.51	478.31±92.30*	542.46±115.56	424.74±141.38*
Total Protein (gm)		74.02±18.99	63.88±16.85*	63.86±19.45	49.21±18.97*
Fat (gm)		31.89±15.37	30.99±13.02	28.17±10.09	26.82±9.91
Iron (mg)		25.79±6.87	19.94±6.28*	27.87±16.80	17.86±13.25*
Calcium (mg)		566.88±294.33	534.20±270.30	596.94±365.11	458.45±345.56***
Vit-A (µg)		1053.66±2125.7	828.69±1468.84	933.29±1736.88	669.62±1470.70
Vit-B1 (mg)		1.93±0.44	1.66±0.37*	1.68±0.43	1.31±0.50*
Vit-B2 (mg)		0.72±0.28	0.65±0.24	0.59±0.21	0.49±0.23**
Niacin (mg)		28.15±5.71	23.85±5.01*	25.20±5.97	19.44±7.0*
Vit-B6 (mg)		1.04±0.27	0.91±0.33**	0.91±0.27	0.81±0.32***
Folic Acid (mg)	Free	73.41±29.63	72.81±33.02	60.04±22.38	54.92±27.01
	Total	140.68±58.38	130.30±53.42	118.82±42.76	104.19±49.72
Vit C (mg)		101.43±73.39	93.61±77.80	98.51±67.23	83.22±74.95
Choline (mg)		578.31±331.85	508.24±320.98	571.54±304.31	495.15±349.42

w.r.t. Non anemic *p<0.001, **p<0.01, *** p<0.05

Based on BMI (WHO, 1995) cutoff values the participants were subdivided into three nutritional categories, viz., the underweight, normal and overweight/obese. Table 5.23 presents the mean values hemoglobin by BMI categories. Significant ($p<0.001$) differences in hemoglobin content was observed among the categories. Mean hemoglobin values increased steadily from underweight through normal to overweight/obese groups. Overweight/obese individuals had the highest mean value of hemoglobin. The magnitudes of differences were significantly higher between underweight and overweight/obese groups than between underweight and normal groups or between normal and overweight/obese groups of both sexes. Scheffe's test revealed that hemoglobin values were varying significantly among all the groups.

Table 5.23: Mean±SD of hemoglobin content (g/dl) of cultivators in different BMI categories

BMI categories	Male	Female
Underweight (BMI<18.5 kg/m^2)	10.79 ±3.02	9.61 ±2.33
Normal (BMI 18.5 - 24.9 kg/m^2)	12.52*** ±1.77	10.53* ±2.28
Overweight/Obese (BMI ≥25 kg/m^2)	13.47***## ±0.97	11.9***## ±1.65
F ratio	13.81 (p<0.001)	7.74 (p<0.001)

w.r.t. Underweight * p<0.05, ***p<0.001 w.r.t. Normal ##p<0.01

The prevalence of anemia in the individuals of different BMI categories was studied (Table 5.24) and it was found that the prevalence of anemia was high in the underweight (male: 62.5%; female: 80.65%) and the normal groups (male: 45.98%; female: 62.67%) as compared to overweight/obese group (male: 19.05%; female: 25.0%). From the chi-square statistics significant differences were found in the prevalence of anemia among the groups based upon BMI of both sexes (male: χ^2 10.48; female: χ^2 19.35). The results also indicated that there were significant differences in the occurrence of anemia among the categories except between the underweight and the normal groups of male participants. The Odd Ratio (OR) became significantly higher in underweight group compared to the normal and overweight/obese groups of both sexes (Table 5.24). In case of male, it was about seven times higher in underweight group and approximately four times higher in normal group compared to the overweight/obese group. In case of female the odd ratio was approximately twelve times higher in underweight group and five times higher in normal group compared to that of the overweight/obese group. The results indicated that the thin cultivatiors (BMI <18.5 kg/m^2) of both sexes were more likely to be anemic compared to of normal and overweight individuals. Gupta et al. (2011) reported that the prevalence of anemia was significantly increased with a decrease in the BMI. Bentley and Griffiths, (2003) also reported a similar finding in their study.

Table 5.24: Percentage (%) of normal (non anemic) and different groups anemia according to BMI categories

		BMI		
		Underweight	**Normal**	**Overweight/Obese**
MALE		(n=40)	(n=87)	(n=21)
Normal		37.5	54.02	80.05
Anemia	**Mild**	20.0	36.78	19.05
	Moderate	25.0	9.20	0
	Severe	17.5	0	0
	Total	62.50	45.98	19.05
OR		7.08##	3.62#	1
(95% CI)		(2.0-25.05)	(1.12-11.63)	-
FEMALE		(n=72)	(n=75)	(n=16)
Normal		19.44	37.33	75.0
Anemia	**Mild**	37.50	38.67	18.75
	Moderate	26.39	16.0	6.25
	Severe	16.67	8.0	0
	Total	80.56	62.67	25.0
OR		12.43###	5.04##	1
(95% CI)		(3.48-44.4)	(1.48-17.13)	-

# p<0.05, ##p<0.01, ###p<0.001

Ramachandra and Kasthuri, (2008-2010) studied on anemia in the elderly South Indian rural population and shown an association between the higher prevalence of anemia and low BMI. In the National Family Health Survey (NFHS-2) study (National Family Health Survey (NFHS-2) 1998–99), it was stated that individual with a low BMI had a somewhat higher prevalence of anemia than another.

5.4.2 Blood Pressure

The blood pressure of the participants was measured by auscultatory method, with the help of a sphygmomanometer and a stethoscope and the results have been shown in Table 5.25 according to the sex. It was noted that the average blood pressure values (SBP and DBP) of both male and female cultivators were within the normal range. However, those values were significantly lower in female than that of their male counterpart.

In the study population, the participants were categorized into normotensive, hypotensive and hypertensive according to the blood pressure cut-off values as described in previous section (Sec. 4.6.2) (Chobanian et al. 2003) and it was found that the most of the participants were in the normotensive range (male: 67.61%; female: 76%) (Table 5.26). However, a notable percentage of the participants had hypertension (male: 21.86%; female: 15.27%), although the prevalence of hypotension was low (male: 10.53%; female: 8.73%). The results also indicated that the prevalence of hypertension was significantly ($p<0.001$) higher in male than that in female. However, in case of hypotension, no significant difference was noted between the sexes.

The mean values of blood pressure of three blood pressure categories of both sexes have been shown in Table 5.27. Different measures of body compositional paprameters (obesity indicators) have also been presented in three categories of blood pressure in Table

5.28. The results indicated that mean values of blood pressures (SBP, DBP and MAP) and all obesity indicators were significantly higher (P<0.001) in hypertensive individuals than that the hypotensive and normotensive individuals. On the other hand, these parameters were significantly lower (P<0.001) in hypotensive individuals than the normotensive individuals. The findings were similar to other studies (Fang et al. 2003; Sukhonthachit et al. 2014). Kotchen et al. (2008) also reported such differences between hypertensive and normotensive individuals.

Table 5.25: Mean±SD of blood pressure values of the subjects

	Male (n=247)	Female (n=275)
	Mean±SD	**Mean±SD**
SBP (mm Hg)	122.62±18.20	117.96±17.51**
DBP (mm Hg)	78.82±12.04	77.82±11.31
MAP (mm Hg)	93.42±13.55	91.20±12.88*

SBP- Systolic blood pressure; DBP- Diastolic blood pressure, MAP- Mean artial pressure
w.r.t. Male * p<0.05, ** p<0.01

Table 5.26: Frequency and percentage of the subjects of different blood pressure categories

Blood pressure categories	**Frequency (f)**		**Percentage (%)**	
	Male	**Female**	**Male**	**Female**
Hypotension	26	24	10.53	8.73
Normotension	167	209	67.61	76.0*
Hypertension	54	42	21.86	15.27**

w.r.t. Male * p<0.05, ** p<0.001

Based on BMI cutoff value (WHO, 1995) the participants were again subdivided into three nutritional categories, viz., underweight, normal and overweight/obese. Table 5.29 presents the mean values of SBP, DBP and MAP by BMI categories. Significant differences

($p<0.001$) in blood pressure values (SBP, DBP, and MAP) were observed among the BMI categories. Overweight/obese individuals had significantly higher ($P<0.001$) blood pressure values (SBP, DBP, and MAP) compared to normal as well as underweight categories for both sexes. By contrast, the participants belonged to the underweight category had significantly lower ($P<0.001$) blood pressure values compared to normal. Mean values increased steadily from underweight through to the normal and then in the overweight/obese groups. It was noted from the results of ANOVA that the blood pressure values were varying significantly ($p<0.001$) among all groups.

Table 5.27: Mean±SD of blood pressure values of different blood pressure categories

Blood pressure	Normotensive		Hypotensive		Hypertensive	
	M (n=167)	F (n=209)	M (n=26)	F (n=24)	M (n=54)	F (n=42)
SBP (mm Hg)	119.72 ±11.88	115.85 ±11.46	94.62* ±11.4	89.58* ±5.75	145.06*# ±10.51	144.71*# ±11.68
DBP (mm Hg)	77.56 ±7.27	75.71 ±6.65	57.77* ±4.05	62.33* ±6.2	92.87*# ±8.7	97.14*# ±7.94
MAP (mm Hg)	91.61 ±8.5	89.09 ±7.65	70.05* ±4.51	71.42* ±4.56	110.27*# ±7.01	113.0*# ±7.81

w.r.t. normotensive * $p<0.001$ w.r.t. hypotensive # $p<0.001$

Table 5.28: Mean±SD of measures of obesity indicators in different blood pressure categories

Parameters	Normotensive		Hypotensive		Hypertensive	
	M (n=167)	F (n=209)	M (n=26)	F (n=24)	M (n=54)	F (n=42)
BMI (kg/m^2)	20.09 ±2.8	19.46 ±3.19	16.89* ±3.02	17.16* ±2.48	23.08*# ±2.69	23.96*# ±4.7
Fat %	15.05 ±3.57	18.23 ±7.62	12.76* ±2.95	12.29* ±5.13	20.05*# ±4.11	29.38*# ±7.58
LBM (kg)	45.46 ±6.53	35.92 ±4.19	39.5* ±7.02	34.32 ±4.58	47.85**# ±6.92	38.69**## ±5.8
TWF (kg)	8.17 ±2.68	8.67 ±5.31	5.88* ±2.02	5.1* ±3.47	12.06*# ±3.16	17.24*# ±7.6

w.r.t. normotensive ** $p<0.01$, * $p<0.001$ w.r.t. hypotensive ## $p<0.01$, # $p<0.001$

Table 5.29: Mean±SD of blood pressure of different BMI categories

Parameters	BMI categories						F ratio	
	Normal		Underweight		Overweight / Obese			
	M (n=135)	F (n=122)	M (n=87)	F (n=116)	M (n=25)	F (n=37)	M	F
SBP	127.40 ±15.87	120.51 ±14.39	112.16* ±16.64	109.26* ±14.83	133.20# ±18.89	136.86*# ±17.38	28.42$	50.65$
DBP	81.97 ±10.24	79.03 ±9.87	71.85* ±11.05	72.59* ±8.88	86.08# ±13.23	90.22*# ±11.94	31.27$	47.31$
MAP	97.11 ±11.29	92.86 ±10.87	85.29* ±12.51	84.81* ±10.13	101.79# ±14.83	105.77*# ±13.37	32.55$	54.03$

w.r.t. normal * p<0.001 w.r.t. underweight # p<0.001

$ p<0.001

The prevalence of hypertension and hypotension among the cultivators of different BMI categories was studied (Table 5.30) and it was found that the prevalence of hypertension was low in underweight (male: 16.09%; female: 10.34%) and normal groups (male: 19.26%; female: 10.65%), whereas a considerably high prevalence of hypertension was noted in the overweight/obese group (male: 56%; female: 45.94%). The result indicated that there were significant differences in the occurence of hypertension among the BMI categories except between underweight and normal groups of both sexes. However, opposite trends were observed in the case of hypotension. A higher prevalence of hypotension was found in the underweight group (male: 26.44%; female: 16.38%) compared to the normal (male: 1.48%; female: 4.09%) and overweight/obese groups (male: 4%). The result also indicated that there were significant differences in the percentage of hypotension among the BMI categories except between normal and overweight/obese groups. The odd ratio became significantly higher in the overweight/obese group, and it was approximately seven times higher in the overweight/obese group compared to the underweight group in the hypertensive category of both sexes. In case of the hypotensive category, the odd ratio was significantly higher in the underweight group, and they were approximately nine times higher in underweight group compared to the overweight/obese group of males and five times higher in the underweight group compared to the normal group in females.

Table 5.30: Prevalence (%) of hypertension and hypotension according to the nutritional categories

	Hypertension				**Hypotension**			
	Prevalence		**OR (95% CI)**		**Prevalence**		**OR (95% CI)**	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Underweight	16.09	10.34	1	1	26.44	16.38	8.62# (1.1-67.43)	4.58# (1.65-12.73)
Normal	19.26	10.65	1.24 (0.61-2.54)	1.03 (0.45-2.37)	1.48	4.09	0.36 (0.03-4.14)	1
Overweight /Obese	56	45.94	6.64# (2.5-17.57)	7.36# (3.05-17.77)	4	-	1	-
χ^2	19.29*	31.09*	-	-	36.24*	9.89**	-	-

** p<0.01, * p<0.001 # p<0.05, # p<0.001

Therefore, it appeared that the increase in BMI had a significant clinical effect on blood pressure variables. Chakraborty et al. (2009) also reported that the prevalence of hypertension significantly increased from underweight to obese categories. The significant trend of an increased risk of hypertension with an increased BMI reports was similar to the results from cross-sectional studies conducted in Asian populations (Santhirani et al. 2003; Simony et al. 2007). Hu et al. (2007) also found higher prevalence of hypertension with higher BMI levels. According to Chakraborty et al. (2009), a prevalence of hypotension lower than 15% was of no consequences to public health.

Correlation analysis demonstrated that all the anthropometric parameters and obesity indicators were significantly correlated with SBP, DBP and MAP of both sexes. A higher degree of correlation coefficient (P<0.001) was noted in cases of body weight and obesity indicators (Table 5.32). Chakraboty et al. (2009) demonstrated a significant positive correlation of BMI with blood pressure in Bengali slum dwellers of Kolkata. Gupta et al. (2007) studied an Indian urban population and reported a significant association of BMI with blood pressure in both male and female. A strong graded relationship between blood pressure and anthropometric parameters was also noted by Oyewole and Oritogun (2009).

The energy and nutrient intake of male and female participants were studied in relation to blood pressure categories. It was found that the hypertensive individuals had significantly higher consumption of energy, carbohydrate and fat compared to the hypotensive individuals (Table 5.32).

Table 5.31: Correlation between body dimensions and blood pressure variables of the subjects

Parameters	**SBP**		**DBP**		**MAP**	
	M	**F**	**M**	**F**	**M**	**F**
Height	-0.096	0.108	-0.075	0.139*	-0.087	0.130*
Weight	0.392**	0.540**	0.411**	0.542**	0.416**	0.562**
BMI	0.450**	0.566**	0.462**	0.560**	0.472**	0.584**
Thigh skin fold	0.361**	0.573**	0.342**	0.547**	0.361**	0.580**
Chest skin fold	0.290**	-	0.316**	-	0.315**	-
Abdomen skin fold	0.326**	-	0.340**	-	0.345**	-
Triceps	-	0.566**	-	0.556**	-	0.582**
Supra-iliac	-	0.558**	-	0.552**	-	0.576**
Fat %	0.428**	0.602**	0.428**	0.582**	0.442**	0.614**
Lean body mass	0.473**	0.351**	0.479**	0.369**	0.492**	0.375**
Total weight of Fat	0.287**	0.596**	0.308**	0.587**	0.308**	0.614**

*p<0.05, ** P<0.001

Table 5.32: Comparison of nutrient intake among normotensive, hypotensive and hypertensive individuals

Nutritional parameters	Normotensive		Hypotensive		Hypertensive	
	M	F	M	F	M	F
Energy (kcal)	2629.78 ±422.01	2130.56 ±622.29	2310.9*** ±334.76	1901.49 ±429.24	2727.6### ±534.98	2620.96***### ±670.78
Carbohydrate (gm)	521.58 ±100.73	450.71 ±136.73	454.82** ±77.04	398.43 ±94.55	539.54### ±114.58	574.04***### ±157.56
Protein (gm)	69.14 ±17.9	54.98 ±20.92	73.21 ±26.66	54.42 ±16.37	67.63 ±15.83	49.11 ±19.28
Fat (gm)	31.5 ±11.99	26.95 ±10.26	24.84* ±11.1	22.52** ±5.64	34.72# ±18.78	32.09*### ±8.92
Iron (mg)	22.95 ±6.59	20.81 ±14.7	19.52* ±6.75	22.83 ±18.1	25.05## ±8.14	21.95 ±16.4
Calcium (mg)	579.16 ±276.8	518.26 ±352.08	615.7 ±365.33	662.78 ±430.17	463.94* ±239.17	327.3**## ±261.87

w.r.t. normotensive *P<0.05, ** p<0.01,*** p<0.001
w.r.t. hypotensive ##p<0.01, ###p<0.001

Table 5.33: Correlation between nutritional status and blood pressure of the individuals

Parameters		SBP	DBP	MAP
Energy (Kcal)	M	0.185*	0.204*	0.203*
	F	0.289***	0.257***	0.280***
Carbohydrate (gm)	M	0.167*	0.176*	0.178*
	F	0.333***	0.298***	0.324***
Protein (gm)	M	-0.219**	-0.231**	-0.234**
	F	-0.193*	-0.188*	-0.196*
Fat (gm)	M	0.205*	0.261***	0.246**
	F	0.225**	0.193*	0.214**
Iron (mg)	M	0.115	0.104	0.113
	F	-0.066	-0.074	-0.073
Calcium (mg)	M	-0.216**	-0.178*	-0.202*
	F	-0.351***	-0.311***	-0.339***

*p<0.05, **P<0.01, *** P<0.001

Correlation analysis also demonstrated that the blood pressure parameters (SBP, DBP and MAP) had a significant positive correlation with energy, carbohydrate and fat intake. These parameters had a significant negative correlation with protein and calcium consumption (Table 5.33). Jakobsen et al. (2004); Kotsis et al. (2010) and Willett, (2012) reported that dietary fat was associated with an increase in the risk of coronary disease. Nowson et al. (2005) reported an inverse association between dietary protein and calcium versus blood pressure. Several investigators (Appel et al. 1997; Houston and Harper, 2008 and Pal et al. 2014c) also reported a similar findings in their study. Cutler and Obarzanek, (2005) discussed the probable mechanisms by which protein might reduce blood pressure, including increasing insulin sensitivity and dietary arginine-induced increases in nitric oxide levels. Van-Mierlo et al. (2006) studied the response of blood pressure to calcium supplementation and found that calcium (1200mg/day) significantly reduced SBP by 1.9 mmHg and DBP by 1.0 mm Hg. Dietary calcium might lower the activity of the rennin- angiotensin system, improved sodium, potassium balance and inhibited vascular smooth muscle cell contraction (Resnick, 1999; Houston and Harper, 2008). Moreover, higher calcium intake facilitates weight loss and enhances insulin sensitivity, which also contributes to blood pressure reduction (Wang et al. 2008).

Occupational Stress

Part B

Contents

5.5 Occupational Health Hazards

5.5.1 Musculoskeletal Disorder

Musculoskeletal disorders (MSDs) are defined as a group of injuries that affect the musculoskeletal system, including nerves, tendons, muscles, and supporting structures such as intervertebral discs (NIOSH, 1997; Punnett and Wegman, 2004; Summers et al. 2015). MSDs are also referred to as overexertion / overuse injuries, cumulative trauma disorders, repetitive strain injuries, sprains and strains. Work-related musculoskeletal disorders (WMSDs) constitute an important occupational health problem for both developed and developing countries, with rising costs of wage compensation and medical expenses, reduced productivity and lower quality of life (Karwowski and Marras, 2003; Punnett and Wegman, 2004; Dall et al. 2013; Summers et al. 2015).

Farming is one of the most hazardous occupations with respect to injuries and MSDs (Osborne et al. 2012; Kar et al. 2012; Pal et al. 2014b; Pal et al. 2015a). Many of the farmers have major concerns about their safety and what can be done to maintain their health and safety (Zhou and Roseman, 1994; Pal et al. 2015a). In the United States, sprains and strains accounted for 28.2% of the approximately 200,000 lost times injuries that occurred on farms (Myers, 2001). Overexertion or MSDs impact farming extensively with more than 43% of all agricultural injuries falling in this category (Meyers et al. 1997). Zhou and Roseman, (1994) and Bhattacharya and McGlothlin (2012) reported that sprains and strains are the leading causes of farm injuries. However, health care providers do not focus upon musculoskeletal disorders in the agricultural population. This may occur due to the assumption that musculoskeletal disorders are an unavoidable result of farm labor (Fenske and Simcox, 2000). The National Research Council and Institute of Medicine (2001) defines work related illness or disease as being caused by aggravated, accelerated or exacerbated by workplace exposures, which result in impaired work capacity (NIOSH, 2001).

In the present study the prevalence of musculoskeletal disorders of the vegetable cultivators was evaluated by the modified Nordic Questionnaire method (Section 4.7.1) and the prevalence of MSDs among the workers has been presented in Table 5.34. It was revealed that the prevalence of MSDs was very high among the workers of both sexes. The lower back problem was highly prevalent (Male: 93.25%; Female: 92.26%) among the workers when all potato cultivation tasks were considered together and it was followed by upper back (Male: 63.8%; Female: 65.16%), waist (Male: 60.12%; Female: 57.42%), shoulder (Male: 47.24%; Female: 61.94%), hip (Male: 44.17%; Female: 55.48%) and elbow (Male: 46.63%; Female: 50.57%). The higher prevalence of work related MSDs at different body segments of the workers might be related to their postural pattern, repetitive movements as well as longer duration of exposure in awkward posture (Caicoyal and Delclos, 2010; Da-Costa and Vieira, 2010; Pal et al. 2014b; Pal et al. 2015a), which have been discussed later in this chapter (Section 5.7). Osborne et al. (2012) reported that lower back pain was the most common MSD among the farmers, followed by upper and then lower extremity MSDs. They also reported that the prevalence of MSDs in farmers was greater than in non-farmer populations. The lower back pain was commonly associated with decrease muscular strength, spinal flexibility, incapacity and eventually activity limitation due to sick leave and corresponding high costs to the society, which also reported by Van-Tulder et al. (1995) and Volpato et al. (2014). Das and Gangopadhyay, (2012) studied on potato cultivators and reported that prolonged work activity, high repetitiveness and remaining constantly in an awkward posture for a prolonged period may lead to MSDs. A constant repetition of movements imposed a cumulative work load which could cause pain and weakness and impaired function of the muscles and other soft tissues (Gangopadhyay et al. 2007). Physiological evidence showed that the rate and degree of tissue damage was dependant on the amount of force, repetition and duration of exposure (Geronilla et al. 2003; Barbe et al. 2013). The physiological problems that arise from repetitive work or overuse of certain muscles, tendons and soft-tissue structures have been addressed in terms of muscle fatigue, tissue density changes and tissue strain (Valachi and Valachi, 2003; Gallagher and Heberger, 2013; Gerr et al. 2014).

Table 5.34: Percentage of workers reported musculoskeletal disorders (MSDs) in different parts of the body during performing potato cultivation tasks

Body Segments	Male (n=163)	Female (n=155)	Unadjusted OR (95th CI)	Adjusted OR # (95th CI)
Neck	57 (34.97)	71 (45.81)*	1.587 (1.01-2.49)	1.833 $ (1.08-3.1)
Shoulder	77 (47.24)	96 (61.94)**	1.838 (1.18-2.87)	2.056 $$ (1.18-3.59)
Elbow	76 (46.63)	79 (50.97)	1.204 (0.78-1.87)	1.013 (0.6-1.7)
Wrist	98 (60.12)	89 (57.42)	0.908 (0.58-1.42)	0.859 (0.51-1.46)
Upper Back	104 (63.80)	101 (65.16)	1.079 (0.68-1.71)	1.207 (0.69-2.09)
Lower Back	152 (93.25)	143 (92.26)	0.941 (0.41-2.16)	0.814 (0.31-2.11)
Hip	72 (44.17)	86 (55.48)*	1.593 (1.02-2.48)	1.493 (0.89-2.51)
Knee	45 (27.61)	54 (34.84)	1.414 (0.88-2.28)	1.267 (0.73-2.18)
Feet	31 (19.02)	45 (29.03)*	1.755 (1.04-2.96)	1.756 (0.94-3.27)

OR- Odd Ratio; 95th CI-95% confidence interval Male- reference category
w.r.t. Male * p<0.05; ** p<0.01 $ p<0.05; $$ p<0.01
after adjusting age, BMI, work experience and work category

The upper extremity MSDs problem was also very high among the workers. In all tasks of potato cultivation, workers had to move their arms repetitively. This might evoke shoulder muscular tenderness disorder, which might be due to the static fatigue of the Trapezius muscle and multifactorial identification, including static and awkward posture and work practices (Hayes et al. 2009).

It has been noted that the female workers had higher incidence of MSDs in majority of their body segments compared to the male workers. Multinomial logistic regression analysis showed that even after controlling for the effect of age, BMI, work experience and work category the female workers were more likely to have musculoskeletal pain / discomfort compared to the male cultivators. The odd ratio of neck discomfort in female was 1.59 (95% CI: 1.01-2.49) compared to that of the male workers (OR = 1). The odd ratio of shoulder, hip, knee and feet discomforts in female were 1.84 (95% CI: 1.18-2.87), 1.59 (95% CI: 1.02-2.48), 1.41 (95% CI: 0.88-2.28) and 1.75 (95% CI: 1.04-2.96) respectively compared to that of the male workers (OR = 1). Guo et al. (2004); Sabharwal and Kaushik, (2011) and Das, (2015) also indicated that the female workers had a significantly higher prevalence of MSDs than that of the male workers which might be due to performing different household activities that lead to enhanced discomfort feeling in their different body parts.

Before follow up, complete information of work experience of the cultivators was noted on the basis of a questionnaire and the participants were divided into three groups based on their work experiences viz., Gr.-A (work experience ≤5 years); Gr.-B (work experience 6-15 years) and Gr.-C (work experience >15 years). From the results it was revealed that about 14.72% male and 36.13% female had their work experiences for ≤5 years, 54.6% male and

46.45% female had their work experiences for 6 to 15 years and 30.68% male and 17.42% female had experience of at least 16 years.

The occurrence of MSDs in different work experience groups was studied and from the results (Table 5.35) it has been revealed that there was a significant difference in the occurrence of MSDs in the shoulder ($p<0.001$) and hip ($p<0.01$) of male and in neck ($p<0.05$), shoulder ($p<0.01$), elbow ($p<0.001$), hip ($p<0.001$) and knee ($p<0.01$) of female workers among the different work experience groups. The results showed that the occurrence of MSDs were significantly higher in different body segments in workers of Gr.-A compared to that of the Gr.-B and Gr.-C workers. The workers of Gr.-C also showed a significantly higher percentage of MSD in different body parts compared to the workers of Gr.-B.

The impact of work experience on the prevalence of musculoskeletal disorders was studied and presented in Table 5.35a. The occurrence of MSDs exhibited variation in the participants having different work experience. The multinomial logistic regression analysis showed that both Gr. A and Gr. C workers were more likely to have musculoskeletal pain / discomfort compared to that of the Gr. B workers. The odd ratio of shoulder discomfort in Gr. A and Gr. C workers were 4.36 (95% CI: 2.41-7.91) and 2.28 (95% CI: 1.31-3.97) compared to that of the Gr. B workers (OR = 1). The odd ratio of lower back, elbow, hip, knee and feet discomforts in Gr. A workers were 10.49 (95% CI: 1.38-79.89), 3.76 (95% CI: 2.12-6.68), 3.62 (95% CI: 2.06-6.36), 2.25 (95% CI: 1.26-4.02) and 2.61 (95% CI: 1.42-4.79) respectively compared to that of the Gr. B workers (OR = 1). For the workers of Gr. A and Gr. C, a positive relationship with musculoskeletal pain was found in the unadjusted and adjusted analyses. Such difference might be due to involvement of less skill workers in the lower age group. As the workers were newly recruited they were untrained and possessed a little knowledge to operate the hand tools. From the study of the Häkkänen et al. (2001) it has been revealed that among trailer assembly workers a higher rate of sick leave due to disorders of the upper limbs was found for new workers compared with experienced ones.

Table 5.35: Prevalence of MSDs among the male and female workers on the basis of their work experiences (the values in parenthesis indicate the percentage of MSD)

Body segments	**Male (n=163)**				**Female (n=155)**			
	Gr-A (≤5 yrs.) (n=24)	**Gr-B (6-15 yrs.) (n=89)**	**Gr-C (>15 yrs.) (n=50)**	**$\chi 2$**	**Gr-A (≤5 yrs.) (n=56)**	**Gr-B (6-15 yrs.) (n=72)**	**Gr-C (>15 yrs.) (n=27)**	**$\chi 2$**
	f (%)	f (%)	f (%)		f (%)	f (%)	f (%)	
Neck	11 (45.83)	28 (31.46)	18 (36.0)	1.751	33 (58.93)	27* (37.50)	11 (40.74)	6.165 (p<0.05)
Shoulder	21 (87.5)	30*** (33.71)	26**# (52.0)	22.601 (p<0.001)	39 (69.64)	36*$ (50.0)	21#$ (77.78)	9.619 (p<0.01)
Elbow	16 (66.66)	36* (40.45)	24 (48.0)	5.276	40 (71.43)	26*** (36.11)	13* (48.15)	15.826 (p<0.001)
Wrist	17 (70.83)	51 (57.30)	30 (60.0)	1.444	38 (67.86)	35* (48.61)	16 (59.26)	4.818
Upper Back	19 (79.16)	50* (56.18)	35 (70.0)	4.205	42 (75.0)	40* (55.56)	19 (70.37)	5.637
Lower Back	24 (100.0)	80 (89.88)	48 (96.0)	3.937	55 (98.21)	63* (87.50)	25 (92.59)	5.068
Hip	18 (75.0)	30*** (33.71)	24* (48.0)	13.498 (p<0.01)	35 (62.50)	27** (35.50)	24*###$$ (88.89)	22.742 (p<0.001)
Knee	10 (41.66)	20 (22.47)	15 (30.0)	3.691	22 (39.29)	17 (23.61)	15##$ (55.56)	13.556 (p<0.01)
Feet	8 (33.33)	13* (14.61)	10 (20.0)	4.349	21 (37.50)	16 (22.22)	8 (29.63)	3.574

w.r.t. Gr. A in each gender group * p<0.05, ** p<0.01, *** p<0.001
w.r.t. Gr. B in each gender group #p<0.05, ## p<0.01, ### p<0.001
w.r.t. male workers $ p<0.05, $$ p<0.001

On the other hand, the higher incidence of MSDs in the workers of the upper age group might be due to reduced muscle strength and endurance with the advancement of age (Holmström and Engholm, 2003; Fejer and Ruhe, 2012; Keller and Engelhardt, 2013). Guo et al. (2004) noted in their studies that MSDs was significantly increased with age. From the findings of the Alexopoulos et al. (2003) and Habib et al. (2005) it has been revealed that age has been strongly associated with chronic complaints.

Table 5.35a: Cross-sectional associations between work experience and MSDs

Body segments	Gr-A (≤5 yrs.)		Gr-C (>15 yrs.)	
	Unadjusted OR (95th CI)	Adjusted OR # (95th CI)	Unadjusted OR (95th CI)	Adjusted OR # (95th CI)
Neck	2.378 (1.37-4.11)	1.2 (0.54-2.67)	1.175 (0.67-2.07)	1.446 (0.59-3.56)
Shoulder	4.364 (2.41-7.91)	3.03** (1.28-7.15)	2.279 (1.31-3.97)	1.423 (0.57-3.58)
Elbow	3.763 (2.12-6.68)	3.41** (1.48-7.86)	1.492 (0.86-2.58)	0.547 (0.22-1.34)
Wrist	1.944 (1.11-3.42)	2.317* (1.0-5.36)	1.311 (0.76-2.27)	0.445 (0.17-1.16)
Upper Back	2.568 (1.41-4.68)	1.595 (0.64-3.97)	1.878 (1.05-3.35)	1.667 (0.68-4.11)
Lower Back	10.497 (1.38-79.89)	6.236 (0.49-79.57)	2.425 (0.79-7.39)	4.027 (0.69-23.56)
Hip	3.616 (2.06-6.36)	4.247*** (1.85-9.73)	3.049 (1.74-5.35)	5.851*** (2.24-15.29)
Knee	2.252 (1.26-4.02)	3.827** (1.52-9.66)	2.156 (1.19-3.88)	2.371 (0.95-5.92)
Feet	2.608 (1.42-4.79)	1.933 (0.76-4.92)	1.399 (0.72-2.72)	2.287 (0.79-6.65)

* p<0.05, ** p<0.01, *** p<0.001 Gr-B (6-15 yrs.)- Reference category
# after adjusting sex, age, BMI and work category

The potato cultivators had to perform mainly three types of tasks, viz. planting of seeds, tunneling in the land and potato harvesting. The prevalence of MSDs among the male and female workers has been presented in three categories of tasks separately in Table 5.36. The results indicated that the prevalence of MSDs was comparatively higher in tunneling task when compared to that of potato harvesting and seed planting operations. The multinomial logistic regression analysis showed that the participants those were involved in tunneling and potato harvesting tasks, were more likely to have musculoskeletal pain compared to that of the seed planting operators (Table 5.36a). However, lower back problem was extremely prevalent in all types of tasks of potato cultivation. It was the highest in tunneling task (96.3%) followed by potato harvesting (95.28%) and planting of seed (86.54%). The upper back problem was also prevalent in all types of task of potato cultivation. It was the highest in tunneling task (75.93%) followed by potato harvesting (69.81%) and seed planting operation (47.12%). The predominant posture of different potato cultivation tasks were forward bend and squat sitting posture which has been discussed later in this chapter (Sec. 5.7.1). Adopting these awkward postures during work might be possible causes of back pain. According to the report of NIOSH (1997), forward bending, squatting and non-neutral trunk postures are the awkward posture, which are responsible for lower back disorder. The National Research Council and Institute of Medicine (2001) also reported that there was a clear relationship between back disorders and physical load and awkward posture. The present results also indicated that MSDs was prevalent in different parts of upper limbs. It was also revealed that most of the workers reported disorders in shoulder and wrist. Disorder in the shoulder was the highest in tunneling task (66.67%) followed by potato harvesting (52.83%) and seed planting task (43.26%). However, wrist problem was the highest in seed planting task (60.58%)

followed by tunneling task (58.33%) and potato harvesting task (57.55%). The high prevalence of wrist problem during planting of seeds might be due to frequent flexion and twisting movement at wrist joints.

All these potato cultivation tasks required frequent movement of the shoulder, but the frequency of movement was very high in case of tunneling job due to spade operation. In case potato harvesting task, the workers collect potato and loaded into a basket/sac and the workers had to lift the loaded container in the head of the carrier in a regular interval. Thus the frequency of upper arm movement was very high and this might be the reason for the occurrence of shoulder pain of the workers. In all those potato cultivation tasks, major percentages of workers were affected bilaterally. This might be due to the fact that in all operations the workers were using both right and left arms almost equally during performing the task.

Table 5.36: Percentage (%) of cultivators reported MSDs in different body parts during performing different potato cultivation tasks (the values in parenthesis indicate the percentage of MSD)

Body segments	**Planting of Seeds (n=104)**	**Tunneling (n=108)**	**Harvesting (n=106)**	**$\chi 2$**
Neck	37 (35.58)	49 (45.37)	42 (39.62)	2.139
Shoulder	45 (43.26)	72 (66.67)***	56 (52.83)#	11.851 (p<0.01)
Elbow	50 (48.08)	64 (59.26)	41 (38.68)##	9.096 (p<0.05)
Wrist	63 (60.58)	63 (58.33)	61 (57.55)	0.214
Upper Back	49 (47.12)	82 (75.93)***	74 (69.81)***	21.181 (p<0.001)
Lower Back	90 (86.54)	104 (96.30)*	101 (95.28)*	9.018 (p<0.05)
Hip	57 (54.81)	49 (45.37)	54 (50.94)	1.193
Knee	34 (32.69)	25 (23.15)	40 (37.74)#	3.488
Feet	24 (23.08)	16 (14.81)	36 (33.96)##	10.841(p<0.01)

w.r.t. Planting of Seeds * p<0.05, *** p<0.001
w.r.t. Tunneling # p<0.05, ## p<0.01, ### p<0.001

Table 5.36a: Cross-sectional associations between work categories and musculoskeletal disorders [OR: odd ratio]

Body segments	Tunneling				Harvesting	
	OR \$ (95th CI)		OR £ (95th CI)		OR \$ (95th CI)	
	Unadjusted	Adjusted #	Unadjusted	Adjusted #	Unadjusted	Adjusted #
Neck	1.526 (0.88-2.65)	1.472 (0.81-2.67)	1.266 (0.73-2.18)	0.97 (0.52-1.79)	1.206 (0.69-2.11)	1.113 (0.57-2.16)
Shoulder	2.667 (1.53-4.65)	2.925*** (1.52-5.64)	1.786 (1.03-3.1)	1.696 (0.88-3.26)	1.493 (0.87-2.57)	1.94 (0.96-3.96)
Elbow	1.6 (0.93-2.75)	1.743 (0.95-3.19)	2.306 (1.33-3.99)	2.381** (1.28-4.44)	0.694 (0.4-1.9)	0.764 (0.39-148)
Wrist	0.933 (0.54-1.61)	0.848 (0.47-1.53)	1.033 (0.6-1.78)	0.929 (0.49-1.75)	0.904 (0.52-1.56)	0.908 (0.45-1.82)
Upper Back	3.6 (2.0-6.47)	3.422*** (1.82-6.43)	1.364 (0.74-2.49)	1.001 (0.51-1.97)	2.64 (1.5-4.65)	2.967** (1.51-5.82)
Lower Back	4.333 (1.39-13.53)	3.694* (1.12-12.15)	1.287 (0.34-4.93)	0.781 (0.15-4.06)	3.367 (1.18-9.63)	2.949 (0.88-9.89)
Hip	0.755 (0.44-1.29)	0.688 (0.385-1.23)	0.8 (0.47-1.37)	0.591 (0.32-1.1)	0.944 (0.55-1.62)	1.421 (0.7-2.88)
Knee	0.629 (0.34-1.15)	0.583 (0.31-1.1)	0.497 (0.27-0.9)	0.289*** (0.14.-0.6)	1.266 (0.72-2.23)	1.485 (0.75-2.93)
Feet	0.587 (0.292-1.18)	0.474 (0.22-1.01)	0.338 (0.17-0.66)	0.235*** (0.1-0.53)	1.736 (0.94-3.19)	1.932 (0.93-4.01)

* $p<0.05$, ** $p<0.01$, *** $p<0.001$
# after adjusting sex, age, BMI and work experience
\$ Planting of seeds (reference category) £ Harvesting (reference category)

A comparison of MSDs has also been done among the task groups (planting of seeds, tunneling and potato harvesting) according to their gender. The results have been presented in Table 5.37 and 5.38 for male and female workers respectively. In case of male workers, the occurrence of MSDs was significantly different in different segments of the body among the workers engaged in different potato cultivation tasks. The workers engaged in tunneling task had significantly higher percentage of MSDs in the shoulder ($p<0.001$), upper back ($p<0.001$) and lower back ($p<0.05$) compared to that of the workers engaged in planting of seeds. In addition to those, the workers engaged in tunneling task also had a higher percentage of MSDs in different body segments compared to that of the seed planting workers except in wrist, knee and feet. From the results it was revealed that the workers engaged in potato harvesting task had significantly higher percentage of MSDs in shoulder ($p<0.01$), upper back ($p<0.01$) and lower back ($p<0.05$) than that of the seed planting task. However, the potato harvesting workers had significantly lower prevalence of MSD in elbow ($p<0.001$) than that of the seed planting workers. The results also indicated that potato harvesting workers had significantly higher percentage of discomfort in the knee ($p<0.05$) and feet ($p<0.01$) compared to that of the workers engaged in tunneling task.

Table 5.37: Comparison of MSDs in male workers among different groups of potato cultivation tasks

Body Segments	Planting of Seeds (n=51)	Tunneling (n=60)	Harvesting (n=52)	$\chi 2$
Neck	13 (25.49)	22 (36.67)	22 (42.31)	3.323
Shoulder	12 (23.53)	38 (63.33)***	27 (51.92)**	18.196 (p<0.001)
Elbow	24 (47.06)	37 (61.67)	15 (28.85)###	12.063 (p<0.01)
Wrist	34 (66.67)	30 (50.00)	34 (65.38)	4.076
Upper Back	21 (41.18)	45 (75.00)***	38 (73.08)**	16.499 (p<0.01)
Lower Back	43 (84.31)	58 (96.67)*	51 (98.08)*	9.510 (p<0.05)
Hip	19 (37.25)	29 (48.33)	24 (46.15)	1.494
Knee	16 (31.37)	11 (18.33)	18 (34.62)#	4.222
Feet	10 (19.61)	5 (8.33)	16 (30.77)##	9.121 (p<0.05)

w.r.t. Planting of Seeds * $p<0.05$, ** $p<0.01$, *** $p<0.001$
w.r.t. Tunneling # $p<0.05$, ## $p<0.01$, ### $p<0.001$

In case female workers, there was a significant difference in MSDs in upper back and hip among the workers in different task groups. The workers engaged in tunneling task had significantly higher prevalence of MSDs in the upper back ($p<0.05$) compared to that of the seed planting task. In addition to those, the workers engaged in tunneling task also had a higher percentage of MSDs in different body segments than that of workers engaged in seed planting except in hip, knee, and feet. The workers engaged in seed planting task had a higher percentage of discomfort in different body segments (neck, shoulder, elbow, wrist and hip) compared to that of the workers engaged in potato harvesting task except in upper back, lower back, knee and feet. From the results it was revealed that the workers engaged in tunneling task had higher percentage of discomfort in different body segments than that of the workers performing potato harvesting task except in hip, knee and feet. The occurrence of discomfort in the lower back was almost the same in all the groups.

Table 5.38: Comparison of MSDs in female workers among different groups of potato cultivation tasks

Body segments	**Planting of Seeds (n=53)**	**Tunneling (n=48)**	**Harvesting (n=54)**	χ^2
Neck	24 (45.28)	27 (56.25)	20 (37.04)	3.788
Shoulder	33 (62.26)	34 (70.83)	29 (53.7)	3.166
Elbow	26 (49.06)	27 (56.25)	26 (48.15)	0.785
Wrist	29 (54.72)	33 (68.75)	27 (50.00)	3.895
Upper Back	28 (52.83)	37 (77.08)*	36 (66.67)	6.609 ($p<0.05$)
Lower Back	47 (88.68)	46 (95.83)	50 (92.59)	1.818
Hip	38 (67.92)	20 (41.67)**	30 (55.56)	9.307 ($p<0.01$)
Knee	18 (33.96)	14 (29.17)	22 (40.74)	1.527
Feet	14 (26.42)	11 (22.92)	20 (37.04)	2.727

w.r.t. Planting of Seeds * $p<0.05$, ** $p<0.01$

The comparison of MSDs between male and female potato cultivators revealed that the female workers had higher incidence of MSD at different segments of the body than that of the male workers (Table 5.39). It was noted that the female workers engaged in seed planting task had significantly higher percentage of MSDs at different segments of the body than that of male workers except in the wrist. The workers had to perform seed planting tasks in squatting postures for a prolonged period (Section 5.7.1). During seed planting, the workers had to move their upper limb frequently. They were also compelled to twist their trunk and wrist frequently. The musculoskeletal disorders may be attributed to awkward work posture and repeated movement of the body parts. The spinal rotation may cause chronic strain as when the workers twist their waist during work. Twisting of the waist and wrist was noted when the workers taken potato and planting on land repeatedly. Bending or twisting back in an awkward way significantly increased prevalence of lower back pain (Gallagher et al. 2005; Todd, 2008). The frequent kneeling and squatting postures in the workplace were significant contributors to MSDs of the knee and lower back (Baker et al. 2003), and should be avoided as substitutes for stooped work because of the MSD risks of these postures as well.

In case of tunneling jobs, similar results were also noted among the workers. From the results it has been revealed that the female workers engaged in tunneling task also had a higher incidence of MSD than that of that of the male workers. The occurrence of problems in neck, wrist and knee in female workers were significantly ($p<0.05$) higher than that of male workers. The workers had to adopt forward bending posture for long periods (about 85-90% of the work-time) for performing tunneling task (Section 5.7.1) which might impose high static muscular load in the trunk region. The bend posture imposed a higher postural strain and important risk factor of origin of discomfort (Kothiyal and Yuen, 2004; Chaffin et al. 2006; Drake and Callaghan, 2008).

Similar trends of results were also noted in the case of potato harvesting task. From the results it has been revealed that the female workers also had a higher incidence of MSD than that of the male workers except in neck, upper and lower back.

Table 5.39: Percentage (%) of cultivators reported MSDs in different body parts during performing different potato cultivation tasks (the values in parenthesis indicate the percentage of MSD)

Body segments	Planting of Seeds		Tunneling		Harvesting	
	Male (n=51)	**Female (n=53)**	**Male (n=60)**	**Female (n=48)**	**Male (n=52)**	**Female (n=54)**
Neck	13 (25.49)	24 (45.28)*	22 (36.67)	27 (56.25)*	22 (42.31)	20 (37.04)
Shoulder	12 (23.53)	33 (62.26)***	38 (63.33)	34 (70.83)	27 (51.92)	29 (53.70)
Elbow	24 (47.06)	26 (49.06)	37 (61.67)	27 (56.25)	15 (28.85)	26 (48.15)*
Wrist	34 (66.67)	29 (54.72)	30 (50.00)	33 (68.75)*	34 (65.38)	27 (50.00)
Upper Back	21 (41.18)	28 (52.83)	45 (75.00)	37 (77.08)	38 (73.08)	36 (66.67)
Lower Back	43 (84.31)	47 (88.68)	58 (96.67)	46 (95.83)	51 (98.08)	50 (92.59)
Hip	19 (37.25)	38 (67.92)**	29 (48.33)	20 (43.75)	24 (46.15)	30 (55.56)
Knee	16 (31.37)	18 (33.96)	11 (18.33)	14 (29.17)	18 (34.62)	22 (40.74)
Feet	10 (19.61)	14 (26.42)	5 (8.33)	11 (22.92)*	16 (30.77)	20 (37.04)

w.r.t. Male * $p<0.05$, ** $p<0.01$, *** $p<0.001$

5.5.2 Pain mapping

The quantitative assessment of the pain/discomfort of the workers engaged in different potato cultivation tasks had also been done. The perceived rating of discomfort of the workers was studied by using a 10-point scale which was graded from Grade 0 (no pain) to Grade 10 (very severe pain) as mentioned in section 4.7.2. According to the degree of severity, the scores of the 10-point scale were divided into three subgroups, i.e., mild (1–4), moderate (>4–7) and severe (>7) (Dutta and Dhara, 2012).

The results presented in Table 5.40 and Fig 5.1 showed that both male and female workers engaged in different potato cultivation tasks were suffering from different degrees of perceived exertion. In case of male workers, moderate degree of discomfort (>4 to ≤7) was observed in lower back when all tasks were considered together. However, in case of female workers moderate degree of discomfort (>4 to ≤7) was noted in the lower back, upper back and buttock regions. The high discomfort rating on the back and buttock might be due to their task pattern. Usually the workers adopt forward bend posture with frequent postural change and sometimes twisting posture also. From the discomfort mapping (Fig 5.1) it has been revealed that the female workers had a higher degree of segmental pain than that of the male workers.

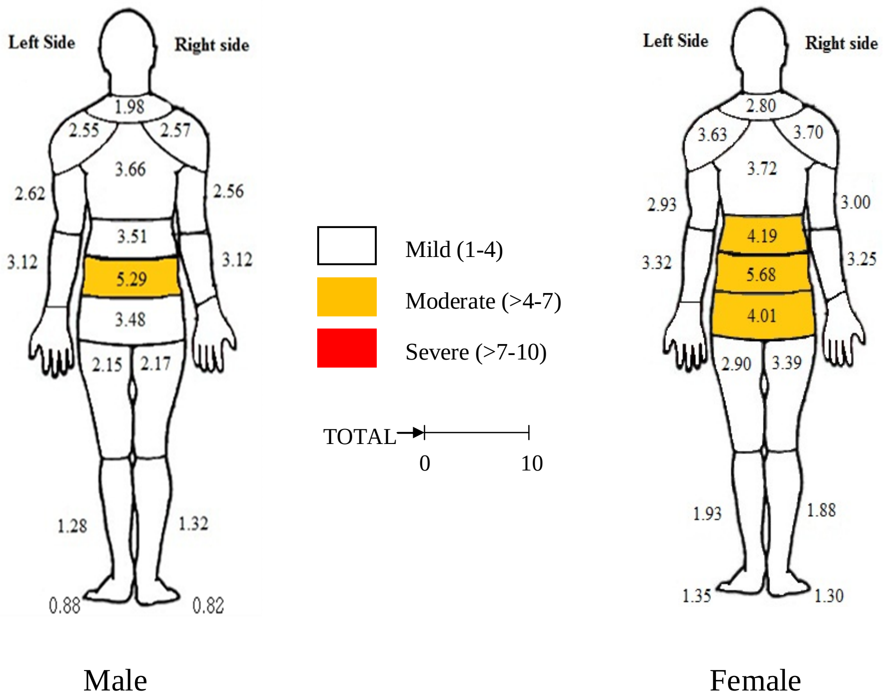


Fig 5.1: Perceived rating of segmental pain in male and female potato cultivators

Table 5.40: The perceived rate of discomfort (Mean ±SD) in different body segments of potato cultivators during performing potato cultivation tasks

Body Segment		**Male (n=163)**	**Female (n=155)**
Neck		1.98±2.87	2.8±3.29*
Shoulder	R	2.57±2.94	3.7±3.22**
	L	2.55±2.92	3.63±3.16**
Upper arm	R	2.56±2.95	3.0±3.18
	L	2.62±2.96	2.93±3.09
Lower arm	R	3.12±2.73	3.25±3.2
	L	3.12±2.83	3.32±3.24
Upper back		3.66±3.01	3.72±3.04
Middle back		3.51±2.31	4.19±2.75*
Lower Back		5.29±2.23	5.68±2.42
Buttock		3.48±2.54	4.01±2.56
Thigh	R	2.17±2.56	3.39±2.85***
	L	2.15±2.52	2.9±2.87*
Cuff	R	1.32±2.17	1.88±2.69*
	L	1.28±2.13	1.93±2.73*
Feet	R	0.82±1.75	1.3±2.12*
	L	0.88±1.87	1.35±2.2*
Over all discomfort rating		2.53±1.15	3.12±1.76**

w.r.t Male * $p<0.05$, ** $p<0.01$, *** $p<0.001$

The comparison of perceived discomfort rating between the male and female workers showed that the female workers had a significantly higher degree of pain / discomfort at the neck ($p<0.05$), shoulder ($p<0.01$), middle back ($p<0.05$), thigh (right side: $p<0.001$, left side: $p<0.05$), cuff ($p<0.05$) and feet ($p<0.05$) compared to their male counterpart. The mean value of scores (perceived rating of discomfort) of all segments was taken as the overall discomfort rating of the workers and the score in the female workers was significantly higher ($p<0.01$) than that of the male workers. The female workers were more prone to have higher degrees of MSDs than that of male workers. Such difference might be due to the physical and physiological difference between male and female workers. Nordander et al. (2009) and Das, (2015) also reported that women had a higher risk of musculoskeletal disorders than men. The female cultivators had to start their day before dawn to finish off their household chores and cooking before they moved off to the fields, which altogether results in a higher degree of musculoskeletal problems. The female workers might have a lower endurance capacity than that of male workers (Juhas, 2011). It has already pointed out that the female had lower lean body mass than the male (section 5.3.1) which might be another reason for occurrence of higher degree of pain / discomfort in females (Attar, 2014).

According to the degree of severity, the participants were divided into three subgroups, i.e., mild (1–4), moderate (>4–7) and severe (>7) and a comparative study has been worked out and the results have been presented in Table 5.41. From the results it was revealed that the moderate degree of pain was prevalent in different body segments among the workers, which followed by mild degree and sever degree pain. Basher et al. (2015) reported that the most of the farmers complained dull aching pain (40.6%), whereas only 2.3% noticed severe acute pain.

The results of comparative studies in the perceived rate of discomfort of the workers engaged in different potato cultivation tasks have been presented in Table 5.42. It showed that the male workers performing tunneling task had a significantly higher degree of pain at shoulder ($p<0.001$), upper arm ($p<0.001$) and upper back ($p<0.05$) compared to that of the workers engaged in seed planting. They also had a significantly higher degree of pain at upper arm ($p<0.05$) compared to that of the workers performing harvesting task (Table 5.42). The male potato harvesting workers had a significantly higher degree of pain at shoulder ($p<0.01$), upper back ($p<0.01$) and middle back ($p<0.001$) compared to that of seed planting workers. They also had a significantly higher degree of pain in middle back ($p<0.01$), calf (right side: $p<0.05$) and feet (right side: $p<0.05$; left side: $p<0.01$) compared to that of the tunneling workers.

The female workers performing tunneling task were suffering from significantly higher degree of pain / discomfort at upper arm (left side: $p<0.05$), lower arm ($p<0.01$), upper back ($p<0.001$), middle back ($p<0.001$), lower back ($p<0.01$), buttock ($p<0.001$) and thigh ($p<0.05$) than that of seed planting workers and had significantly higher degree of pain / discomfort in neck ($p<0.05$), shoulder (left side: $p<0.01$) and lower arm ($p<0.01$) than that of female workers engaged in potato harvesting. The female harvesting workers had significantly higher degree of pain / discomfort at upper back ($p<0.001$), middle back ($p<0.001$), lower back ($p<0.01$), buttock ($p<0.01$), thigh (right side: $p<0.001$), calf (right side: $p<0.001$; left side: $p<0.01$) and feet (right side: $p<0.001$; left side: $p<0.01$) than that of the seed planting workers and had significantly higher degree of pain / discomfort at middle back ($p<0.01$), thigh (right side: $p<0.001$; left side: $p<0.01$) calf (right side: $p<0.01$, left side: $p<0.05$) and feet (right side: $p<0.01$; left side: $p<0.05$) than that of the tunneling workers. The higher degree of pain / discomfort was noted in potato harvesting task which followed by tunneling and seed planting tasks. The higher discomfort rating in harvesting and tunneling tasks might be due to their task pattern. Usually the workers, who were performing tunneling and harvesting tasks, had to adopt forward bend posture with frequent postural change and sometimes twisting posture also. Kothiyal and Yuen, (2004) and Chaffin et al. (2006) pointed that bending and twisting of the back could impose higher postural strain and might be an important risk factor of origin of discomfort. Repeated movement of the hand due to spade operation, which might be the possible cause of higher discomfort in both upper and lower arms. Several research observations revealed that heavy physical work (Punnett and Wegman, 2004; Girish et al. 2012), higher lifting frequency (Da-Costa and Vieira, 2010) and prolonged tasks (Al-Rahamneh et al. 2010), holding time (Reneman et al. 2001; Laura et al. 2010), complex postures (Gallagher, 2005; Gangopadhyay et al. 2010; Girish et al. 2012) and higher biomechanical loadings (Szeto and Lam, 2007) have been positively associated with discomfort rating.

Table 5.41: Percentage distribution of individual according to severity of perceived rate of discomfort in different body segments during performing potato cultivation jobs

Body Segment		**Male**			**Female**		
		Mild (1–4)	**Moderate** (>4–7)	**Severe** (>7)	**Mild** (1–4)	**Moderate** (>4–7)	**Severe** (>7)
Neck		12.88	15.34	6.75	14.84	20.65	10.32
Shoulder	R	20.86	18.40	7.98	22.58	25.16	13.55
	L	19.63	21.47	6.13	21.29	28.39	11.61
Upper arm	R	12.27	28.83	4.91	10.97	30.32	9.68
	L	12.27	28.83	5.52	12.26	31.61	7.10
Lower arm	R	30.67	26.38	4.91	19.35	21.94	14.84
	L	25.77	29.45	4.91	20.65	23.87	12.90
Upper back		18.40	37.42	7.98	21.29	29.03	14.84
Middle back		42.94	30.06	1.84	29.03	29.68	16.77
Lower Back		37.42	38.04	17.79	19.35	49.68	23.23
Buttock		34.97	31.29	5.52	27.74	37.42	10.97
Thigh	R	21.47	21.47	1.84	31.61	25.16	7.10
	L	19.02	23.93	1.23	23.87	23.23	7.10
Cuff	R	13.50	14.72	0.00	17.42	14.84	3.23
	L	13.50	12.88	0.61	13.55	17.42	3.87
Feet	R	11.66	6.75	0.00	18.06	10.97	0.00
	L	10.43	8.59	0.00	15.48	12.90	0.65
Over all discomfort rating of the body		87.12	12.88	0.00	72.90	23.23	3.87

Table 5.42: The perceived rate of discomfort (Mean ±SD) in different body segments of potato cultivators during performing different potato cultivation jobs

Body Segment		Planting of seeds		Tunneling		Harvesting	
		M (n=51)	**F (n=53)**	**M (n=60)**	**F (n=48)**	**M (n=52)**	**F (n=54)**
Neck		1.37 ±2.49	2.70* ±3.23	2.13 ±2.98	3.42* ±3.38	2.40 ±3.04	2.35$ ±3.25
Shoulder	R	1.27 ±2.36	3.74*** ±3.23	3.58### ±3.0	4.08 ±3.04	2.67## ±2.95	3.33 ±3.38
	L	1.25 ±2.27	3.60*** ±3.12	3.57### ±2.98	4.21 ±3.10	2.67## ±2.98	3.13$$ ±3.22
Upper arm	R	1.43 ±2.47	2.77* ±2.97	3.52### ±3.16	3.44 ±3.35	2.26$ ±2.69	2.83 ±3.24
	L	1.47 ±2.48	2.62* ±2.85	3.62### ±3.09	3.50# ±3.36	2.30$ ±2.77	2.72 ±3.06
Lower arm	R	3.33 ±2.36	2.96 ±2.97	2.60 ±2.84	4.06*## ±3.25	3.50 ±2.9	2.80$$ ±3.28
	L	3.25 ±2.56	2.92 ±3.04	2.68 ±2.95	4.19*## ±3.25	3.48 ±2.93	2.94$$ ±3.33
Upper back		2.67 ±3.29	2.81 ±2.86	3.95# ±2.66	4.15### ±2.70	4.31## ±2.91	4.22### ±3.35
Middle back		2.61 ±2.39	3.21 ±2.67	3.32 ±2.11	4.23### ±2.68	4.62###$$ ±2.01	5.11###$$ ±2.60
Lower Back		4.92 ±2.64	5.21 ±2.53	5.37 ±2.0	5.88## ±2.21	5.58 ±2.03	5.98## ±2.48
Buttock		3.18 ±2.34	3.45 ±2.34	3.80 ±2.26	4.42### ±2.45	3.42 ±3.01	4.20## ±2.80
Thigh	R	1.84 ±2.58	2.94* ±2.35	2.43 ±2.62	2.21# ±2.81	2.19 ±2.47	4.87***###$$$ ±2.73
	L	1.94 ±2.65	2.92* ±2.34	2.37 ±2.57	2.31# ±2.85	2.12 ±2.37	3.41*$$ ±3.28
Cuff	R	1.63 ±2.50	1.53 ±2.22	0.83 ±1.8	1.60 ±2.62	1.58$ ±2.15	2.48###$$ ±3.09
	L	1.59 ±2.46	1.68 ±2.40	0.80 ±1.73	1.65 ±2.69	1.52 ±2.16	2.43##$ ±3.04
Feet	R	0.96 ±2.01	1.08 ±1.85	0.38 ±1.33	1.13* ±2.14	1.17$ ±1.84	1.67###$$ ±2.33
	L	0.98 ±2.05	1.19 ±2.03	0.42 ±1.41	1.19* ±2.26	1.33$$ ±2.06	1.65##$ ±2.31
Over all discomfort rating of the body		2.22 ±0.97	2.78* ±1.33	2.67# ±1.18	3.27# ±2.83	2.69 ±2.53	3.30### ±1.91

w.r.t Male * $p<0.05$, ** $p<0.01$, *** $p<0.001$
w.r.t Planting of seeds # $p<0.05$, ## $p<0.01$, ### $p<0.001$
w.r.t Tunneling $ $p<0.05$, $$ $p<0.01$, $$$ $p<0.001$

5.6 Work-Rest Cycle

The work-rest cycle is dichotomized into work and rest periods. The human body shows a rhythmic balance between energy consumption and energy replacement during work and rest periods. This dual process is an integral part of the operation of muscles of the heart. Work-rest is, therefore, indispensable as a physiological requirement, if performance and efficiency are to be maintained. Rest pauses are essential, not only during manual work, but equally during work that taxes the nervous system, whether by requiring manual dexterity or by the need to monitor a great many incoming sensory signals (Kroemer and Grandjean, 2001). Fatigue and recovery are related concepts, fatigue is the state that results from having been exposed to demands, and recovery is the process that replenishes the resources again. This fatigue is usually short-lived and reversible: they disappear after a respite from work (Hooff et al. 2007). However, under certain circumstances the recovery process may be insufficient or inadequate, and then short-term fatigue may turn into adverse and more chronic health problems, such as prolonged fatigue, chronic tension, and sleep deprivation and eventually may lead to ill-health (Sluiter et al. 2001; Van-Hooff et al. 2005; Åkerstedt, 2006; Härmä, 2006).

The work-rest patterns of the potato cultivators have been presented in Table 5.43. The workers used to start work by 7 a.m. and continued the work for about two hours. After this, they used to take a food break (breakfast) for about 20 to 40 minutes. They would resume the work after this break and continued the work for about 2 to 2½ hours. Then they used to take another food break (lunch) for a longer duration than the former break. It would continue for about 1½ to 2 hours. During this break they would also take a bath and rest for some time. The female workers would also perform their household work like; cooking, wiping, and washing clothes and dishes during this period. After this break they had to start work from 2.30 p.m., which would continue for 3 hours.

The work-rest pattern (Table 5.43) showed that the male cultivators worked for longer duration and took rest for lesser duration than that of the female workers and this difference was statistically significant. From the observed results it was revealed that the work rest patterns were found to vary a little in different tasks of potato cultivation. The work time varied from 67.38% to 68.77% of the total work shift in male workers and 63.81% to 65.25% of the total work shift in female workers and rest time varied from 31.23% to 32.62% of the total work shift in male workers and 34.75% to 36.19% of the total work shift in female workers in different tasks of potato cultivation.

Table 5.43: Mean ± SD of work time and rest time (min) of male and female cultivators in different potato cultivation tasks (The figures in the parentheses indicate the percentage of total time)

Different potato cultivation jobs	Sex	Total work time (min)	Total rest time (min)	Total duration of work shift (min)
Planting of seeds	Male	380.74±28.98 (68.77%)	172.87±11.67 (31.23%)	553.60±30.71
	Female	355.49±22.07** (65.25%)	189.32±9.67*** (34.75%)	544.81±25.21
Tunneling	Male	373.12±25.25 (67.38%)	180.60±13.70 (32.62%)	553.73±29.93
	Female	350.35±34.52* (64.26%)	194.82±15.01** (35.74%)	545.16±35.34
Potato Harvesting	Male	391.68±25.90 (67.79%)	186.06±14.27 (32.21)	577.74±32.91
	Female	363.48±10.38*** (63.81%)	206.15±14.58*** (36.19%)	569.62±19.94
All categories	Male	380.87±27.31 (67.96%)	179.56±14.01 (32.04%)	560.43±32.38
	Female	356.44±24.46*** (64.43%)	196.76±14.81*** (35.57%)	553.20±29.39

w. r .t. Male workers * $p<0.05$, ** $p<0.01$ *** $p<0.001$

The rest period of the cultivators included the food breaks. It was noted that the total working hours was approximately 9 hours including rest pause. The prolonged tasks performed in awkward postures (forward bend posture) which have been discussed later in this chapter (Sec. 5.7.1) may be possible causes of pain/discomfort in different segments of the body of the cultivators. Al-Rahamneh et al. (2010) also pointed out in their studies that prolonged tasks were positively associated with body part discomfort. According to Caicoyal and Delclos (2010), those performing highly repetitive tasks for longer duration reported higher extent of pain at different segments of their body.

The rest pause was further analyzed and the results have been presented in Table 5.44. The total rest period was divided into two subcategories, viz., the work related rest and the prescribed rest. The spontaneous rest during performing the tasks was included within the work related rest. The prescribed rest was only the food breaks; hence it was continuous in nature. But the work related rests was discontinuous in nature. From the results it was noted that the prescribed rest was varying a little in different tasks of potato cultivation for both sexes, but the work related rests was varied from task to task and also between the sexes. It has been noted that the work related rest was significantly higher in female workers than that of the male workers of all potato cultivation tasks. This might be due to onset of earlier fatigue in the female workers than that of the male workers (Lee et al. 2014; Masson et al. 2015). As the female workers would not take the proper amount of food and they suffered from energy deficiency, as mentioned earlier in this chapter (Sec. 5.3), it might be one of the causes for the onset of fatigue in female workers promptly than that of the male workers (Schenker, 2003; Jeejeebhoy, 2012). From the heart rate study, discussed later in this section (Sec. 5.8.1), it has been revealed that the female workers had greater mean working heart rate than that of the male workers indicating greater workload of the female workers. The female workers would also perform their household work like; cooking, cleaning, and washing clothes and dishes during the prescribed rest (food breaks) as mentioned earlier which may impose additional stresses among the female workers. This might be the reason for taking greater rest pauses among the female workers than the male workers.

Table5.44: Mean ± SD of different rest pauses (min) of male and female workers in different potato cultivation tasks (The figure in the parentheses indicates the percentage of total rest time)

	Sex	Work related rest			Prescribed rest			Total rest time
		Sitting idle	Standing idle	Total	Tiffin	Lunch	Total	
Planting of seeds	M	9.09 ±4.25 (5.26%)	17.83 ±5.11 (10.31%)	26.92 ±6.59 (15.57%)	26.42 ±5.05 (15.28%)	119.53 ±8.43 (69.14%)	145.95 ±11.08 (84.43%)	172.87 ±11.67
	F	13.86** ±4.62 (7.32%)	22.80* ±7.21 (12.04%)	36.66*** ±7.52 (19.36%)	29.87 ±5.10 (15.78%)	122.80 ±8.21 (64.86%)	152.67 ±9.10 (80.64%)	189.32*** ±9.67
Tunneling	M	9.54 ±3.94 (5.28%)	19.15 ±5.01 (10.60%)	28.70 ±5.17 (15.89%)	26.36 ±5.42 (14.60%)	125.55 ±11.22 (69.51%)	151.91 ±13.52 (84.11%)	180.60 ±13.70
	F	12.74* ±5.15 (6.54%)	26.95** ±8.07 (13.83%)	39.68*** ±9.29 (20.37%)	27.93 ±4.77 (14.34%)	127.20 ±9.08 (65.29%)	155.13 ±11.86 (79.63%)	194.82** ±15.01
Harvesting	M	16.03 ±7.09 (8.61%)	20.34 ±6.92 (10.93%)	36.37 ±10.69 (19.55%)	29.06 ±5.45 (15.62%)	120.63 ±9.27 (64.83%)	149.69 ±8.28 (80.45%)	186.06 ±14.27
	F	20.80 ±6.67 (10.09%)	26.28* ±6.41 (12.75%)	47.08** ±8.02 (22.84%)	33.13 ±6.83 (16.07%)	125.93 ±10.65 (61.09%)	159.07* ±14.17 (77.16%)	206.15*** ±14.58
All categories	M	11.21 ±5.86 (6.24%)	19.04 ±5.62 (10.61%)	30.26 ±8.37 (16.85%)	27.14 ±5.35 (15.12%)	122.16 ±10.03 (68.03%)	149.30 ±11.53 (83.15%)	179.56 ±14.01
	F	15.80*** ±6.51 (8.03%)	25.34*** ±7.33 (12.88%)	41.14*** ±9.25 (20.91%)	30.31* ±5.92 (15.40%)	125.31 ±9.34 (63.69%)	155.62 ±11.92 (79.09%)	196.76*** ±14.81

w. r .t. Male workers * p<0.05, ** p<0.01 *** p<0.001

In the present study, it was observed that there was a long continuous rest period (food breaks) of about 2½ hours for both sexes; it might be more useful if the long food break were reduced and the number of short breaks were provided within the work-time. Ahamed, (2014) stated that few short breaks are better than one long break in a day’s work. This is because short and frequent breaks were much more effective in preventing excessive fatigue and possible injury than longer, less frequent breaks (Ontario Ministry of Labour, 2005). Thus the proper designing of work-rest cycle for the potato cultivation workers would be beneficial.

5.7 Analysis of Posture

5.7.1. Posture Analysis by Direct Observation Method

The potato cultivators had to adopt different awkward postures while performing different tasks of potato cultivation. The change of posture was a common factor during dynamic work and in long term working condition. Although awkward postures were most prevalent in the jobs, it was also noted that there were a lot of inappropriate postures of certain parts of the body which may be the possible contributing causes of pain in different body segments. A good posture becomes even more important when forceful tasks are performed. Posture is as important for the performance of tasks as it is related for protecting health and minimizing stress and discomfort during work (Corlett, 1981; Rahman, 2014). Thus, assessment of work postures is one of the starting points to address the problem of work-related body pain. There are many practical methods for evaluating postural stress based on a postural classification (Keyserling, 1986; Mc-Atamney and Corlett, 1993). The direct observation method was proved to be a good method for studying the work postures in agricultural and other work when involved in whole body work requiring moving. The validity of visual observation to assess posture in a laboratory-simulated material-handling task was established (De-Looze et al. 1994). However, continuous direct observation of individual workers was not only very expensive, but was likely to lead to changes in working patterns and habits on the part of those being observed. Furthermore, minor changes in forward or lateral adjustments of the relative position of the loads to the axis of the spine may well pass unnoticed by the human observer.

The direct observation method was used for the analysis of postural patterns and results have been shown in Table 5.45. It was noted from the results that the workers had to adopt forward bending posture throughout the work time. The forward bending posture was the dominating posture in potato cultivation tasks in both sexes. The workers were found to twist and bend their body frequently during seed planting and potato harvesting tasks. There was no squatting posture during performing tunneling task. The duration for adopting forward bending posture was the maximum (more than 80% of total work time) in case of performing tunneling task.

Table 5.45: Mean ±SD and percentage (%) of time (min) for adopting different postures in a work shift by male and female cultivators during performing different potato cultivation tasks

Different working posture	Different potato cultivation tasks					
	Planting of seeds		Tunneling		Potato Harvesting	
	Male (n=19)	Female (n=15)	Male (n=22)	Female (n=15)	Male (n=16)	Female (n=15)
Sitting (squatting)	149.12 ±49.36 (39.17%)	140.40 ±46.60 (39.49%)	-	-	134.15 ±51.66 (34.25%)	127.33 ±30.36 (35.03%)
Forward Bending	196.19 ±60.95 (51.53%)	169.26 ±58.28 (47.61%)	333.22 ±22.84 (89.31%)	297.59** ±41.68 (84.94%)	221.47 ±48.28 (56.54 %)	188.26* ±29.33 (51.79%)
Walking	35.43 ±12.44 (9.31%)	45.83* ±15.29 (12.89%)	39.90 ±14.25 (10.69%)	52.76* ±16.93 (15.06%)	36.06 ±10.60 (9.21 %)	47.76* ±13.09 (13.14%)
Total working period	380.74 ±28.98 (100%)	355.49 ±22.07 (100%)	373.12 ±25.25 (100%)	350.35 ±34.52 (100%)	391.68 ±25.9 (100%)	363.48 ±10.38 (100%)

w.r.t. Male workers * $p<0.05$ ** $p<0.01$

In case of potato harvesting and seed planting it was lesser (around 50% of the total work time) than the tunneling task. The female cultivators had lesser time for adopting forward bending posture in comparison to male cultivators. The duration for adopting squatting posture was slightly greater in seed planting task than that in harvesting task. The duration of walking posture was much lesser than that of other two postures. The prolonged forward bending posture imposes a high static muscular load, particularly in the trunk region (Gangopadhyay et al. 2007; Goswami et al. 2012). So, a flexed posture in different phases of potato cultivation tasks was generally stressful to the musculoskeletal structures, including the vertebral column. This was consistent with the past studies that had shown that bending and twisting of the back imposed higher postural strain than the straight back postures which were important risk factors of origin of discomfort (Singh, 2010; Gangopadhyay et al. 2010). Gallagher and Heberger, (2013) showed the relation between stressful work postures and functional disturbance of pain in various parts of the musculoskeletal system. They stated that adoption of awkward or non-neutral postures lead to increased force requirements and thereby increased stresses on musculoskeletal tissues and lead to a more rapid escalation of MSD risk. The workers usually moving forward (sometimes sideways) under squat posture and such movements were strenuous and awkward.

The male workers had to spend significantly longer duration of time in squat–bend postures than that of the female workers. This was due to the greater work time in male workers in a whole day than that of female workers, as noted in the analysis of the work rest cycle (Table 5.43). On the other hand, female workers had spent significantly ($p<0.05$) longer duration of time in walking posture than that of male workers.

Studies of MSDs and discomfort rating (sec. 5.5.1 and 5.5.2) revealed that the workers performing different potato cultivation tasks were suffering from pain or discomfort at different segments of the body, which might be related to their postural pattern as well as duration of work in awkward postures. Osborne et al. (2012) studied on farmers and reported that lower back pain was the most common MSD among the farmers, followed by upper and then lower extremity MSDs. Long term adoption of bend and twist posture was associated with postural stress. Investigation suggested that bending and twisting of back awkwardly and working in the same position were both significantly associated with prevalence of lower back problem and both were judged by workers to be the most problematic job factors contributing to pain and injury (Merlino et al. 2003; Roffey et al. 2010). Goldsheyder et al. (2002) reported that there was a significant association of awkward postures with back pain and the prevalence of lower back problems was significantly increased with work tasks described as "bending or twisting back in awkward way". Das and Gangopadhyay (2012) studied on potato cultivators and reported that prolonged work activity, high repetitiveness and remaining constantly in an awkward posture for a prolonged period may lead to MSDs.

5.7.2. Posture Analysis by OWAS, REBA, RULA and QEC Methods

The postures adopted by the workers in their working place depend upon the type of work, personal characteristics, the tools required for performing particular work and also the duration and frequency of the work cycle. Postural analysis can be a powerful technique for assessing work activities as the risk of musculoskeletal injury associated with the posture (Kee and Karwowski, 2007). The potato cultivators were compelled to adopt different awkward postures for prolonged period while performing different tasks of potato cultivation. Ergonomic assessment of work postures is one of the starting points to address the problem of work related body pain. Researcher proposed different methods for ergonomic assessment of working posture and quantification of ergonomic risk factors. There are several observational techniques for evaluating postural workload based on a postural classification, viz., OWAS (Heinsalmi, 1986), TRAC (van der Beek et al. 1992), PATH (Buchholz et al. 1996), RULA (Mc-Atamney and Corlet, 1993), REBA (Hignett and Mc-Atamney, 2000), LUBA (Kee and Karwowski, 2001), QEC (Li and Buckle, 1999) etc. Of these techniques OWAS, RULA, and REBA are widely used for body posture assessment of the workers. The Ovako Working Posture Analysis System (OWAS) has been one such ergonomic assessment tool used for over 30 years to estimate risk of MSDs (Karhu et al. 1977). It has been shown to be an effective method for analyzing jobs and estimating the risk of injury in many different types of industries (Li, 2000; Grecchi et al. 2006). The versatility of its posture coding components provides applicability to most working postures. OWAS is posture-based technique that is used to evaluate job-task demands and classifies jobs into categories. This is an overall 'risk' or 'action category' (Kivi and Matilla, 1991) and based on the perceived harmfulness of the postures, making recommendations for the urgency of remedial action to prevent the need for the postures to be adopted by individuals carrying out their work (Karhu et al. 1977; 1981).

Because of all potato cultivation tasks were dynamic work and require the involvement of whole body work, OWAS method proved to be a good method to study the work postures in manual workers (Grecchi et al. 2006). OWAS postural analyses have been worked out on a wide range of postures, from brick kilns workers (Sahu and Sett, 2010) to nurses (Goswami et al. 2013) to the workers in industry (Kee and Karwowski, 2007) but the results can be poor in detail because some of the body parts were not included in the analysis (Hignett and Mc-Atamney, 2000, Pal et al. 2015a). Hignett and McAtamney (2006) stated that RULA is generally used if the person is sitting, standing still or in an otherwise sedentary position, and mainly using the upper body and arms to work. Quick Exposure Checklist (QEC) is an observational method is used for the assessment of exposure of upper body and limb for static and dynamic tasks. For all other tasks REBA should be used. Researchers (Sahu and Sett, 2010; Mukhopadhyay and Srivastava, 2010) used several posture analysis methods viz. OWAS, RULA, REBA etc. simultaneously for posture analysis. In the present study different methods for posture analysis was applied to get additional information about the postural stress during performing potato cultivation tasks. In all the tasks of potato cultivation continuous movement of upper limb was noted. Thus, the RULA and QEC methods were applied for posture analysis. The QEC method indicated the risk level of different body segments.

The results of the posture analysis by employing OWAS, RULA, REBA and QEC methods been presented in Tables 5.46 to Table 5.49 for three tasks of potato cultivation.

Planting of Seeds:

It has already been mentioned that the dominant postures adopted by the workers during planting of seed were forward bending and squat sitting postures. From the results of postural assessment by OWAS method, it was found that the forward bending posture needed corrective measure as soon as possible and squat sitting posture needed corrective measures in near future for both sexes. Similarly, from the results of postural assessment by RULA and REBA methods, the both forward bending and squat sitting postures were categorized as high risk and it needed investigation and immediate change. The analysis of seed planting tasks using QEC method indicated the risk level to specific body parts including the back, shoulder/arm, wrist/hand, and neck (Table 5.48 and 4.49).

If we observe postural risk for male and female workers separately we can see that in case of male workers, the risk level was high in back, wrist/hand, and neck and moderate in shoulder/arm while adopting forward bending posture. While adopting a squat sitting posture, the risk level was high in back and neck and moderate in the shoulder / arm and wrist/hand. In case of female workers, the risk level was high in back and neck and moderate in the shoulder/arm and wrist/hand while adopting both forward bending and squat sitting postures.

Table 5.46: Postural analysis showing action and risk levels in male potato cultivators during performing different potato cultivation tasks

Tasks		**OWAS**		**REBA**		**RULA**	
		Action Level	**Risk level**	**Action Level**	**Risk level**	**Action Level**	**Risk level**
Planting of seeds	Forward bending **(n=20)**	3	Corrective measures as soon as possible	10	High risk, investigate and implement change	7	Investigate and change immediately
	Squatting **(n=21)**	2	Corrective measures in the near future	8	High risk, investigate and implement change	7	Investigate and change immediately
Tunneling **(n=29)**		3	Corrective measures as soon as possible	11	Very high risk, implement change	7	Investigate and change immediately
Harvesting	Forward bending **(n=20)**	3	Corrective measures as soon as possible	12	Very high risk, implement change	7	Investigate and change immediately
	Squatting **(n=22)**	3	Corrective measures as soon as possible	11	Very high risk, implement change	7	Investigate and change immediately

Tunneling:

In case of tunneling, the results of postural assessment by OWAS method indicated that the posture needed corrective measure as soon as possible. Similarly from the results of postural assessment by RULA and REBA methods, it was found that the posture adopted during tunneling task was of very high risk and needed change of the posture immediately. The results of the posture analysis by QEC method revealed that the risk level was high in back and neck and moderate in shoulder/arm and wrist/hand while performing tunneling task.

Table 5.47: Postural analysis showing action and risk levels in female potato cultivators during performing different potato cultivation tasks

Tasks		**OWAS**		**REBA**		**RULA**	
		Action Level	Risk level	Action Level	Risk level	Action Level	Risk level
Planting of seeds	Forward bending **(n=26)**	3	Corrective measures as soon as possible	10	High risk, investigate and implement change	7	Investigate and change immediately
	Squatting **(n=24)**	2	Corrective measures in the near future	7	Medium risk, further investigation, change soon	6	Investigate further and change soon
Tunneling (n=32)		3	Corrective measures as soon as possible	11	Very high risk, implement change	7	Investigate and change immediately
Harvesting	Forward bending **(n=25)**	3	Corrective measures as soon as possible	12	Very high risk, implement change	7	Investigate and change immediately
	Squatting **(n=23)**	3	Corrective measures in the near future	11	Very high risk, implement change	7	Investigate and change immediately

Potato Harvesting:

The analysis of postures adopted by the workers during potato harvesting task showed that the posture needed corrective measure as soon as possible (OWAS method). According to the analysis by REBA and RULA methods the postures adopted by the workers during potato harvesting operation was categorized as very high risk and needed change in the posture soon. The results of the posture analysis by QEC method indicated that the risk levels were high at back, shoulder/arm, and neck and moderate at the wrist/hand, while performing potato harvesting task in forward bending posture and the risk levels were high at back, wrist/hand and neck and moderate at shoulder/arm while performing potato harvesting job in squatting posture.

Table 5.48: Postural analysis by QEC method showing scores and risk levels in male potato cultivators in different potato cultivation tasks

Body parts / Stress	Score / Risk level	Tasks				
		Planting of seeds		Tunneling (n=29)	Harvesting	
		Forward bending (n=20)	Squatting (n=21)		Forward bending (n=20)	Squatting (n=22)
Back	score	34	32	34	40	34
	Risk level	High	High	High	High	High
Shoulder/ arm	score	30	28	30	32	26
	Risk level	Moderate	Moderate	Moderate	High	Moderate
Wrist/ Hand	score	34	30	30	30	34
	Risk level	High	Moderate	Moderate	Moderate	High
Neck	score	14	14	14	14	14
	Risk level	High	High	High	High	High
Vibration	score	1	1	1	1	1
	Risk level	Low	Low	Low	Low	Low
Work pace	score	4	4	4	4	4
	Risk level	Moderate	Moderate	Moderate	Moderate	Moderate
Stress level	score	9	7	9	9	9
	Risk level	High	Moderate	High	High	High

If we go for a comparative analysis for three tasks of potato cultivation, it was observed that the potato harvesting task was very stressful. From the results of QEC it was noted that most of body segments were under high risk level and the stress level was also high when performing potato harvesting task. If we consider the risk level of different body segments (QEC results), it was revealed that the back and neck were exposed to high risk level in all potato cultivation tasks both in male and female workers (Tables 5.48 & 5.49).

Table 5.49: Postural analysis by QEC method showing scores and risk levels in female potato cultivators in different potato cultivation tasks

Body parts / Stress	**Score / Risk level**	**Tasks**				
		Planting of seeds		**Tunneling (n=32)**	**Harvesting**	
		Forward bending **(n=26)**	Squatting **(n=24)**		Forward bending **(n=25)**	Squatting **(n=23)**
Back	score	34	32	34	40	34
	Risk level	High	High	High	High	High
Shoulder/ arm	score	30	28	30	34	26
	Risk level	Moderate	Moderate	Moderate	High	Moderate
Wrist/ Hand	score	30	30	30	30	34
	Risk level	Moderate	Moderate	Moderate	Moderate	High
Neck	score	14	14	14	14	14
	Risk level	High	High	High	High	High
Vibration	score	1	1	1	1	1
	Risk level	Low	Low	Low	Low	Low
Work pace	score	4	4	4	4	4
	Risk level	Moderate	Moderate	Moderate	Moderate	Moderate
Stress level	score	9	7	9	9	9
	Risk level	High	Moderate	High	High	High

Studies of MSDs and discomfort rating revealed that the workers performing different potato cultivation tasks were reported to suffer from pain/ discomforted in different body segments which might due to their postural pattern as well as duration of work in awkward postures. The results of the posture analysis supported the results of MSD. Das, (2015) and Mc-Millan et al. (2015) noted that MSDs in different segments of the body was highly prevalent among the famers. They also stated that the most common MSDs site in farmers were the lower back followed by the upper and then lower extremities. Das, (2015) reported that the most of the farmers (99%) suffered discomfort at different parts of the body due to awkward posture and excessive repetitive task for a prolonged period of time. Basher et al. (2015) reported that musculoskeletal pain was more common among the farmers when they worked in squatting position. Long term adoption of bend and twist posture was associated with postural stress. Several researchers (Taechasubamorn et al. 2011; Birabi et al. 2012; Gupta and Tarique, 2013) reported that the major work-related risk factors associated with lower back pain have been identified as awkward work postures, forward bending and twisting movements, lifting and physical strenuous work. Awkward working posture always occurs when the workers perform the job with their body parts deviating significantly from the natural posture. When performing job in awkward working posture, high force was applied in the skeletal system and may lead to acute overloading and damage of skeletal structures (Halim et al. 2012). Halim et al. (2012) also reported that prolonged jobs with inclined trunk may create WMSDs associated with lower back pain especially in the lumbar region. Hauret et al. (2010) and Barbe et al. (2013) reported that repetitive movements and activities, prolonged static positioning, forceful exertions and non-neutral body postures have been identified as key risk factors for MSDs.

From different posture analysis methods it may be summarized that the postures adopted by the workers had risk levels from 'medium' to 'very high' in different tasks of potato cultivation. The workers suffered account of health problems, perhaps because of prolonged working hours, awkward posture and used less safety measures while working. Moreover, ergonomic interventions such as redesigning the hand tools and modifying work-rest schedule would improve the conditions and postures of the workers and reduce their MSDs. From this study it has been recommended that workers should avoid awkward work postures as far as possible and take adequate rest during their work for reducing job related health hazards.

5.7.3. Evaluation of Center of Gravity

The human body has a center of gravity (CG) and in any consideration of movement the position of the CG of the body plays an important role. The location of the CG in the body is extremely important in determining the state of equilibrium at any moment.

The dominant postures adopt by the workers during performing potato cultivation tasks were forward bending and squat sitting postures, as mentioned earlier. The location of the CG was determined in those two postures for both male and female workers. The location of the whole body CG has been expressed as the percentage of the height of the body. The location of the CG under normal erect posture was taken as reference. The change of location of CG from the reference position was regarded as the deviation of CG. The location of the CG of male and female workers engaged in different task of potato cultivation has been shown in Table 5.50.

It was observed that the location of whole body CG in normal standing posture was 60.01 (range 58.24 to 62.04) for male workers and 61.25 (range 58.82 to 63.38) for female workers. It was observed that the location of the whole body CG in normal standing posture was fairly constant in most of the subjects. Harless, (1860) reported that the location of the whole body CG was 58.6 in the German population, which was slightly lower than that of the present study. That variation might be due to differences in body dimension and body composition between two populations.

Table 5.50: Center of gravity (CG) (expressed as % of the length of the body) of male and female workers in different postures in different potato cultivation tasks

Different potation cultivation job		Normal standing	Bending	Deviation	Squat sitting	Deviation
Planting of seeds	Male (n=15)	60.92 ±1.11	68.74 ±2.87	7.82 ±2.94	49.05 ±4.94	11.68 ±5.57
	Female (n=15)	61.42 ±1.31	71.39* ±3.29	10.03* ±2.96	46.93 ±5.15	14.18 ±5.25
Tunneling	Male (n=15)	60.87 ±1.27	72.47## ±3.60	11.60## ±3.36	-	-
	Female (n=15)	61.49 ±2.51	73.66# ±2.30	12.17 ±3.75	-	-
Potato harvesting	Male (n=15)	60.99 ±1.05	69.28$ ±4.03	8.29$ ±4.39	50.58 ±4.06	10.07 ±4.62
	Female (n=15)	61.28 ±1.01	70.27$$ ±3.26	8.99$ ±3.60	48.37 ±3.89	12.65 ±4.14

w.r.t. Male *p<0.05
w.r.t. Planting of seeds # p<0.05; ## p<0.01 w.r.t. Tunneling $ p<0.05; $$ p<0.01

There was a significant difference ($p<0.05$) in location of the CG at different working posture between male and female workers. This difference might be due to variation in style of adopting posture during work and such variation was probably for different dress ("Sharee") worn by the female workers.

The results of center of gravity showed that the whole body CG was found to shift away from the base of the body for both male and female workers when performing planting of seeds, tunneling in the land and potato harvesting tasks in forward bent posture. The location of the CG shifted upward during this work causing the body relatively unstable than that of the reference position and biomechanical stress was imposed on the body which might be the cause of MSDs among the workers (Page, 1978; Goswami et al. 2012). Goswami et al.

(2012) reported that if the CG shifted upward during work, biomechanical stress was imposed on the body which might be the cause of MSDs in different segments of the body. Das and Ganguli, (1982) and Sen and Ray, (1983) observed in their studies that the shift in CG imposed maximum postural load in forward bend postures when considered from the viewpoint of biomechanical stress. A large shift of whole body CG might impose biomechanical stress on the workers. The biomechanical stress may be reduced if the CG remains on the central axis of the body and it was symmetric in nature (Ray and Vasudha, 1997). While performing the planting of seeds and potato harvesting tasks in squat sitting posture, the whole body CG was found to shift toward the base of the body. When the CG was shifted towards the base of the body, it became more stable than that in erect posture. However, squatting is a very awkward posture, which leads to strain in different joints and muscles of the lower limbs (Basher et al. 2015). Although the location of CG indicating the stability of the body, but the static postural load on the said areas caused musculoskeletal pain during performing seed planting and potato harvesting task (Hayes et al. 2009).

5.8 Physiological Stress

The physiological stress of the potato cultivators was evaluated in terms of heart rate and blood lactate measurement.

5.8.1 Evaluation of Cardiovascular Status

Heart rate is the important determinant factor to estimate the cardiovascular status. Cardiovascular diseases have been estimated to be the most chronic factor for the disability adjusted life years lost by 2020 (WHO, 2002). Numerous epidemiological studies have reported increases in the daily incidence of cardiovascular mortality and morbidity associated with increase of work stress (Kivimäki et al. 2002). In India, a study of occupational cardiovascular stress among the agricultural workers found scanty. The literature survey revealed that there are several risk factors significantly associated with cardiovascular stress. The most important are job strain (Väänänen**,** 2008), job demand (Song et al. 2010), high physical effort (Makowiec-Dabrowska et al. 2007), work place factors like long working hours, psychosocial work stress (Thomas and Power, 2010) etc. Evidences also suggested that high job strain or occupational stress is associated with stroke incident (Tsutsumi et al. 2011) and work related cerebrovascular and cardiovascular diseases (Park et al. 2011).

The heart rate of the workers engaged in different tasks of potato cultivation was recorded throughout the day. From the results it has been noted that the mean working heart rate increased significantly ($p<0.001$) from the resting level in all tasks of potato cultivation job (Table 5.51). The average working heart rate was 105.33±10.77 beats/min in male and 109.97±9.94 beats/min in female when all tasks (planting of seeds, tunneling and potato harvesting operation) were considered together. It was found that they were working at about 55% and 58% of their age-predicted maximum heart rate in male and female respectively.

Among the different tasks of potato cultivation, the highest mean working heart rate was noted in tunneling operation in both sexes compared to potato harvesting and seed planting tasks. The working heart rates in tunneling operation was 110.08±10.83 beats/min in male and 115.02±8.81 beats/min in female respectively and on average they were working at about 58% and 61% of their age-predicted maximum heart rate in male and female respectively. Besides this, the working heart rates of the workers engaged in seed planting and potato harvesting operation were also high. On average, the workers engaged in seed planting were working at about 53% and 56% of their age-predicted maximum heart rate in male and female respectively. The potato harvesting workers were working at about 55% and 58% of their age-predicted maximum heart rate in male and female respectively. It was noted from the results of ANOVA that the working heart rate was significantly different (p<0.001) among the workers of different potato cultivation tasks. According to the work category classification on the basis of mean working heart rate, the potato cultivation tasks ware categorized as moderate work category (Christensen, 1964). According to the classification of physical work in terms of heart rate the seed planting and potato harvesting tasks were considered as the moderate work. But tunneling task was belonging to the heavy work category. This indicated that workers engaged in tunneling task had a higher degree of physiological costs than that of the workers performing seed planting and potato harvesting tasks. From the findings of the different investigators (Hasalkar et al. 2004; Miyamoto et al. 2006) it has also been revealed that the heart rate was increased at the onset of high-work intensity. It has also been revealed that heart rate was increased linearly with the increase in oxygen consumption in both trained and untrained individuals (Smolander et al. 2008; Ghosh et al. 2014).

Table 5.51: Mean ± SD of resting and working heart rate of agricultural workers during different potato cultivation tasks

Worker Group	Resting HR (beats/min)		Working HR (beats/min)	
	Male	Female	Male	Female
Planting of seeds (Male:52; Female:50)	74.76 ±3.6	75.50 ±5.63	101.02* ±8.78	105.50¥ * ±9.85
Tunneling (Male:53; Female:50)	74.58 ±5.37	75.76 ±4.80	110.08*### ±10.83	115.02¥¥*### ±8.81
Potato harvesting (Male:55; Female:50)	73.89 ±5.26	74.78 ±4.84	104.84*#$ ±10.74	109.38¥* #$$ ±8.87
All tasks (Male:160; Female:150)	74.40 ±4.81	75.35 ±5.09	105.33* ±10.77	109.97¥¥¥* ±9.94
F ratio			10.489 (p<0.001)	13.564 (p<0.001)

w.r.t. Male ¥ p<0.05; ¥¥ p<0.01; ¥¥¥ p<0.001 w.r.t. Resting HR * p<0.001
w.r.t. Planting of seeds # p<0.05; ### p<0.001 w.r.t. Tunnelling $ p<0.05; $$ p<0.01

Kilbom, (1995) argues that if heart rates are below 90 beats/min, the strain on the cardiovascular system is "light". Heart rates ranging from 90 to 110 beats/min indicate "moderate" strain; while those between 150 to 170 beats/min suggest "extremely heavy" strain is being placed on a worker. However, Kumar et al. (2000) argued that acceptable, rather than the upper limit for continuous work, is a heart rate range of 104 to 114 beats/min. The increase in heart rate of the workers might be due to impose of stresses. Several evidences revealed that heart rate increased during work as a result of cardiovascular responses might be due to physical, psychosocial stressors (Belkiae et al. 2004; Kivimäki et al. 2006) and also due to work related stress (Savonen et al. 2006). All these factors might collectively be responsible for increased heart rate of the workers during performing tasks. Heart rate acceleration is the main cardiovascular response to demands for the increased oxygen necessary for the performance of physical work, over and above that required at rest. Different investigators (Hasalkar et al. 2004; Miyamoto et al. 2006 and Kadoya et al. 2010) also noted that heart rate increases linearly with oxygen consumption in response to increasing workload or intensity. The higher working heart rate in the case of tunneling operators might be due to the degree of severity of job (Dey et al. 2007). The tunneling operators required constant rigorous motion, which acted as sympathetic modulator, might be the cause of higher heart rate (Soares-Miranda et al. 2009).

The gender difference in heart rate was also noted; the female workers had significantly higher mean working heart rate than that of the male workers in the entire work category (Table 5.51). Male have greater cardiovagal reflex gains than females, which may reflect differences in parasympathetic action on heart rate (Tanaka, 2004). The greater working heart rate in females might be due to greater psychological stress and fatigue level.

The female workers were found to be fatigued more quickly than that of male workers. The female workers probably suffered from additional psychological stress because of their family burden (such as kids of their family). Other investigators (Tersman et al. 1991; Overfield, 1995; Knight and Rickard, 2001) also reported that heart rate in females was more than males during stress conditions. It has been shown that subchronic physiological stress in human increased alpha2-adrenergic receptor density, which is related to stress-induced anxiety (Maes et al. 2002).

The whole day working heart rate, taken in each hour of the work shift and presented in the Fig 5.2, Fig 5.3 and Fig 5.4. The workers use to take a food break (breakfast and lunch) for about 2 hours 30 min (Sec. 5.4). They would perform their personal works and take rest after or before taking food break. The heart rate was not recorded during that period.

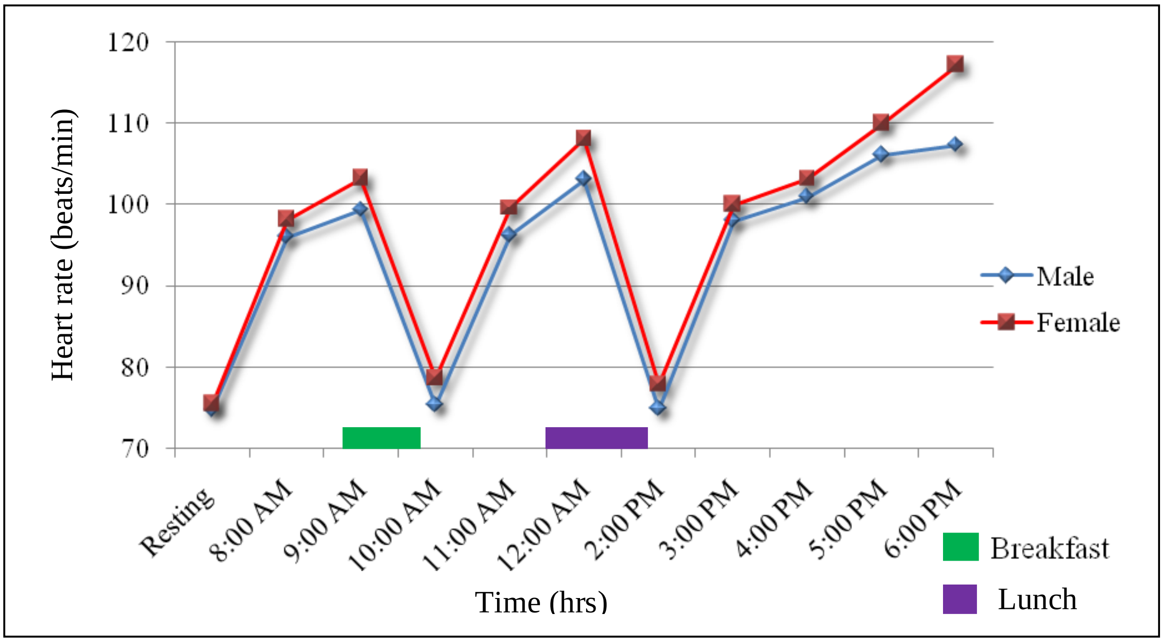


Fig. 5.2: Variation of working heart rate of seeds planting workers in different working hours

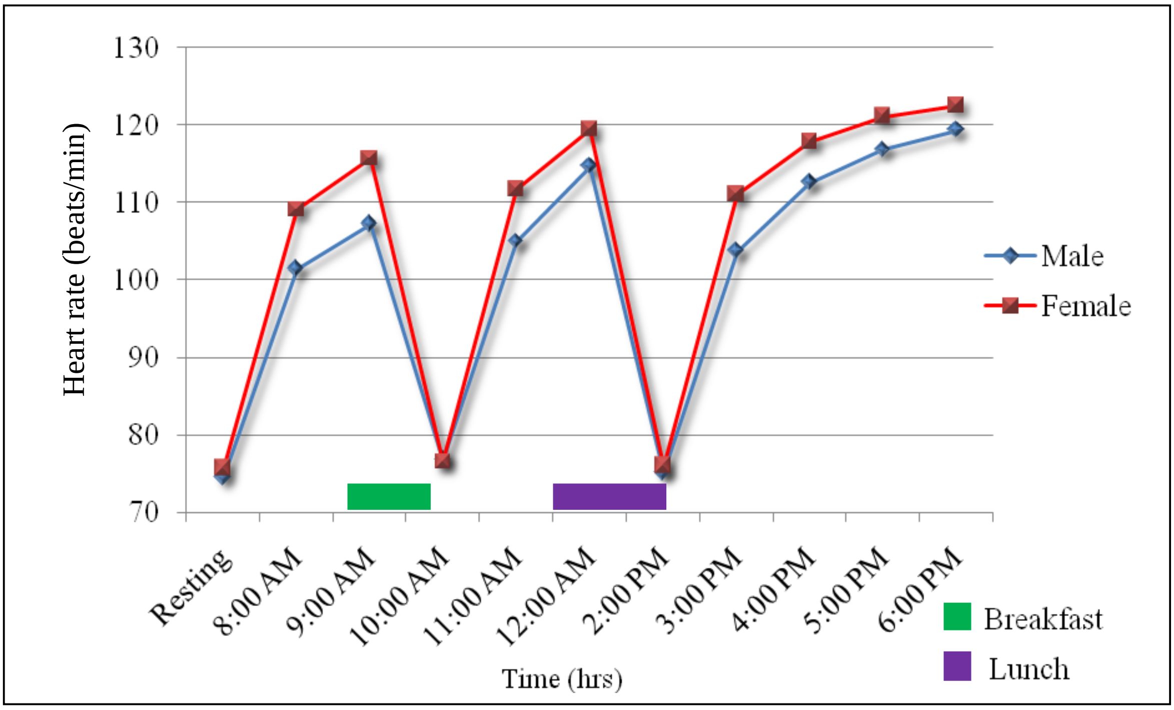


Fig. 5.3: Variation of working heart rate of tunneling workers in different working hours

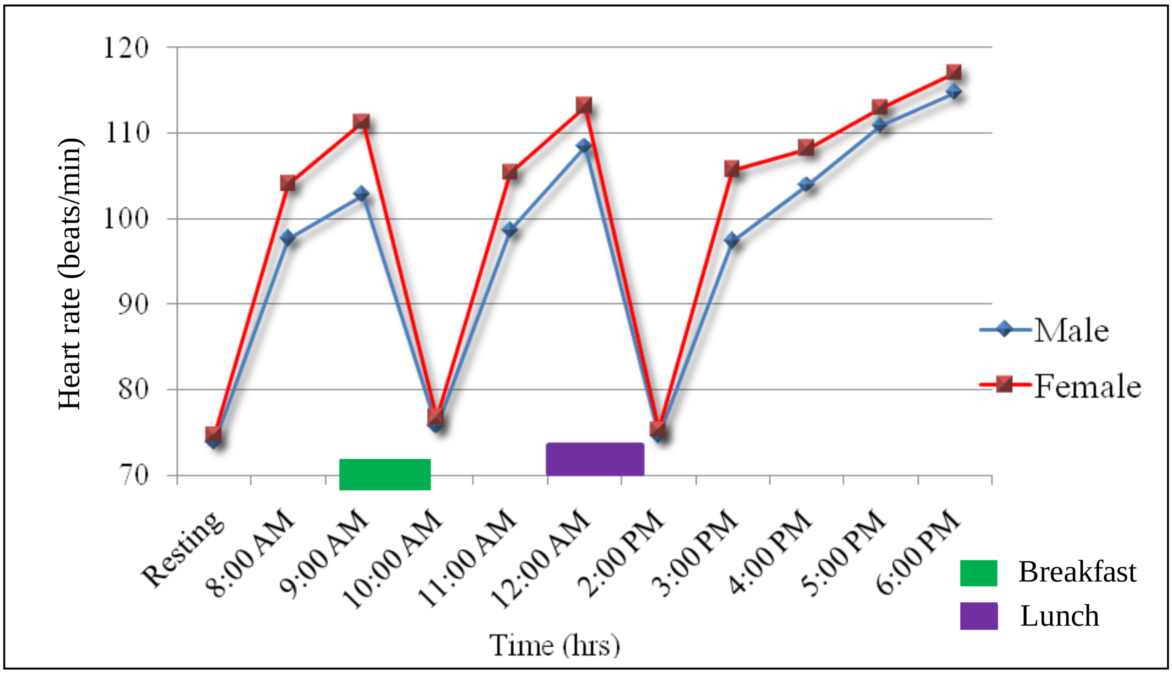


Fig. 5.4: Variation of working heart rate of potato harvesting workers in different working hours

The heart rate of both male and female workers was increased gradually up to the 2nd hour of the work shift. Then there was foods break (breakfast). After that break, when they resumed the work, the heart rate was found to be increased. Again, it was increased and reached to a peak at 6th hour. After the lunch break when the workers resumed the work, the heart rate was gradually raised. The increase in heart rate of the workers might be due to impose of work stresses. Several evidences revealed that heart rate increased during work as a result of cardiovascular responses might be due to physical, psychosocial stressors (Belkiae et al. 2004; Kivimäki et al. 2006; Pal et al. 2015b) and also due to work related stress (Savonen et al. 2006; Clays et al. 2011). All these factors might collectively be responsible for increased heart rate of the workers during performing tasks.

5.8.2 Cardiovascular Stress Index

The potato cultivators were exposed to cardiovascular stress during performing different tasks. In the present study, Cardiovascular Stress Index (CSI) was computed from pre-recorded heart rate (Sec. 5.8.1) and the result has been presented in the Table 5.52. The results showed that there was a variation in CSI among different groups of workers. Those workers involved in tunneling task had a significantly higher CSI than that of the potato harvesting and seed planting workers. The potato harvesting workers also had significantly ($p<0.05$) higher CSI than that of the seed planting workers. Such variation of the cardiovascular stress index among different groups of workers might be due to differences in the heaviness of the jobs. According to CSI classification (Brant, 2009), all the tasks of potato cultivation have been classified as stressful category except planting of seed in male. According to this classification all categories of potato cultivation tasks were above the normal limit and those possessed cardiovascular stress. From the results it was also noted that the female workers had a significantly higher degree of CSI (p<0.05) than that of the male workers in each category of work.

Table 5.52: Mean ± SD of Cardiovascular Stress Index (CSI) of the workers during different potato cultivation task

Worker Group	Male		Female	
	CSI	Stress Category	CSI	Stress Category
Planting of seeds	23.18 ±7.91	No stress	26.68* ±9.30	Stressful
Tunneling	30.74### ±9.28	Stressful	34.63* ### ±8.60	Stressful
Potato harvesting	26.77#$ ±9.37	Stressful	30.20* #$$ ±8.19	Stressful
All category	26.84 ±9.37	Stressful	30.48** ±9.22	Stressful
F ratio	10.113		5.858	

w.r.t. Male * p<0.05; **p<0.001 w.r.t. Planting of seeds # p<0.05; ### p<0.001
w.r.t. Tunnelling $ p<0.05; $$ p<0.01

Table 5.53: Comparison of CSI between present work and other works

Potato cultivators[1]		Silviculture workers[2]	Paddy cultivators[3]	Steel workers[4]	China clay mine workers[5]	Coalmine workers[6]
Male	Female					
26.84 ±9.37	30.48 ±9.22	39.2 ±4.0	25.34 ±10.85	25.0 ±14.0	26.2 ±8.35	43.32 ±6.47

1. Present study 2. Trites et al. 1993 3. Ghosh et al. 2003 4. Vitalis et al. 1994
5. Pari and Dhara, 2008 6. Verghese-Joseph et al. 2011

The mean cardiovascular stress index of the potato cultivators (present study) has been compared with that of other workers. It have been noted that the stress was much higher in Coalmine workers (Verghese-Joseph et al. 2011) and silviculture workers (Trites et al. 1993) than that of the potato cultivators. The paddy cultivators (Ghosh et al. 2003); steel workers (Vitalis et al. 1994) and china clay mine workers (Pari and Dhara, 2008) had got lower stress in comparison to the potato cultivators. Such variation of the cardiovascular stress index among different groups of workers might be due to differences in the heaviness of the jobs, environmental conditions and duration of activity.

5.8.3 Blood Lactate

The blood lactate level of the workers engaged in different tasks of potato cultivation was determined in resting as well as in working periods. The results have been presented in Table 5.54. The working blood lactate level increased significantly from the resting level in male and female workers during performing different tasks of potato cultivation. The higher working blood lactate level was noted in tunneling operation in both male and female cultivators compared to seed planting and potato harvesting tasks. The results indicated that the workers engaged in tunneling task had a higher degree of physiological stress than that of the workers engaged in seed planting and potato harvesting. It was noted from the results of ANOVA that the blood lactate level was significantly different (male: $p<0.001$; female: $p<0.01$) among workers who were engaged in different potato cultivation tasks.

Table 5.54: Mean ± SD of blood lactate accumulation (BLA) of Female workers engaged in different jobs of potato cultivation jobs

Worker Group	Resting BLA (mM/lit)		Working BLA (mM/lit)	
	Male	Female	Male	Female
Planting of Seeds	1.41 ±0.24	1.78 ±0.39	2.54***$ ±0.3	3.22 ¥**$ ±0.63
Tunneling	1.54 ±0.36	1.78 ±0.28	3.77***# ±0.83	5.20 ¥***# ±1.37
Potato Harvesting	1.59 ±0.3	1.98 ±0.37	2.93#*** ±0.38	3.33* ±1.14
F ratio			9.219	5.701

w.r.t. Male ¥ p<0.05 w.r.t. Resting *p<0.05, **P<0.01, ***p<0.001
w.r. t. Planting of Seeds # p<0.05 w.r.t. Tunneling $ p<0.01

Table 5.55 demonstrates the results of correlation coefficients between blood lactate level and working heart rate as well as blood lactate level and cardiovascular stress index. Correlation studies revealed that the blood lactate level had highly significant positive associations with heart rate and cardiovascular stress index.

Table 5.55: Correlation coefficient of working heart rate, cardiovascular stress index (CSI) with blood lactate level

Worker Group	Working HR		CSI	
	Male	Female	Male	Female
Planting of seeds	0.861*	0.820*	0.715*	0.805*
Tunneling	0.819*	0.759*	0.706*	0.693*
Potato harvesting	0.898*	0.857*	0.885*	0.761*

* $p<0.001$

Blood lactate levels is an indicator of muscular fatigue (Mohanty et al. 2008; Pal et al. 2015b). The lactate threshold or onset of blood lactate accumulation (OBLA) represents the point at which blood lactate begins to rise above baseline levels during exercise. It is considered to be a good predictor of endurance performance and can be used to prescribe intensities of work based on the relationship between blood lactate levels and heart rate. Mohanty et al. (2008) reported that the point of onset of blood lactate accumulation (OBLA) that begins when BLA is 4.0 mM/l of blood. In tunneling operation the blood lactate level of female workers was higher than the point of onset of blood lactate accumulation (OBLA). The blood lactate level was also high in planting of seed and potato harvesting. Mc-Ardle et al. (2000) reported that OBLA took place when the workload was 55-65 % of the VO_2 max. During relatively low level aerobic activity, blood lactate levels remain low and will not differ significantly from resting values. As exercise intensity increases, there comes a point at which blood lactate levels begin to rise above baseline levels. This rise in blood lactate is believed to occur due to increased rates of glycogen breakdown and increased conversion of glucose to pyruvate. In essence the lactate threshold represents a point at which the rate of lactate formation exceeds the utilization of lactate during oxidative-phosphorylation. As lactate levels rise, there is an associated increase in hydrogen ions. If the concentration of hydrogen ions increases significantly it can lead to a reduction in cellular pH, which at a certain level may start to interfere with cellular enzymes, metabolism and may lead to muscular fatigue. The work intensity at which the lactate threshold occurs appears to be related to a number of factors including the percentage of type I (slow twitch) muscle fibres and possibly the ratio of type IIa to type IIb fibres (Coyle et al. 1991; Pette, 2001; Bogdanis, 2012). Other factors that are likely to influence the lactate threshold include mitochondrial size and density, aerobic enzyme concentrations, muscle capillary density, and enhanced fatty acid metabolism (Joyner and Coyle, 2008). In addition body mass also appears to be an important factor influencing the lactate threshold (Buresh et al. 2004). In the present study biochemical changes during performing potato cultivation tasks supported the extent of cardiovascular stress imposed on the workers.

Designing of Hand Tools

Part C

Contents

Ergonomic Designs of Small Spade

Contents

5.9.1 Ergonomic designs of small spade

Small farmers and labourers use a number of tools each day, which given improved design, could lead to higher productivity. At the same time, attention to, details such as these have the potential to increase worker performance and productivity. Those factors underpin the current analysis of the hand-operated small spade. Spade used almost universally for farming and other laboring work. Spade is a manually operated common hand tool used for digging and nursery bed preparation. It is known by different names in different parts of the country. It consists of a thin flat blade set transversely on a handle. The digging head has an “eye” or socket for the insertion of the handle. The socket is either separately welded to the digging blade or is an integral part of the blade, which is usually made of medium carbon steel. Its shape is developed by a forging operation. These tools are available in different shapes and sizes. In operation, the handle of the spade is held in the hand, head raised and struck into the soil for digging. For grounding operation the tool head is pulled towards the operator who is obliged to adopt a bent forward posture.

In potato cultivation, the workers are required to use a small spade for tunneling operation. Such spade is smaller in size than the conventional standard spade and there may be some scope for improvement in small spade design.

The small spade were made with conventional idea without due consideration of human factors. There may be some drawbacks in the design of the small spade from the view point ergonomics. For example, the main problem of this small spade was that the handle length of the spade was short. Therefore, the workers were required to bend too much for a long time while performing tunneling operation with this tool, which might cause biomechanical stress in different body joints and could produce segmental pain. The workers reported pain/discomfort at different body segments, viz., lower back, upper back, finger, palm, wrist, etc., i.e., an overall discomfort was prevalent in the hand (Tables 5.34 -5.36). Secondly, during summer and hot humid conditions, excessive sweating creates problem of gripping the handle. Twisted movement was also observed at the wrist joint during the operation of the small spade. Redesigning of existing spade may solve some of the above stated problems. For several reasons, it is important to reconsider the design of hand tools that is- a) to avoid feelings of discomfort during performing the task; b) to reduce musculoskeletal disorders on a longer term; c) to increase the productivity.

Several researchers studied on the relationship between hand tool design and musculoskeletal disorders and indicated poor hand tool design as a risk factor of musculoskeletal disorders (Mital and Kilbom, 1992; Chaffin et al. 1999). Moreover, studies showed that less discomfort was experienced by using appropriately designed hand tools (Kilbom et al. 1993; Chang et al. 1999; Dempsey et al. 2002). Several researchers pointed out that the discomfort due to hand tool use seem to be inversely related to productivity (Dempsey et al. 2002; Wu and Hsieh, 2002; Kong and Freivalds, 2003). Discomfort in different body segments may also reduce job satisfaction (Fellow and Freivalds, 1991). For those reasons, the avoidance of discomfort has been a crucial issue in hand tool design for many years (Kong and Freivalds, 2003; Dempsey et al. 2004; Das et al. 2005; You et al. 2005). Therefore, it was important to prevent workers from discomfort by appropriate hand tool design.

To overcome the above problems, in the present study, an effort had been made to modify the design of the spade considering ergonomic principles. For modifying the design of the spade the following steps were undertaken.

5.9.1.1 Evaluation of the Existing Small Spade

The existing spade was evaluated by the subjective assessment as well as by some objective measurements from the viewpoint of ergonomics. Ten existing models of small spade were collected from the workers of different areas and their physical dimensions were studied. There was an appreciable variation in physical dimensions of the small spade as shown in Table 5.56.

Table 5.56: Physical dimensions of different existing small spade (all dimensions in cm except weight in Kg and angle in degrees)

Model no.	Weight	Handle		Blade		angle between handle and blade
		Length	Diameter	Length	breadth	
1	3.1	58.5	1.96	28.4	4.9	34
2	2.5	66.2	1.72	27	5.6	35
3	1.9	57.4	1.81	24.5	4.5	42
4	2.25	60.3	1.96	27.8	5.1	38
5	2.55	66.5	1.62	27.5	5	35
6	2.25	55.4	2.15	25.6	5.3	33
7	2.5	62.5	1.85	26.2	5.6	35
8	2.6	68.3	1.72	28.8	5.2	34
9	2.2	65.3	1.67	27.3	5	34
10	2.3	67.7	1.65	27.5	5.1	39
Mean ±SD	2.42±0.32	62.81±4.65	1.81±0.17	27.06±1.30	5.13±0.33	35.9±2.85
Range	1.9-3.1	55.4-68.3	1.62-2.15	24.5-28.8	4.5-5.6	33-42

Plate 5.1: Existing model of small spade

It was observed that the average weight of the existing spade was 2.42 kg, which varied from 1.9 to 3.1 kg. From the results it was noted that the average length of the handle of the existing spade was 62.81 cm which varied from 55.4 to 68.3 cm. The average diameter of the handle was 1.81 cm. The average length and width of the blade were about 27.06 cm and 5.13 cm respectively. The angle between blade and handle was 35.9^{o}. It appeared from the physical dimension of the existing spade that the breadth of the spade was narrow and it was much smaller than that of a standard spade. The narrow breadth was suitable for the tunneling task in potato cultivation. It also noted that the handle surface was uneven. In some of the models bamboo stick was used as handle in stead of wood.

From the subjective assessment it was observed that the existing spade had some problems from the user's point of view. They complained the lower back and neck pain (more than 90% of the respondent) while using the tool (Table 5.57). MSDs were also prevalent in shoulder, elbow, palm and finger during performing tasks with this existing spade.

Table 5.57: Frequency (Percentage) of workers reported musculoskeletal disorder (MSD) in different parts of the body during using existing spade

Body segments	Male (n=31)	Female (n=30)
Neck	13 (41.94%)	15 (50.0%)
Shoulder	20 (64.52%)	23 (76.67%)
Elbow	18 (58.06%)	20 (66.67%)
Wrist	20 (64.52%)	21 (70.0%)
Palm	23 (74.19%)	24 (80.0%)
Finger	25 (80.65%)	25 (83.33%)
Upper back	22 (70.97%)	24 (80.0%)
Lower back	27 (87.1%)	28 (93.33%)
Hip	16 (51.61%)	18 (60.0%)
Knee	7 (22.58%)	9 (30.0%)

About 87% male and 93 % female workers were reported pain/discomfort in lower back and about 71% male and 80% female workers were reported disorders at upper back. More than 80% of the workers reported pain at fingers. About 74% male and 80% female spade operators had pain at palm and 65% male and 70% female had pain at wrist. This might be due to exertion of load / force on the hand due to repeated operation of spade. Beside this, about 58% male and 67% female reported pain at the elbow joint. Higher MSDs was also found in the shoulder (male: 64.52%; female: 76.67%), which might be due to repeated flexion at the joint. Those problems might be due to ill fitting of existing spade in respect to length and diameter of the handle to the body dimensions of the workers. Therefore, efforts have been made to modify the design considering the body dimensions of the users and subjective perception, which may reduce some of the above problems of the workers without reducing productivity.

5.9.1.2 Evaluation of Users' Satisfaction Regarding Physical Dimensions Existing Small Spade

A study was conducted to assess the users' satisfaction regarding different physical characteristics of the small spade during its operation in the field. The study was carried out on 31 randomly chosen subjects among previously selected potato cultivators. The subjects were chosen according to the albetical order of the name of the subjects. The responses of the subjects regarding the suitability and the unsuitability of different dimensions of existing small spade were noted. The users also suggested some modifications in the dimensions of the small spade (Table 5.58 and Table 5.59). The results showed that the most of the spade users didn't prefer the existing weight of the spade and most of them desired for modification in weight. About 74% of the users preferred the range of weight from 2 to 2.2 kg. Similarly the users also opined for the change of other criteria, viz., length and diameter of the handle, length and breadth of the blade, and the angle between handle and blade. From the results it was revealed that most of the spade users (84%) didn't prefer the present length of the handle of the spade. About 77% users opined to increase the handle length and suggested a length ranged from 70 to 75 cm. About 75% of the users had choice of handle diameter ranged from 2.7 to 3.0 cm. Most of the users opined to increase the length and breadth of the blade and suggested a length ranged from 26 to 30 cm and suggested a breadth ranged from 5.5 to 6.0 cm. About 64% users desired to increase the angle between handle and blade and suggested an angle ranged from 50^0 to 55^0. Most of the workers preferred present shape of the blade and shape of cutting end, thus present shape should be considered during designing of spade.

Table 5.58: Percentage of users' satisfaction of physical dimensions of the existing spade (n=31)

		Weight	Handle		Blade				Angle between Handle and Blade
			Length	Diameter	Length	breadth	Shape of Blade	Shape of Cutting End	
Preference of existing model	Yes	25.8%	16.1%	22.6%	38.7%	45.2%	87.1%	80.64%	35.5%
	No	74.2%	83.6%	77.4%	61.3%	54.8%	12.9%	19.35%	64.5%
Modification suggested	No change	25.8%	16.1%	22.6%	38.7%	45.2%	87.1%	80.64%	35.5%
	Increase	-	77.4%	74.19%	51.6%	54.8%	-	-	64.5%
	Decrease	74.2%	6.45%	3.23%	9.7%	-	-	-	-

Table 5.59: Preference of range of dimensions of the tool by the respondents (%)

Weight (kg)		Handle				Blade								angle between handle and blade	
		Length (cm)		Diameter (cm)		Length (cm)		Breadth (cm)		shape of blade		Shape of Cutting End			
Range	%	Range	%	Range	%	Range	%	Range	%	Types	%	Types	%	Range	%
2.0 -2.2	73.9%	65 -70	34.6%	2.4-2.7	16.7%	26-28	42.1%	5-5.5	23.5%	Flat	12.9%	Flat	19.4%	40-45	0
2.2 -2.4	26.1%	70-75	53.8%	2.7-3.0	75%	28-30	42.1%	5.5-6	58.8%	Inward curved	87.1%	Curved	80.6%	45-50	35%
2.4 -2.6	0	75-80	11.5%	3.0-3.3	8.3%	30-31	15.8%	6-6.5	17.7%	Backward curved	0	Any other	0	50-55	58.8%
>2.6	0	>80	0	>3.3	0	>31	0	>6.5	0	Any other	0	-	-	>55	17.7%

After identifying the drawbacks of the existing spade, efforts have been made to redesign the small spade on the basis of the user's preference score as well as body dimensions of the workers. Considering different human factors including body dimension of the users, mode of operation of the spade and user preference, some design concept were developed for improving the design of small spade. On the basis of design concepts, some prototype models were prepared. The suitability of the dimension was tested later by means of psychophysical tests which indicated the preference of the users. For this purpose paired comparison test was performed. Body dimensions of the workers were used for determining different physical dimensions of these tools. After the trial on those models the final design is selected.

5.9.1.3 Design Approach

In the last few years, it was observed that emphasis on hand tool has shifted more towards the ergonomic needs of the user, i.e., to do the job harmlessly, effortlessly and comfortably. The tool should perform the task for which it was designed and corresponded to the characteristics of the greatest possible number of users (Aptel et al. 2002; Marsot and Claudon, 2004). But in India, rural farming tools and implements are generally made by members of tool-making families who vary in their knowledge and personal experience of the tasks to be performed in fabricating the different tools. This presents a major problem for females, particularly those with small hands, as the tools are likely to be oversized and difficult to handle in the face of excess tool weight. Hallbeck (1994) also reported that the male had large physical dimensions and ability than the female. When a number of workers use common equipment, computation of users population data is essential for industrial workstation and equipment design because people differ significantly in their anthropometric characteristics (Okunribido, 2000).

Evaluation of existing small spade showed that the main problems of users were associated with back and hand-arm systems of the workers. The problem was continued till the end of a work shift and even after finishing of work. A large percentage of users reported about the origin of such problem that might be due to repeated use that small spade (Table 5.57). Keeping all these in mind efforts was made to redesign the small spade used in different tasks of potato cultivation.

Two design concepts were developed in which some modifications were made and some new characteristics were incorporated. The followings are the design concepts:

5.9.1.3.1 Design Concept I

In the new design concept, it was postulated that the size and shape of the spade should be compatible to the body dimension of the workers. In design concept I, a same tool for both male and female users has been suggested. From the results of the present study (Sec. 5.2) it is also be noted that relatively larger hand dimensions in male than female, which indicates some tools fit to male hand but may not fit to female hand comfortably. To solve this problem design concept has been made by considering anthropometric dimensions of both male and female workers as a combined sample. The percentile values should also be computed considering the measured anthropometric values of male and female together. Some of the physical dimensions of the spade could be selected by taking the percentile values of the anthropometric data of the user population. For example, the diameter of the handle of the spade should be made considering 5th percentile value of the hand grip diameter of the users which might be helpful for the proper griping of the handle.

5.9.1.3.2 Design Concept II

The behavioral pattern of the users should satisfy the design criteria. With this consideration the following changes were suggested in redesigning the small spade.

The length of the handle of the spade was suggested to increase from the existing length. Such change may improve the postures of the workers when performing the spade operation. The angle between the blade and handle was suggested to increase from that of existing models. Such changes in angle might improve the biodynamic parameter of the body (e.g. body joint angles). The length of the blade was proposed to be increased from that of existing one. The width of the blade was also suggested to increase for improving the surface area of the blade. Modification of the shape of cutting end was made according to the need of the task and preference of the users. Usually the cutting end was flat. The shape of the cutting end could be selected by psychophysical behaviors of the users towards the particular characteristic features of the product. The weight of the spade was suggested to decrease from that of the existing spade. Each of the design criteria might be selected by psychophysical analysis of the users employing paired comparison test. This concept was also developed for providing a better grip in the hand tool so that the operators can hold it firmly and comfortably and slippage can be avoided. It was suggested to incorporate rubber pad in the grip area.

5.9.1.4 Making Prototypes of Spade

According to the above design concepts some prototype models were made and tested. According to the design concepts four prototypes were made having different physical dimensions of spade, viz., weight of the spade, length and diameter of the handle, length and width of the blade, shape of the cutting end of the blade and the angle between handle and blade. The characteristics of the different prototype models have been shown in Table 5.60. Four modified models (MS1, MS2, MS3 and MS4) were made following the above concepts.

Plate 5.2: Different prototype models of handle of small spade

Plate 5.3: Different prototype models of blade of small spade

Table 5.60: Physical dimensions and other criteria of four prototype models of spade

Model no	Weight (kg)	Handle		Blade				angle between handle and blade (^{O})
		Length (cm)	Diameter (cm)	Length (cm)	Breadth (cm)	Shape of blade	Shape of Cutting End	
MS1	2.0	67.5	2.4	25.0	5.0	curved inward	Curved	40
MS2	2.25	70.0	2.7	27.0	6.0	curved inward	Curved	45
MS3	2.5	72.5	3.0	29.0	7.0	Flat	Flat	50
MS4	3.0	75	3.3	31.0	8.0	Flat	Flat	55

.5.9.1.5 Testing of Prototypes: Paired Comparison Test

Some simulation studies were conducted with those prototypes. From the results of the simulation studies the design was altered, wherever needed. Then those prototypes were given to the workers and asked to perform the tasks. The subjective assessment was done with those models by employing paired comparison tests. The tests for different variables are discussed below:

5.9.1.5.1 Weight of the Small Spade

As the most of the participants desired for modification in weight, the preferred weight should be determined. For the selection of appropriate weight of the small spade, four different prototype models of spade with varying weight were tested by paired comparison test. The modified models tested were MS1, MS2, MS3 and MS4 with weight 2.0 Kg, 2.25 Kg, 2.5 Kg and 3.0 Kg respectively. For this study ten spade operators were selected randomly from the previously chosen workers. The subjects were provided with four prototype models and asked to work with those models. The test was performed by the procedure, as discussed in chapter 4 (Section 4.11.4.4). They were requested to judge the better weight of each pair of the prototype models and to score it in 10-point quantitative scale. All the selected subjects for the test were requested to put their relative preference scores. The raw scores obtained were presented in Table 5.61a. The resultant scores obtained by each of the prototypes were computed from the mean scores of the different pairs of stimuli and those are presented in table 5.61b. The final score of the test were plotted on a subjective scale (varied from -5 to +5) (Ebe and Griffin, 2001) shown in Fig 5.5. From the results it was observed that the model MS1 (weight: 2 Kg) had got the highest preference score. The result obtained from the paired comparison test was in conformity with the results of users' satisfaction choice (Table 5.58). The results in Table 5.59 showed that about 74% of the users were suggested weight varied from 2 to 2.2 kg.

Table 5.61a: Raw score for paired comparison test for selecting the weight of the spade

Parameter: Weight of small spade **No of sample:** 4

MS1 = 2.0 kg MS2 = 2.25 kg MS3 = 2.5 kg MS4 = 3.0 kg

Stimuli Set	Subjects										Mean
	1	2	3	4	5	6	7	8	9	10	
MS1:MS2	-2	-2	-3	-4	-2	-2	-3	-2	-2	-1	-2.3
MS1:MS3	-3	-4	-3	-3	-4	-5	-3	-4	-4	-4	-3.7
MS1:MS4	-4	-4	-3	-4	-4	-3	-5	-3	-4	-4	-3.8
MS2:MS3	-2	-3	-2	2	-2	-3	2	-2	-2	-2	-1.4
MS2:MS4	-3	-3	-3	2	-1	-4	-2	-3	-3	-2	-2.2
MS3:MS4	-1	-2	-1	2	1	-1	2	-1	-1	-1	-0.3

Table 5.61b: Resultant score for paired comparison test computed from table 5.61a

Prototype models	MS1	MS2	MS3	MS4
Resultant scores	+3.27	+0.43	-1.6	-2.1

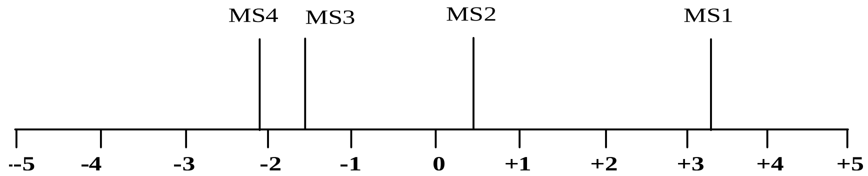


Fig 5.5: Stimuli space of different prototypes for weight of small spade

5.9.1.5.2 Handle Length of Small Spade

The handle length of the spade is related to the degree comfort for operating the tool and also to working posture. The handle of the existing spade was short in length, (about 63 cm) (Table 5.56). So the workers were required to bend while performing spade operations with the existing spade. It might lead to the occurrence of MSD at lower back and earlier fatigue. About 84% of the workers did not prefer the present length of the handle of the spade and all of them suggested for modification (Table 5.58). About 77% of the workers opined to increase the handle length of spade. For testing the handle length of the small spade four prototypes having different handle length were used. The paired comparison test was performed and the raw scores were obtained (not shown). The resultant score of the test was computed and shown in Fig. 5.6. The results of paired comparison showed that the modified model MS3 having a length of 72.5 cm had got the highest preference score (Fig. 5.6). This finding was in conformity with the results indicating user's satisfaction score (Table 5.59). Khidiya and Bhardwaj, (2010) designed hand operated spade and suggested handle length of spade 75 cm because it minimizes the need for operators to bend their backs. When the workers performed their job with such handle length, the deviation in waist angle (as shown in the later part of the discussion) was lesser than the other prototypes, indicating lesser degree body bending and more comfortable to use than that of other handles. Another study indicated that the long-handled tools were more efficient to operate the particular type of agricultural equipment (Yadav and Gite, 1982). The results of the present study were in conformity with that of above-mentioned studies in which long handle was suggested.

MS1 = 67.5 cm MS2 = 70.0 cm MS3 = 72.5 cm MS4 = 75.0 cm

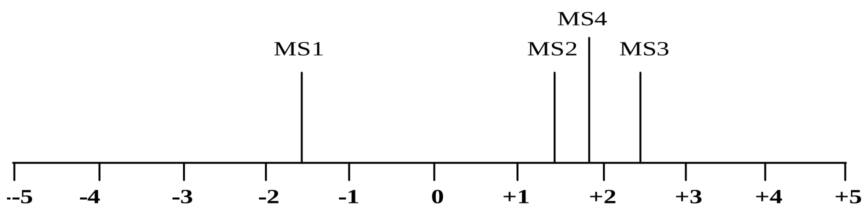


Fig 5.6: Stimuli space of different prototypes for handle length of small spade

5.9.1.5.3 Diameter of Handle of the Spade

The diameter of the hand tool is an important parameter because it might be related to the proper griping of the tool. The diameter of the handle of the spade was optimized form the results of the paired comparison test as well as the hand grip diameter of the user population. Four prototypes (model MS1, MS2, MS3 and MS4) with varying diameter were selected for paired comparison test; the diameters of handle were 2.4 cm, 2.7 cm, 3.0 cm, and 3.3 cm respectively. The computed final scores were plotted in Fig 5.7. From the results of the test it was noted that the modified model (MS3) having a handle diameter of 3.0 cm showed the best score. For better grip the handle diameter should not exceed the inside grip diameter of the operator. Therefore, the handle diameter should be according to 5th percentile value of the inside grip diameter to accommodate the larger population group (Dewangan et al. 2008). The 5th percentile value of hand grip diameter was 4.2 cm. The optimum diameter should be kept lower than this value to ascertain firm grip. A negative clearance value of 1 cm may added to the 5th percentile value of the hand grip diameter to ensure better grip in the handle. A useful rule of thumb for evaluating handle diameters is that the handle should be of such a size that it permits slight overlap of the thumb and fingers of a worker (Bridger, 1995). Dewangan et al. (2008) reported that to allow good grip on handle, the diameter of the handle should be a little lesser than the inside grip diameter. Thus by adding a negative clearance value (-1 cm) the diameter would be 3.2 cm approximately. The diameter (3.0 cm) of the handle of the spade obtained from the paired comparison test was more or less the same with of the results came from anthropometric study (5th percentile of the hand grip diameter of the user population – clearance value). Therefore, the value obtained from the results of paired comparison test (3.0 cm) was selected and thus during gripping the handle the thumb would permit a slight overlap between the thumb and other fingers. According to Sancho-Bru et al. (2003), the ideal diameter for a tool handle is 3.3 cm for the general population. Dewangan et al. (2008) also recommended 3.32 cm for diameter of the handle of hand tools. In a recent study, 3 cm was recommended for the diameter of the handle (Meena and Dangayach, 2015). The optimum diameter for a tool handle should be such that the muscles exert the minimum force needed to hold the tool and perform gripping activities. Optimal handle design reduces the force required for gripping a tool, protects the underlying joint structures, and reduces the risk of developing cumulative trauma associated with repetitive task requiring high grip forces and awkward postures. Investigators (Pheasant and O'Neill, 1975; Seo and Armstrong, 2008) also found that proper handle diameter may be considered optimal for repetitive performance and maximize grip force.

Selection of proper hand grip diameter is important for better performance with hand tools. Fry et al. (2006) studied on grip strength in American junior weightlifter and found a correlation between grip strength and performance in weightlifting. Ratamess et al. (2007) shown an ascending/descending strength curve such that grip force decline in proportion to the diameter of the bar or cylinder used. The strength of one's grip plays a key role in injury prevention and overall strength development (Budoff, 2004; Yasuo et al. 2005; Fry et al. 2006; Smith et al. 2006). Mechanical disadvantages in grip force occur if the fingers are excessively flexed around a small diameter handle or minimally flexed around a large diameter handle. These mechanical disadvantages lead to excessive grip force requirements which in turn lead to fatigue, tendonitis and hazard of accidentally dropping the tool (Cacha, 1999). There are 35 muscles involved in the movement of the forearm and hand, with many of those involved in gripping activities. During gripping activities, the muscles of the flexor mechanism in the hand and forearm create grip strength while the extensors of the forearm stabilize the wrist (Hall, 2007). There are 9 extrinsic muscles that cross the wrist and 10 intrinsic muscles with both of their attachments distal to the wrist (Waldo, 1996). Each of these muscles is active during gripping activities.

The results of the users' satisfaction score was also in conformity with selected handle diameter of the spade. About 77% of the spade users were against the existing diameter (range 1.62-2.15 cm) and about 74% of the workers opined to increase the handle diameter of the spade (Table 5.58). Thus, the diameter of the handle of the spade was fixed as 3.0 cm.

MS1 = 2.4 cm MS2 = 2.7 cm MS3 = 3.0 cm MS4 = 3.3 cm

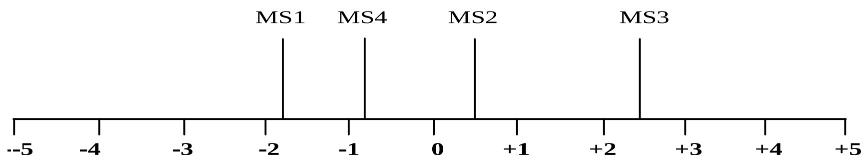


Fig 5.7: Stimuli space of different prototypes for handle diameter of small spade

5.9.1.5.4 Grip of the Handle

Often the handle of the spade can be seen to slip from a worker's hand and this could lead to an accident. A better handle grip has been provided in order to prevent undesired outcomes when the tool is in use. Many researchers suggested use of rubber grip in the grip area of hand tool to hold it stably, to prevent the injury and to reduce hand pain and fatigue significantly when used over time (Grant and Flesh, 2010; Khidiya and Bhardwaj, 2010), some other give stresses on the softness, surface texture of the grip pad to be useful where high forces is applied, as it would make it slip resistant and gives good feedback to the hands (Williams, 2003; Friedman et al. 2008). To ensure a good grip a rubber pad was pasted on the handle. The requirement of rubber grip was tested by paired comparison test by using the tool with and without rubber grip. The final computed scores of the test has been presented in Fig. 5.8. The result was in favour of rubber grip. However, the diameter of the handle was kept at 3.0 cm including the rubber grip.

SG = Spade with rubber grip SOG= Spade without rubber grip

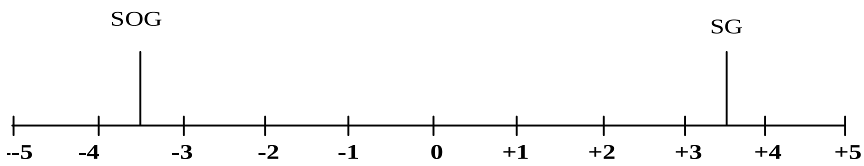


Fig 5.8: Stimuli space of different prototypes for grip of the spade

5.9.1.5.5 Length of the Blade of the Spade

Length of the blade of the spade is an important criterion as it is concerned with the productivity. A blade with longer length may be more productive than a spade with shorter blade as experienced by the workers engaged in potato cultivation task. About 61% of the users did not prefer the present length of blade and almost all of them suggested for modification (Table 5.58). About 52% of the workers opined to increase the length of the blade and their preferred value was ranged from 26 cm to 30 cm (Table 5.59). For the selection of appropriate length of the blade of the spade, four prototype models of spade with varying length of blade were tested by paired comparison test and the final results have been presented in Fig. 5.9.

MS1 = 25 cm MS2 = 27 cm MS3 = 29 cm MS4 = 31 cm

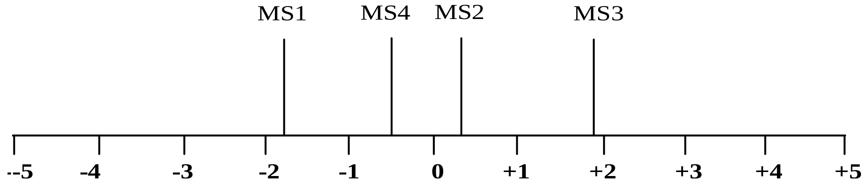


Fig 5.9: Stimuli space of different prototypes for blade length of small spade

The results showed that the modified model MS3 (29 cm) obtained highest positive score among four prototypes. Therefore, the value of 29 cm was finally selected as the length of the blade of the spade. The increase of the length of the blade would increase the total blade area when other dimensions remained the same. The increased blade area might be helpful for increasing the productivity.

5.9.1.5.6 Breadth of the Blade

The breadth of the blade in the spade is also an important criterion as it is be concerned with the productivity. About 55% of the users did not prefer the present breadth of blade and opined to increase the breadth of the blade (Table 5.58). For the selection of appropriate breadth of blade, four prototype models of spade with varying breadth of blade were tested by paired comparison test. The resultant computed score of the test has been shown in Fig. 5.10. The results showed that the modified model MS2 (6 cm) obtained the highest positive scores. Therefore, the value of 6.0 cm was finally selected as the breadth of the blade in the spade. This result was also consistent with the results of users' satisfaction scores (Table 5.59), where it was observed that about 71% of the workers opined for the blade breadth within the range 5.5–6 cm. Thus the total blade area would be increased with the increase of the breadth of the blade if the length of blade is kept fixed. Such modification in breadth of the blade might enhance the productivity.

MS1 = 5 cm MS2 = 6 cm MS3 = 7 cm MS4 = 8 cm

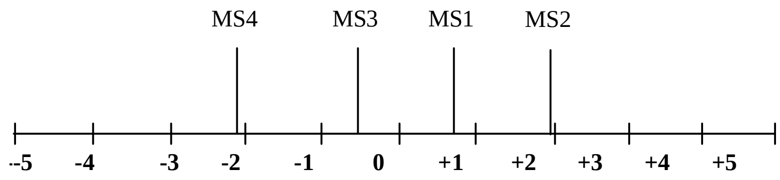


Fig 5.10: Stimuli space of different prototypes for breadth of blade of small spade

5.9.1.5.7 Shape of Blade of the Spade

The shape of the blade of the spade is also an important criterion which might be concerned with the productivity. The blade surface may of flat type or curved. Two prototype models with varying shape (MS1- curved inward and MS2 - flat) were developed. The paired comparison tests were performed with two prototype models and from the results (Fig. 5.11) it was observed that MS1 had got the highest subjective preference score. The shape of the blade of the MS1 was curved inward which was the same as existing spade. Thus the curved shape of the blade was considered for the final design of the spade.

MS1 = Curved inward MS2 = Flat

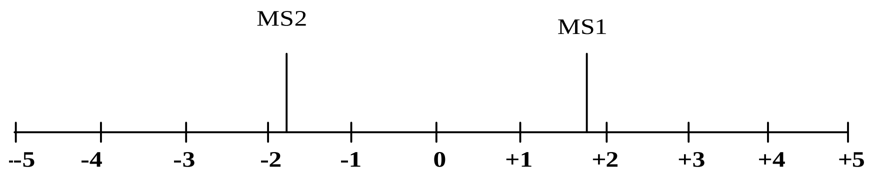


Fig 5.11: Stimuli space of different prototypes for shape of blade of the spade

5.9.1.5.8 Shape of Cutting End of the Blade of the Spade

The shape of the cutting end of the blade may be related to the cutting efficiency of the spade. The cutting end may be made linear of curved. Two prototype models with varying shape of cutting end (MS1- curved and MS2 - linear) were developed. The paired comparison tests were performed between two prototype models and from the results (Fig. 5.12) it was observed that MS1 had got the highest positive preference score.

MS1 = Curved MS2 = Linear

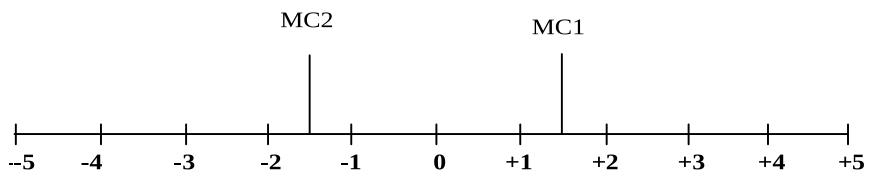


Fig 5.12: Stimuli space of different prototypes for shape of cutting end of blade of the spade

So, a curved cutting end of the blade of the spade was considered for the final design of the blade.

5.9.1.5.9 Angle between Handle and Blade of the Spade

The angle between handle and blade of the spade might be related to the posture of hand –arm system, especially the wrist, during work. The angle between handle and blade of the existing spade was 36^0. Therefore, while working with this existing spade, the workers compelled to bend, which may lead to pain or discomfort in many of the body segments. As the most of the subjects desired for modification in the angle between handle and blade of the spade, the preferred angle was determined.

MS1 = 40^0 MS2 = 45^0 MS3 = 50^0 MS4 = 55^0

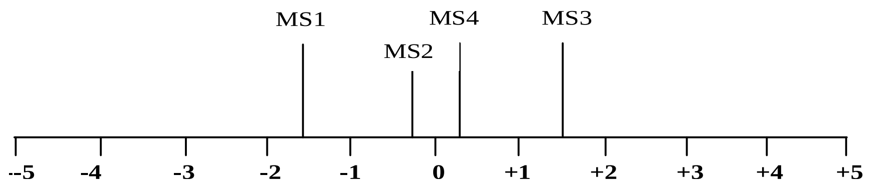


Fig 5.13: Stimuli space of different prototypes for angle between handle and blade of the spade

For the selection of appropriate angle between handle and blade of the spade, four prototype models of spade with varying angle were tested by paired comparison test. From the results (Fig. 5.13) it was observed that the prototype model MS3 (angle =50^0) had got the highest positive preference score. The result obtained from the paired comparison test was in conformity with the results of users' satisfaction choice. This indicated that the workers had preferred the spade with the changed angle between handle and blade of the spade. For the suggested design the angle between the handle and blade was fixed as 55^0.

5.9.1.6 Final Design and Fabrication

From the results of paired comparison test and anthropometric dimensions of the cultivators different design characteristics of the small spade were selected. Table 5.62 shows the criteria for selecting different characteristics of the small spade. The weight of the spade was decreased from that of existing one. It was selected from the weight of the prototype MS1, which was chosen as the best prototype model for this criterion during the performing paired comparison test. So, the weight of the spade was taken as 2.0 Kg.

The length of the handle of spade was increased from that of existing one. The altered length was decided by the paired comparison test. The length of the handle of the prototype model MS3 was preferred by users and the length of the handle was settled as 72.5 cm.

Table 5.62: Design criteria and dimensions for modified small spade

Dimensions of small spade	Required percentile/ Dimension	Value in cm.	Clearance value (cm)	Subjective preference score/ Anthropometric dimension	Final dimension
Weight				Best value: model no. MS1: 2.0 kg	2.0 kg
Length of handle				Best value: model no. MS3: 72.5 cm	72.5 cm
Diameter of handle	5^{th} / hand grip diameter	4.2	-1.0	Best value: model no. MS3: 3.0 cm	3.0 cm
Length of blade				Best value: model no. MS3: 29.0 cm	29.0 cm
Breadth of blade				Best value: model no. MS2: 6.0 cm	6.0 cm
Shape of blade of the spade				Best value: model no. MS1: inward curved	curved inward
Shape of cutting end of the blade of the spade				Best value: model no. MS1: curved	Curved
Angle between handle and blade of the spade				Best value: model no. MS3: 50^0	50^0

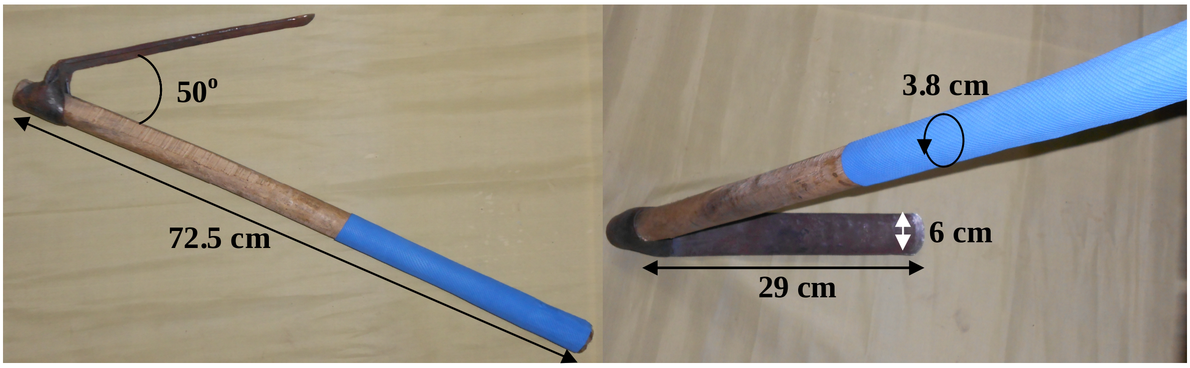


Plate 5.4: Redesign small spade

Plate 5.5: Tunneling with redesigned small spade

The diameter was selected on the basis of 5th percentile value of hand grip diameter of the users. The dimension was also confirmed by the results of paired comparison test. The prototype model, MS3, having diameter 3.0 cm had the best preference score of the test. Thus the diameter of the handle was selected as 3.0 cm. Often the handle of the spade can be slipped from a worker's hand and this may lead to an accident. A better handle grip was provided in order to prevent undesired outcomes during using the tool.

The length of the blade of the spade was slightly increased from that of existing one. The altered length was selected from the blade length of the prototype model MS3, which was chosen as the best prototype model for this criterion during the performing paired comparison test. The length of the blade was settled as 29.0 cm.

The breadth of the blade of the spade was slightly increased from that of existing one. The altered breadth was decided by the paired comparison test. The breadth of the prototype model MS2 was preferred by users and the breadth of the blade was selected as 6.0 cm.

The shape of the blade of the prototype model MS1 was the same as existing spade. Thus the present shape blade might be considered final for modified spade.

The shape of cutting end of the blade of the prototype model MS1 was also the same as existing spade. Thus the present shape of cutting end of the blade might be considered final for modified spade.

The angle between handle and blade of the spade was increased from that of existing one. For the selection of appropriate angle between handle and blade of the spade paired comparison test was done. MS3 (angle $=50^0$) has got the highest preference score. So, the angle between handle and blade of the spade was taken as 50^0.

So the final design was recommended by combining different design criteria from different modified models of spade. The design criteria are shown in Plate 5.4. It may be pointed out that the recommended design had resemblance with the modified model MS3 because most of the criteria were selected from this prototype model.

5.9.1.7 Evaluation of Redesigned Spade

The effectiveness and acceptability of the modified design of the spade were evaluated. The following studies were employed.

5.9.1.7.1 Subjective Study

The workers were given the redesigned spade for performing their work and to express views regarding the comfort, easiness of work and acceptability in comparison to the existing spade. The subjects were asked to grade it as “bad”, “fair”, “good” and “very good”. The results of this study showed that most of the users expressed as “good” (62.3%) (Table 5.63). Appreciable numbers of them categorized as “fair” (25%). About 8% and 5% of the workers graded as “very good” and “bad” respectively. Therefore, the subjective assessment was in favour of modified spade.

Table 5.63: Subjective assessment of modified spade. Percentage of subjects graded the redesigned spade

Grade	Bad	Fair	Good	Very Good
Male (n=31)	3.23%	32.26%	58.06%	6.45%
Female (n=30)	6.67%	16.67%	66.67%	10.0%
All (n=61)	4.92%	24.59%	62.3%	8.2%

5.9.1.7.2 Study of MSD

The male and female cultivators were provided with the redesigned spade and asked to perform the task (tunneling) for 3 weeks and then the occurrence of MSD was studied. The occurrence of MSD while using the redesigned spade was evaluated by modified Nordic Questionnaire in comparison to that of existing spade. The results have been presented in Table 5.64 in which the occurrence of MSD was compared between existing and modified spade. From the results it was observed that the prevalence of pain / discomfort in different segments of the body was lower during the use of the redesigned spade than that of existing spade. χ^2 –test was performed to find out the level of significance in the difference of subjective response between existing and modified spades. In case of male workers, it was noted that the prevalence of pain in palm ($p<0.05$), fingers ($p<0.001$) and back ($p<0.01$) was significantly lower during the use of modified spade than that of existing one. Whereas, in case of female the prevalence of pain in shoulder ($p<0.05$), palm ($p<0.05$), fingers ($p<0.001$), upper back ($p<0.05$), lower back ($p<0.01$), and hip ($p<0.05$) was significantly lower during use of redesigned spade than that of existing one.

Further, it was noted that the prevalence of MSD became lowered, although non-significantly, in the body segments other than mentioned above. Thus the results indicated that the workers would be able to use the modified spade with a lower degree of discomfort, especially in the hand arm system.

Table 5.64: Frequency (percentage) of occurrence of pain/discomfort in different body segments of spade operators during using existing and modified spade

Body segments	Existing Spade		Redesigned spade	
	Male (n=31)	Female (n=30)	Male (n=31)	Female (n=30)
Neck	13 (41.94%)	15 (50.00%)	9 (29.03%)	11 (36.67%)
Shoulder	20 (64.52%)	23 (76.67%)	14 (45.16%)	15 (50.00%)*
Elbow	18 (58.06%)	20 (66.67%)	15 (48.39%)	15 (50.00%)
Wrist	20 (64.52%)	21 (70.00%)	15 (48.39%)	16 (53.33%)
Palm	23 (74.19%)	24 (80.00%)	15 (48.39%)*	16 (53.33%)*
Finger	25 (80.65%)	25 (83.33%)	7 (22.58%)***	8 (26.67%)***
Upper back	22 (70.97%)	24 (80.00%)	15 (48.39%)	16 (53.33%)*
Lower back	27 (87.10%)	28 (93.33%)	15 (48.39%)**	17 (56.67%)**
Hip	16 (51.61%)	18 (60.00%)	12 (38.71%)	10 (33.33%)*
Knee	7 (22.58%)	9 (30.00%)	6 (19.35%)	7 (23.33%)

w.r.t. existing spade * $p<0.05$, ** $p<0.01$, *** $p<0.001$

5.9.1.7.3 Joint Angle Study

The body joint angle study was performed with the redesigned spade and the existing spade in view to observe the biomechanical changes in different parts of the body due to using the spade. The joint angles measured in normal erect posture were taken as reference. The difference of the angles between the reference position and during using small spade was taken as deviation of joint angles.

Table 5.65: Mean ± SD of different joint angles (degrees) of the spade operators during working with existing (EM) and modified spade (MM)

			Male (n=15)		Female (n=15)	
			Right	Left	Right	Left
Shoulder	Normal joint angle		22.67±5.08	21.73±5.30	22.53±7.23	23.53±8.69
	EM	Avg. Working angle	70.73±12.71	67.27±12.89	72.07±12.32	68.40±12.76
		Deviation of angle	48.07±13.72	45.53±15.16	49.53±14.81	44.87±16.97
	MM	Avg. Working angle	64.40±9.63	63.40±9.46	66.07±9.66	62.53±11.94
		Deviation of angle	41.73±10.68	41.67±11.75	43.53±12.39	39.00±16.49
Elbow	Normal joint angle		161.93±8.88	164.93±7.81	160.20±11.18	161.33±9.66
	EM	Avg. Working angle	149.47±8.90	142.53±11.35	148.13±9.93	141.20±9.41
		Deviation of angle	12.47±9.72	22.40±9.71	12.07±12.71	20.13±11.97
	MM	Avg. Working angle	156.67±3.85**	152.40±5.40**	154.93±7.88*	149.33±7.48*
		Deviation of angle	5.27±10.46	12.53±9.65	5.27±12.95	12.0±10.13
Wrist	Normal joint angle		171.80±8.39	171.40±6.96	174.40±5.38	173.87±5.18
	EM	Avg. Working angle	167.40±8.84	165.67±9.76	165.53±6.93	163.67±7.99
		Deviation of angle	4.40±11.0	5.73±9.53	8.87±7.42	10.20±9.35
	MM	Avg. Working angle	171.27±6.61	170.20±6.26	169.67±5.31	169.80±4.31*
		Deviation of angle	0.53±10.50	1.20±8.13	4.73±6.02	4.07±5.59
Hip	Normal joint angle		176.20±5.35	175.47±5.76	174.60±5.51	174.73±6.30
	EM	Avg. Working angle	98.93±18.11	97.47±14.89	99.13±17.60	98.80±15.21
		Deviation of angle	77.27±17.03	78.00±15.34	75.47±15.90	75.93±14.09
	MM	Avg. Working angle	110.87±7.72*	108.87±9.14*	113.13±7.74**	112.67±8.50**
		Deviation of angle	65.33±7.59	66.60±10.16	61.47±7.74	62.07±7.99
Knee	Normal joint angle		171.67±4.81	170.07±4.61	170.13±7.42	171.33±6.72
	EM	Avg. Working angle	155.93±12.36	159.60±11.39	158.6±10.4	161.6±9.1
		Deviation of angle	15.73±12.0	10.47±10.23	11.53±13.04	9.73±9.25
	MM	Avg. Working angle	163.00±7.52	165.07±6.53	164.07±7.22	165.07±7.94
		Deviation of angle	8.67±9.69	5.0±6.28	6.07±11.0	6.27±9.10

w.r.t. Existing model * $p<0.05$, ** $p<0.01$

Plate 5.6: Hip angle during working with existing spade

Plate 5.7: Hip angle during working with modified spade

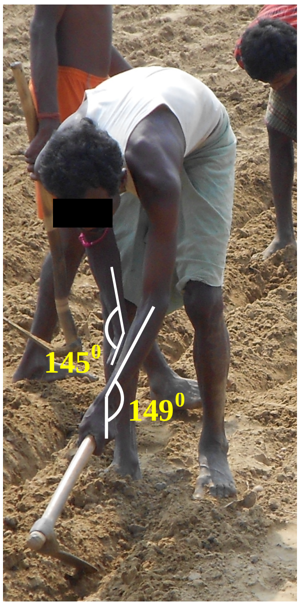


Plate 5.8: Wrist angle during working with existing spade

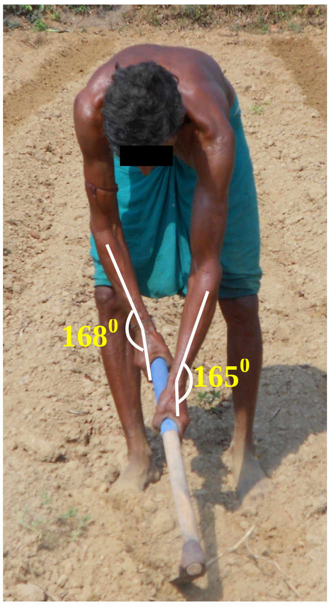


Plate 5.9: Wrist angle during working with existing spade

The shoulder, elbow, wrist, hip and knee angles were studied with existing and redesigned spade for the said purpose and it was noted there were significant differences in most of the joint angles when performing tunneling tasks with redesigned spade (Table 5.65). The results depicted that the hip angle was improved significantly (less forward bending of the body) while performing work with redesigned spade in comparison to existing spade. The elbow angle was increased during working with recommended design from that of existing one. This indicated that there was lesser flexion at elbow joint while using redesigned spade. From the results it was observed that the deviation of the wrist joint angle was found to be lower in case of the modified spade than that of the existing one. The minimum deviation of wrist angle in case of the using redesigned spade indicated that there was lowest degree of wrist flexion during work. The shoulder angle was found to be reduced in redesigned spade indicating lesser abduction of upper arm. From the joint angle study it appeared that the user got some biomechanical advantage when they used the modified spade and they might have lesser musculoskeletal problems.

5.9.1.7.4 Study of Heart Rate

The heart rate of the male and female spade operators was measured during the performance of tunneling task with existing and redesigned spade. The results (Table 5.66) showed that there was a significant decrease ($p<0.05$) in mean working heart rate while using redesigned spade. Thus the cardiac cost during work was decreased. On the other hand the CSI during using redesigned spade was also significantly decreased ($p<0.05$) compared to the existing spade. Thus the cardiovascular stress was lower while using redesigned spade than that of using existing spade.

Table 5.66: Resting and working heart rates of spade operators using existing and modified spade

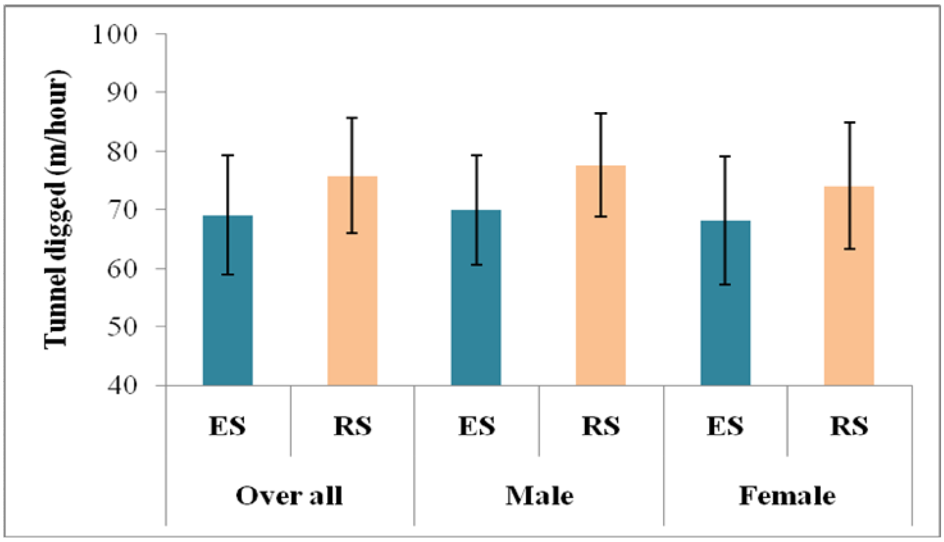
Types of spade	Resting HR (beats/min)		Working HR (beats/min)		CSI	
	Male	Female	Male	Female	Male	Female
Existing spade	74.58 ±5.37	75.76 ±4.80	110.08 ±10.83	115.52 ±9.33	30.74 ±9.28	34.63 ±8.60
Redesigned spade	74.58 ±5.37	75.76 ±4.80	105.68* ±10.69	110.82* ±9.86	26.90* ±9.36	30.42* ±9.16

*p<0.05

5.9.1.7.5 Productivity Study

The productivity study was conducted when the workers used existing and redesigned spades. It was carried out by measuring the length (meter) of a tunnel cut in a unit time (hour). The length of a tunnel cut per unit time was taken as the productivity by expressing the same in meters.

From the results of the productivity study (Fig 5.14) it was observed that there was an increase in productivity by about 10%, while using the redesigned spade than that by using existing spade when both male and female workers considered together. The results indicated that there was an increase in productivity by about 11% in male and by about 9% in female workers respectively. The workers were habituated with the existing spade. But they were not so habituated with the modified models of spade. This might be the reason for non-significant increase of productivity with redesigned spade. However, it may be expected that after regular use of the redesigned spade the productivity would significantly be increased.



ES- Existing Spade; RS- Redesign Spade

Fig 5.14: Mean productivity (length of tunnel dug per hour) with existing and redesign spade

Thus, it can be concluded that the redesigned spade was better than that of existing spade from the view point of productivity.

5.9.1.7.6 Cost Analysis

The cost analysis of redesigned spade was done and it was compared with the existing small spade (Table-5.67). From the cost analysis shown in Table 5.67, it may be stated that the cost of the redesigned spade was slightly higher than that of existing one. This is because the material cost (iron and wood) of redesigned tool would be slightly greater than that of existing one because of increased size of the spade and the requirement of rubber grip. However, it represented the cost of making only one spade. If it is manufactured in a large scale, the making charge will be reduced and there would be a little increase in the cost of the tool.

Table 5.67: Cost analysis of redesigned small spade

Items	Existing Small Spade	Redesigned Small Spade
Iron materials		Rs.60.00
Wooden materials for handle		Rs.50.00
Rubber Grip		Rs.30.00
Making charge		Rs.100.00
Total	Rs.190.00	Rs.235.00

It may be summarized from the above discussion that redesigned spade was acceptable by the users and was comfortable for the workers. The results of the productivity study, joint angle study and heart rate study were also in favour of the modified model. The cost was a little higher than existing spade. On the other hand, new design lowered the risk of injury among workers and provides better comfort for the worker.

Designing of Ground Nut Plucking Tool

Contents

5.9.2 Designing of Ground Nut Plucking Tool

The ground nut cultivators require harvesting nut pods, which are attached into the roots of the plant. In usual practice the workers separate the ground nut pods from the root of the plant manually by the fingers. The workers were interviewed regarding the problems faced during plucking the nut. They reported discomfort/pain in different body segments, especially in the hands (Table 5.68). About 89% of male and 92% of female workers reported musculoskeletal problems in fingers and more than 75% of male and 80% of female reported problems in the palm and wrist. Besides this, about 66% of male and 71% of female workers were found to have problems in the elbow joint. Thus it appeared that musculoskeletal problems in hand–arm system was highly prevalent during detaching nut pods. Beside hand and arm the prevalence of MSD was also noted in other segments of the body. About 77% of male and 82% of female workers had problem on lower back and 63% of male and 71% of female workers had problem on upper back. High prevalence of MSDs was also found in shoulder and hip. These problems might be related to posture adopted during performing the task for a long time.

Table 5.68: Percentage of workers reported musculoskeletal disorder (MSD) in different parts of the body during performing the nut plucking task

Body segments	Male (n=35)	Female (n=38)
Neck	12 (34.29%)	16 (42.11%)
Shoulder	22 (62.86%)	26 (68.42%)
Elbow	23 (65.71%)	27 (71.05%)
Wrist	27 (77.14%)	32 (84.21%)
Palm	28 (80.00%)	33 (86.84%)
Finger	31 (88.57%)	35 (92.11%)
Upper back	22 (62.86%)	27 (71.05%)
Lower back	27 (77.14%)	31 (81.58%)
Hip	19 (54.29%)	25 (65.79%)
Knee	8 (22.86%)	12 (31.58%)

High prevalence of MSDs in hand might be due to manually separating of ground nut pods from the root of the plant by the fingers repeatedly. Therefore, efforts had been made to design of a hand tool, named as nut plucking tool, considering the ergonomic principles, which may reduce some of the above problems of the workers without reducing productivity.

The need for a hand tool for the said purpose was surveyed among the nut cultivators. The workers showed their interest for a hand tool for plucking nuts. Considering different human factors, including body dimension of the users and user preference, some design concept were developed for designing of a ground nut plucking tool. On the basis of design concepts, some prototype models were prepared. The suitability of the dimension was tested latter by means of psychophysical test which indicated the preference of the users. For this purpose paired comparison test was employed. Body dimensions of the workers were used for determining different physical dimensions of these tools. After the trial on those models the final design was selected.

Plate 5.10: The workers are separating the ground nut from the root of the plant manually by the fingers

5.9.2.1 Design Concept

A simple box shaped structure was proposed for plucking the ground nut in the design concept. A flat metal blade may be used to make the box, which may act as container for holding free nuts. The bottom part of the box may be extended with some finger like projections. The projected ends may be made sharp so that those can cut the connecting part of the ground nut pods with the plant root. A box shaped structure may be used to hold the separated nuts. A suitable handle may be attached to the rear part of the blade (box) for holding the tool by the hand. The handle may be made by following the anthropometric principle of design. Some of the physical dimensions of the nut plucking tool could be selected by taking the percentile values of the anthropometric data of the user population. For example, the diameter of the handle of the nut plucking tool was made considering 5th percentile value of the hand grip diameter of the users which might be helpful for the proper griping of the handle. Some gripping arrangements may be added to the handle for assuring a better grip in the hand tool so that the operators can hold it firmly and comfortably and slippage can be avoided. It was suggested to incorporate rubber pad in the grip area. Each of the design criteria might be selected by considering psychophycal behavior of the users towards the proposed tool. By this way the handle length, handle diameter as well as the length and width of the blade could be recommended.

5.9.2.2 Preparation of Prototypes

According to design concept four prototype models, viz., NP1, NP2, NP3, and NP4 were made, as shown in Plate 5.11. The prototypes had some variations in the dimensions as shown in Table 5.69. Some simulation studies were conducted with those prototypes. From the results of the simulation studies the design was slightly altered, wherever needed. Then those prototypes were given to the workers and asked to perform the task. Those prototypes were tested while using them by the selected workers.

Table 5.69: Physical dimensions and other criteria of prototype model of nut plucking tool

Model no	Handle		Blade		
	Length (cm)	Diameter (cm)	Length (cm)	Breadth (cm)	Depth (cm)
NP1	9	3.3	16	8	6
NP2	10.5	2.4	18	10	8
NP3	12	2.7	20	12	10
NP4	13.5	3.0	22	14	12

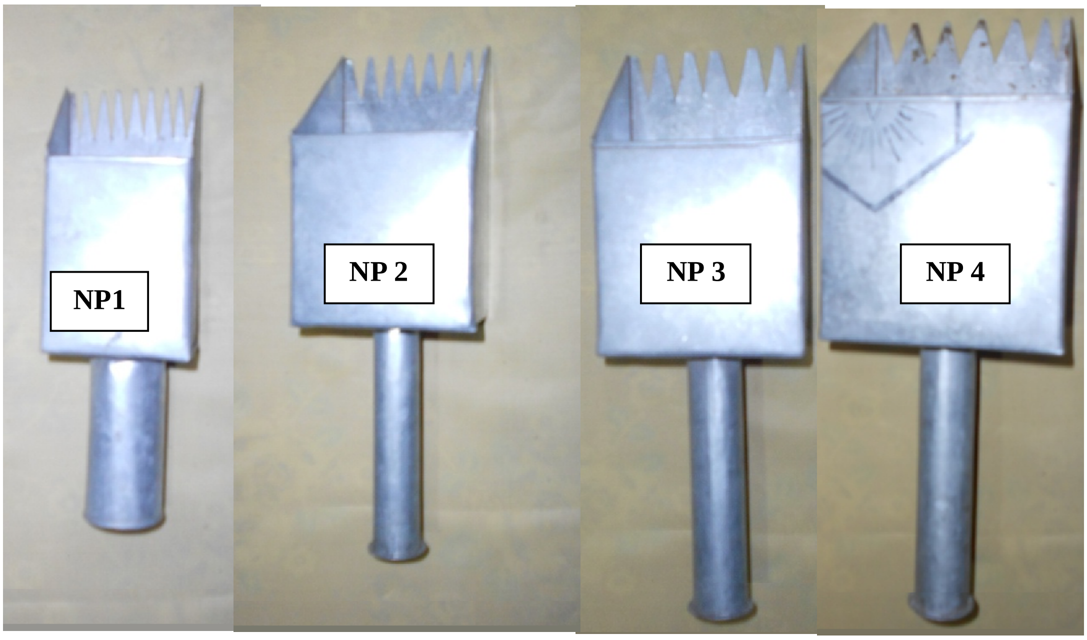


Plate 5.11: Different prototypes of nut plucking tool

5.9.2.3 Testing of Prototypes: Paired Comparison Test

Some simulation studies were conducted to judge the phychophysical behavior of the subjects towards the prototypes. From the results of the simulation studies the design was slightly altered, wherever needed. Those prototypes were given to the workers and asked to perform the tasks. The physiological parameter and subjective assessment were done with those prototype models. The studied variables were the physical dimensions of the proposed tool, viz., length and diameter of the handle, and length, breadth and width of the blade. The psychophysical response of the workers towards different characteristics of the tool was assessed by paired comparison test. These are discussed below:

5.9.2.3.1 Length of the Handle

The handle of the tool is the most important part because it acts as an interface between the user and the main tool. The physical dimensions of the handle may be tested by judging the users' behavior and preference towards the sizes of the hand tool. For this purpose paired comparison tests was employed. Each variable was tested separately. For example, the length of the handle was tested by varying the magnitude of the length. Similarly, diameter of the handle was also tested.

Ten subjects (five male subjects and five female subjects) were selected for this study and the test was performed by the procedure, as discussed earlier (Sec 4.11.4.4). The Models NP1, NP2, NP3 and NP4 were used for the test, in which the lengths of the handle were 9.0 cm, 10.5 cm, 12.0 cm and 13.5 cm respectively. The raw scores of the test were obtained after testing the subjects and the resultant scores for each stimulus (prototype) were computed from the raw scores of the subjects. The computed scores of the test were plotted in Fig.5.15 and the result showed that the model NP3 had got the highest preference score. The handle length of model NP3 was 12 cm. The value, which was obtained from the test, may be compared with that computed from the anthropometric principle of design. As a thumb rule 95th percentile value of the hand breadth of the user population may be used for determining the length of the handle. The 95th percentile of hand breadth of the users (Table 5.5) was 8.6 cm. A clearance value should be added to the computed dimension for fixing its length (Dewangan et al. 2008). A clearance of 3.5 cm was added to it and therefore, the total length came to about 12.0 cm. Thus this value had a perfect match with value obtained from the paired comparison test. So, this value of 12.0 cm was selected for the handle length of nut plucking tool. Garrette, (1971) reported that 12.5 cm handle length was more comfortable for the workers and in another study (Eastman Kodak, 1983) the value 12.0 cm was recommended. Bridger (1995) stated that the handle lengths should be at least 115 mm plus allow clearance for extra large hands. Dewangan et al. (2008) recommended 10.8 cm for the length of the handle. In a recent study, Meena and Dangayach, (2015), recommended that 11 cm for handle length.

NP1 = 9 cm NP2 = 10.5 cm NP3 = 12 cm NP4 = 13.5 cm

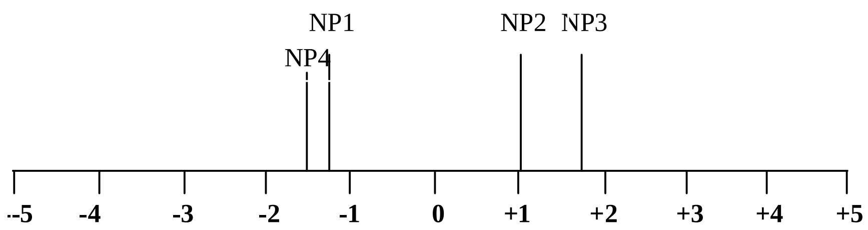


Fig 5.15: Stimuli space for handle length of nut plucking tool

5.9.2.3.2 Diameter of the Handle

The diameter of the handle of the nut plucking tool is an important issue because it is related to the proper griping of the tool. The proper handling diameter may be considered optimal for repetitive performance (Pheasant and O'Neill, 1975). Mechanical disadvantages in grip force occur if the fingers are excessively flexed around a small diameter handle or minimally flexed around a large diameter handle. These mechanical disadvantages lead to excessive grip force requirements which in turn lead to fatigue, tendonitis and the hazard of accidentally dropping the tool (Cacha, 1999). The diameter of the hand tool was initially determined from the anthropometric dimension of the user. It was made on the basis of 5th percentile value of the handgrip diameter of the subjects and it was finalized from the results of the paired comparison test. The 5^{th} percentile value of handgrip diameter (Table 5.5) of the users had more or less the same value in both the hands (right hand: 4.22 cm and left hand: 4.2 cm) when both male and female workers considered together. A negative clearance value of 1 cm may added to the percentile value to ensure better grip in the handle. A useful rule of thumb for evaluating handle diameters is that the handle should be of such a size that it permits slight overlap of the thumb and fingers of a worker with small hands (Bridger, 1995). According to Dewangan et al. (2008), the ideal diameter of the handle for a hand tool is 3.32 cm for the general population. Meena and Dangayach, (2015) also recommended 3.0 cm for the diameter of the handle. Thus by adding a negative clearance value (-1 cm) the diameter would be 3.2 cm approximately. Now to judge subjective preference of the users towards the size of the handle paired comparison test was performed and the results were compared with the anthropometrically computed value.

The four models of nut plucking tool (NP1, NP2, NP3 and NP4) having the handle diameters of 3.3 cm, 2.4 cm, 2.7 and 3.0 cm were selected for the paired comparison test. The computed resultant scores of the test for different prototypes were plotted in Fig 5.16 and from the results it was noted that the prototype model (NP4) having a handle diameter of 3.0 cm showed the best score among four models.

The diameter (3.0 cm) of the handle of the nut plucking tool obtained from the paired comparison test was more or less same with of the results came from anthropometric study (5^{th} percentile of the hand grip diameter of the user population minus clearance value). So, the diameter obtained from the test was selected in this case to ensure better grip of the handle during repeated work.

NP1 = 3.3 cm NP2 = 2.4 cm NP3 = 2.7 cm NP4 = 3.0 cm

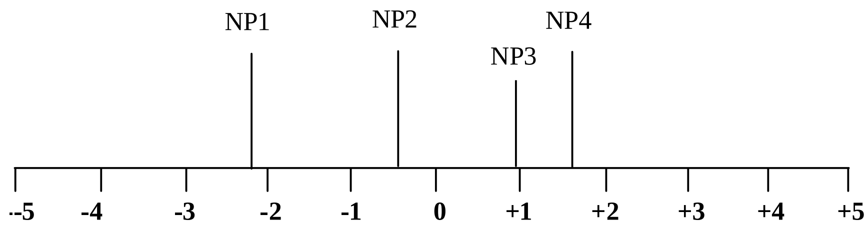


Fig 5.16: Stimuli space for diameter of handle of nut plucking tool

5.9.2.3.3 Grip on the Handles

To ensure a good grip a rubber pad was wrapped on the handle. The suitability of adding rubber grip was tested by paired comparison test by using the tool with and without rubber grip. For this purpose two prototypes were prepared - with rubber grip (NG) and without rubber grip (NOG) and the test was performed. The computed preference scores for two prototypes have been presented in Fig. 5.17. The result was in favour of rubber grip. However, the diameter of the handle was kept at 3.0 cm including the rubber grip.

NG = Nut plucking tool with rubber grip NOG= Nut plucking tool without rubber grip

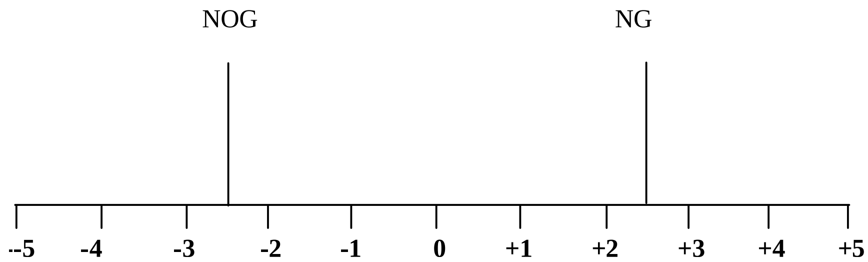


Fig 5.17: Stimuli space for grip of the nut plucking tool

5.9.2.3.4 Length of the Blade

Length of blade is an important criterion as it is concerned with the productivity. Long length blade may be more productive than short blade. However, there should be an optimum size because too long blade may be difficult for handling and too short blade may restrict the productivity. For the selection of appropriate length of the blade of the nut plucking tool, four prototype models (NP1, NP2, NP3 and NP4) having the blade length of 16 cm, 18 cm, 20 and 22 cm were taken for this test. The paired comparison test was performed and the final results have been presented in Fig 5.18. It was noted that that the model NP3 (20 cm) obtained highest preference scores on the positive side of the scale. Therefore, the value of 20 cm was finally selected as the length of the blade of the nut plucking tool.

NP1 = 16 cm NP2 = 18 cm NP3 = 20 cm NP4 = 22 cm

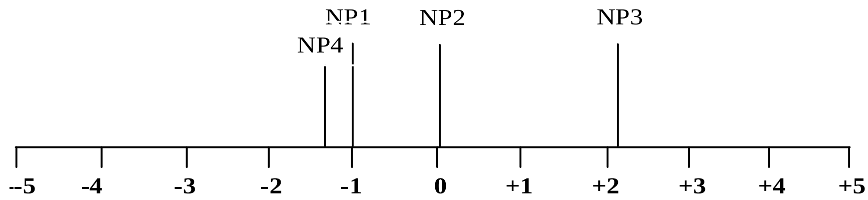


Fig 5.18: Stimuli space for length of handle of nut plucking tool

5.9.2.3.5 Breadth of the Blade

The breadth of the blade of the nut plucking tool is also an important criterion as it is concerned with the productivity. For the selection of appropriate breadth of blade, four different prototype models of nut plucking tool with varying breadth of blade were made and judged by paired comparison test.

NP1 = 10 cm NP2 = 12 cm NP3 = 14 cm NP4 = 16 cm

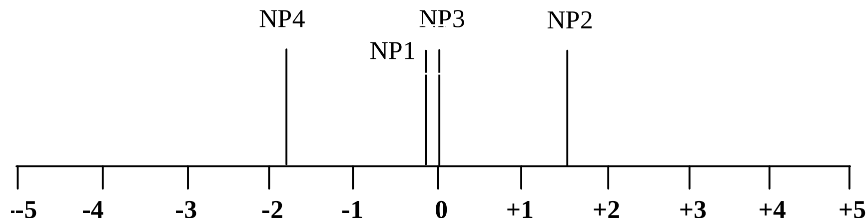


Fig 5.19: Stimuli space for diameter of handle of nut plucking tool

The results showed that the prototype model NP2 represented the highest positive preference scores of the subjects. The breadth of the prototype NP2 was 12 cm. Therefore, the value of 12 cm was finally selected as the breadth of the blade of the nut plucking tool.

5.9.2.3.6 Depth of the container

The rear part of the blade, where the handle was attached, had a box like structure, which might function as a temporary container of the nuts. The depth of this part was an important criterion as it was related to the size of the container for holding separated ground nut temporarily. The paired comparison test was performed with different prototypes with varying depth of the container. The subjects were asked to judge the relative advantage and disadvantage of different sizes of the containers and to put the preference scores for each pair of prototypes. The results (Fig. 5.20) showed that the prototype model NP3 represented the highest preference scores of the subjects. The depth of the prototype NP3 was 10 cm. Therefore, the value of 10 cm was finally selected as the depth of the container of the nut plucking tool.

NP1 = 6 cm NP2 = 8 cm NP3 = 10 cm NP4 = 12 cm

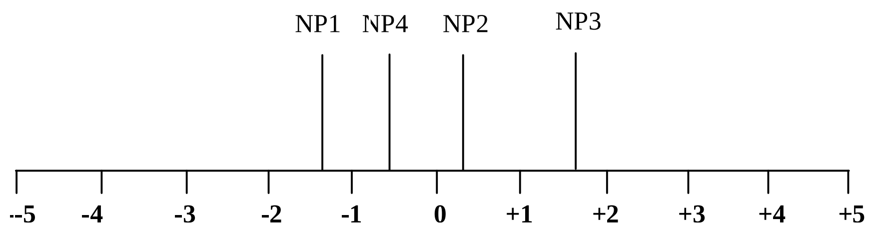


Fig 5.20: Stimuli space for depth of container of the nut plucking tool

5.9.2.3.7 Front Edge of the Blade

Front edge of the blade of the nut plucking tool is very important because it is related to the productivity. The ground nut pods are attached to the roots of the plant. For separating the ground nut pods from the root of the plant, triangular sharp projection at front edge was made by the trial of the subjects. In order to design of the front edge of the blade, a survey was done among the workers. The prototypes with varying shape of the projections and varying gaps between the projected parts were given to the workers and asked to perform the tasks and to express their opinion about the front edge of the blade. All the participants expressed their opinion to triangular sharp projection at the front edge of blade.

5.9.2.3.8 Material

The body of the nut plucking tool including handle was made with iron sheet. The rubber sheet was used for covering the handle for better grip.

5.9.2.4 Final Design and Fabrication

From the results of the paired comparison test and anthropometric dimensions of the users different design characteristics of the nut plucking tool were selected. Table 5.70 summarizes the criteria for selecting different characteristics of the nut plucking tool.

The handle length of the nut plucking tool was selected as 12.0 cm. This value was selected on the basis of the 95th percentile value of hand breadth of the users along with the required clearance value. The dimension was also confirmed by the results of paired comparison test.

The diameter of the handle of the nut plucking tool was selected on the basis of 5th percentile value of the hand grip diameter of the users and a negative clearance value of 1 cm approximately. The dimension was also confirmed by the results of paired comparison test. The diameter of the handle was selected as 3.0 cm. To avoid the slippage of hand, while operating the nut plucking tool, a rubber pad was suggested. The rubber pad was wrapped over the handle of the nut plucking tool.

The length of the blade of the nut plucking tool was selected from the results of paired comparison test. The length of the blade was settled as 20.0 cm.

The breadth of the blade of the nut plucking tool was selected from the results of paired comparison test. The breadth of the blade of the nut plucking tool was selected as 12.0 cm. The breadth of the blade of the nut plucking tool was preferred by users.

The depth of the container of nut plucking tool was settled as 12.0 cm. The dimension was also confirmed by the results of paired comparison test.

The front edge of the blade was cut in such way that some triangular projections were created. The projected part was sharpened to facilitate cutting of the ground nuts from the plant roots.

Table 5.70: Design criteria and dimensions for the nut plucking tool

Dimensions/ criteria	Required percentile/ Dimension	Value in cm.	Clearance value (cm)	Subjective preference score/ Anthropometric dimension	Final dimension
Length of handle	95^{th}/ hand breadth	8.6	+3.5	Best value of subjective preference score: model no. NP3	12.0 cm
Diameter of handle	5^{th}/ hand grip diameter	4.2	-1.0	Best value of subjective preference score: model no. NP4	3.0 cm
Grip of the handle				Best value of subjective preference score: model no. NG	Inclusion of rubber grip
Length of blade				Best value of subjective preference score: model no. NP3	20.0 cm
Breadth of blade				Best value of subjective preference score: model no. NP2	12.0 cm
Depth of the container				Best value of subjective preference score: model no. NP3	10.0 cm
Front edge of the blade				By trial	Triangular sharp projection at front edge

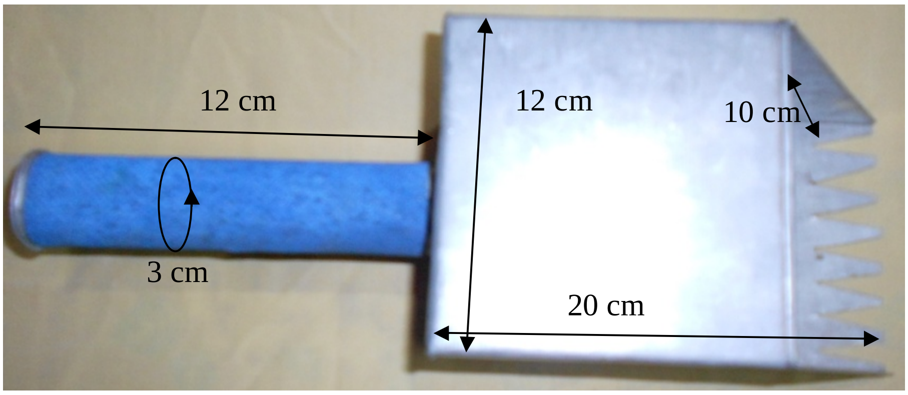


Plate 5.12: The recommended nut plucking tool with dimension of different parts

Plate 5.13: The workers separate the ground nut by newly designed nut plucking tool

So the final design was recommended by combining different design criteria from different models of nut plucking tool. It may be pointed out that the recommended design had resemblance with the model NP3 because most of the criteria were selected from this prototype model.

5.9.2.5 Evaluation of the Recommended Nut Plucking Tool

The effectiveness and acceptability of the recommended design of the ground nut plucking tool were evaluated. The following studies were employed.

5.9.2.5.1 Subjective Study

The cultivators were given the recommended groundnut plucking tool for performing their work and to express views regarding the comfort, easiness of work and suitability of the tool. A survey was made for this purpose. The subjects were asked to grade it as “bad”, “fair”, “good” and “very good”. The results of this study (Table 5.71) showed that most of the users expressed as “good” (75%). Appreciable numbers of them categorized as “fair” (18%). About 7% of the workers graded as “bad”. Therefore, the result of the subjective assessment was in favour of the recommended nut plucking tool.

Table 5.71: Subjective assessment of recommended groundnut plucking tool

Grade	Bad	Fair	Good	Very Good
Male (n=35)	4 (11.43%)	7 (20.0%)	24 (68.57%)	-
Female (n=38)	1 (2.63%)	6 (15.79%)	31 (81.58%)	-
All (n=73)	5 (6.85%)	13 (17.81%)	55 (75.34%)	-

5.9.2.5.2 Study of MSD

The prevalence of MSD was studied while using groundnut plucking tool and the results have been presented in Table 5.72. From the results it was observed that the occurrence of pain / discomfort in different segments of the body was lower during separating groundnut pods from the root by the nut plucking tool compared to that of the manually plucking method by the fingers. χ^2 –test was performed to find out the level of significant difference in subjective response between manually plucking nut by the fingers and separating nut by the newly designed nut plucking tool. It was noted that the occurrence of pain in wrist, palm and fingers was significantly lower ($p<0.01$ or less) during separating groundnut pods from the root by the nut plucking tool than that of existing method. From the results it has been revealed that discomfort or pain in other body segments like neck, shoulder, elbow, back etc. were also lower, although non-significantly, during separating groundnut from the root by nut plucking tool than that of an existing method. Thus the results indicated that the workers would be able to use the groundnut plucking tool with ease and lower degree of discomfort, especially in the hand arm system.

Table 5.72: Percentage of workers reported musculoskeletal disorders (MSDs) in different segments of the body during plucking of nut manually and using nut plucking tool

Body segments	Existing method (manually separating the nut from root by finger)		Modified method (separating the nut from root by nut plucking tool)	
	Male (n=35)	Female (n=38)	Male (n=35)	Female (n=38)
Neck	12 (34.29%)	16 (42.11%)	10 (28.57%)	15 (39.47%)
Shoulder	22 (62.86%)	26 (68.42%)	17 (48.57%)	20 (52.63%)
Elbow	23 (65.71%)	27 (71.05%)	16 (45.71%)	20 (52.63%)
Wrist	27 (77.14%)	32 (84.21%)	13 (37.14%)*	16 (42.11%)**
Palm	28 (80.00%)	33 (86.84%)	14 (40.00%)*	14 (36.84%)**
Finger	31 (88.57%)	35 (92.11%)	12 (34.29%)**	15 (39.47%)**
Upper back	22 (62.86%)	27 (71.05%)	20 (57.14%)	24 (63.16%)
Lower back	27 (77.14%)	31 (81.58%)	24 (68.57%)	26 (68.42%)
Hip	19 (54.29%)	25 (65.79%)	15 (42.86%)	20 (52.63%)
Knee	8 (22.86%)	12 (31.58%)	8 (22.86%)	11 (28.95%)

w.r.t. existing method * $p<0.01$, ** $p<0.001$

5.9.2.5.3 Joint Angle Study

Different body joint angles were measured during performing nut plucking task in existing method (manually separating the nut from root by finger) and modified method (separating the nut from root by the nut plucking tool) in view to observe the biomechanical changes in different parts of the body due to using the nut plucking tool. The joint angles measured in normal erect posture were taken as reference.

Table 5.73: Mean ± SD of different joint angles (degrees) of the workers during performing nut plucking job in existing and modified method

			Male		Female	
			Right	Left	Right	Left
Shoulder	Normal joint angle		29.10±3.28	29.25±3.49	27.55±2.31	27.45±3.75
	EM	Avg. Working angle	76.45±11.18	75.70±11.89	71.25±9.87	70.55±9.41
		Deviation of angle	47.35±12.29	46.45±12.60	43.70±10.38	43.10±9.57
	MM	Avg. Working angle	72.80±8.28	70.45±11.09	69.25±9.15	65.30±7.44*
		Deviation of angle	43.70±8.49	41.20±10.52	41.70±9.45	37.85±7.54
Elbow	Normal joint angle		168.00±5.32	167.40±6.49	166.00±8.84	165.55±9.86
	EM	Avg. Working angle	143.60±8.30	142.85±9.36	140.75±8.45	139.45±9.41
		Deviation of angle	24.40±7.21	24.55±7.76	25.25±8.83	26.10±14.53
	MM	Avg. Working angle	151.6±13.53*	148.35±11.13	148.1±11.34*	153.3±8.84***
		Deviation of angle	16.40±12.39	19.05±10.92	17.95±14.90	12.25±15.45
Wrist	Normal joint angle		174.50±3.12	173.80±3.46	174.15±2.68	174.30±2.32
	EM	Avg. Working angle	160.25±8.04	162.10±7.16	160.90±7.67	166.20±6.28
		Deviation of angle	14.25±8.18	11.70±8.12	13.25±6.80	8.10±6.25
	MM	Avg. Working angle	166.75±8.26*	165.60±6.79	169.75±9.1**	171.1±5.61**
		Deviation of angle	7.75±9.07	8.20±6.92	4.40±9.03	3.20±6.04
Hip	Normal joint angle		174.30±4.85	174.00±4.36	174.65±5.14	174.60±6.07
	EM	Avg. Working angle	70.85±11.42	71.80±12.96	69.25±10.22	69.75±10.18
		Deviation of angle	103.45±11.41	102.20±13.40	105.40±12.45	104.85±12.05
	MM	Avg. Working angle	72.35±10.57	72.30±11.12	69.55±8.72	70.20±8.55
		Deviation of angle	101.95±10.98	101.70±10.69	105.10±9.73	104.40±9.73
Knee	Normal joint angle		172.30±5.12	170.90±5.75	170.05±6.36	171.25±6.20
	EM	Avg. Working angle	60.80±9.43	61.35±10.66	61.15±7.28	57.15±6.75
		Deviation of angle	111.50±11.50	109.55±12.33	108.90±8.74	114.10±7.68
	MM	Avg. Working angle	66.05±8.13	64.35±9.78	63.95±8.80	59.65±10.23
		Deviation of angle	106.25±10.34	106.55±11.19	106.10±12.36	111.60±11.92

w.r.t. Existing method * $p<0.05$, ** $p<0.01$, *** $p<0.001$

The difference of the angles between the reference position and during using hand tool was taken as deviation of joint angles. The shoulder, elbow, wrist, hip and knee angles were studied for the said purpose and it was noted that there were significant differences in joint angles, viz., shoulder, elbow and wrist between manual operation and using nut plucking tool (Table 5.73). The deviation of joint angles were also lower during using hand tool, in most of the cases, compare to manual plucking of nuts. The minimum deviation of wrist angle indicated that there was lowest degree of wrist flexion during working with nut plucking tool. From the joint angle study it appeared that the user got some biomechanical advantage when they used the nut plucking tool and they might have lesser musculoskeletal problems.

5.9.2.5.4 Study of Heart Rate

The heart rate of the workers was measured during performing nut plucking task in existing method and modified method. The results (Table 5.74) of heart rate showed that there were significant differences of mean working heart rate, and CSI during using nut plucking tool compared to the existing method. Therefore, it may be stated that the physiological cost and cardiovascular stress of the workers was decreased while working with the nut plucking tool from that of using manual method.

Table 5.74: Resting and working heart rates of the workers during performing nut plucking task in existing (manual plucking of nuts) and modified method (using nut plucking tool) (Male: 20; Female: 21)

	Resting HR (beats/min)		Working HR (beats/min)		CSI	
	Male	Female	Male	Female	Male	Female
Existing method	72.35 ±6.40	75.55 ±4.38	94.75 ±4.63	96.50 ±5.38	19.34 ±5.43	17.82 ±5.06
Modified method	72.35 ±6.40	75.55 ±4.38	89.50** ±6.21	92.10** ±4.80	14.82** ±4.57	14.08* ±4.01

*p<0.05, **p<0.01

5.9.2.5.5 Productivity Study

The productivity study was performed when the workers performing nut plucking task in conventional method (manually separating the nut from the plant root by finger) as well as using newly designed hand tool. The productivity was assessed by measuring the amount (kg) of nut separated by the workers in a unit time (hour). From the results of the productivity study (Fig 18), it was observed that there was a significant increase (p<0.001) in productivity during using the hand tools from that of manual method. When both male and female workers considered together the increase was about 19% while using the nut plucking tool. The results also indicated that there was an increase in productivity by about 18% in male and by about 21% in female workers respectively.

Thus, it can be concluded that newly designed nut plucking tool was better than that of conventional system (manual) from the view point of productivity.

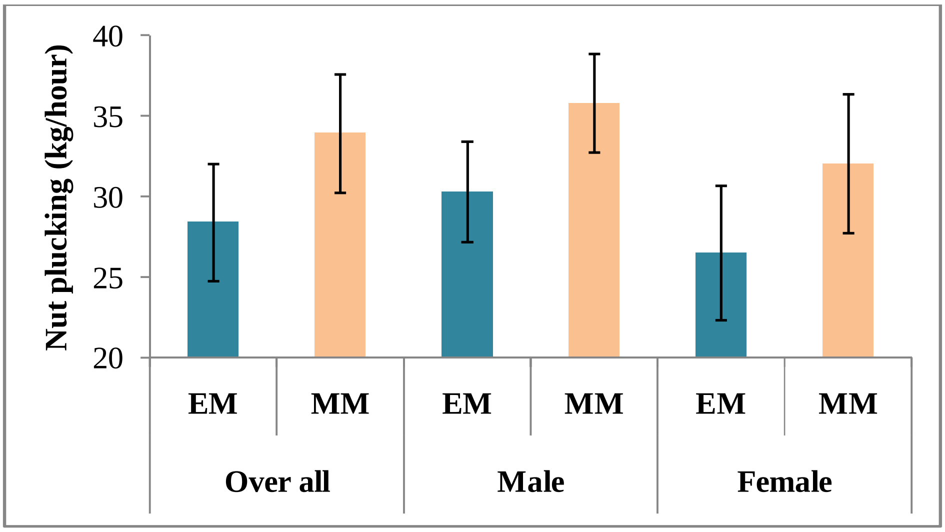


Fig 5.21: Mean productivity (kg/hour) with existing and modified method

5.9.2.5.6 Cost Analysis

The cost analysis of newly designed nut plucking tool was done (Table-5.75). It appears from the results that the tool would of low cost. The cost will be cheaper than this, when it is manufactured in larger quantities.

Table 5.75: Cost analysis of newly designed nut plucking tool

Items	Cost (Rs)
Iron Materials and Making charge	110.00
Rubber Grip	30.00
Total	140.00

From the above discussion, it may be summarized that newly designed nut plucking tool was suitable for the users and it was also comfortable for the workers. The results of the productivity study, joint angle study and heart rate study were also in favour of the newly designed nut plucking tool. The newly designed nut plucking tool lowered the prevalence of musculoskeletal problems of the workers especially in the hand arm system and it provided better work comfort. Decrease in MSDs would obviously reduce the expenses on medical treatment and increase the safety of the workers. Thus in a long term, newly designed nut plucking tool would be cost effective and best value model.

Conclusions & Recommendations

Chapter VI

Conclusions and Recommendations

Apart from cereal production (rice, wheat, etc.) agricultural labourers are engaged in different vegetable cultivations in West Bengal, India, of which potato cultivation is one of the important vegetable cultivations. Both male and female workers are involved in this job and expend a great extent of their physiological cost. There are different tasks in potato cultivation, viz., planting of seeds, tunneling in the land, and potato harvesting which are performed in different phases. The potato cultivation tasks are repetitive in nature and are carried out mainly by manual efforts. Most of the tasks performed by the cultivators are monotonous, strenuous, physiologically demanding as well as time-consuming.

The educational status of the potato cultivators was very poor. About 44% male and 50% female were illiterate. According to the modified Kuppuswami's scale the majority of the cultivators were belonging to upper lower socioeconomic category. The low socioeconomic status of the potato cultivators might be related to their health and nutrition. This might be one of the reasons for the occurrence of occupational hazards. The socio-economic status of the workers may be improved by increasing their wage, by controlling their family size and by increasing the educational level of the family members.

Their nutritional status of the workers was also poor. Both male and female workers were deficient of nutrients. The body mass index (BMI) showed that both male and female participants were in 'low weight' category. From the foregoing analysis, it was evident that undernutrition among the potato cultivators showed a gloomy picture. About 43% of the male and 52% of the female workers were undernourished. In the study population, the workers had low hemoglobin concentration and the prevalence of anemia was 46.62% in males and 66.87% in females, which was more than the global prevalence. The higher prevalence of undernutrition and anemia among the workers may be due to lower socioeconomic status, dietary deficiency and poor dietary patterns in the families. Improving overall nutrition status and their access to resources will have the greatest impact on reducing undernutrition and anemia among the workers. Iron supplementation programs, may be effective in reducing the prevalence of anemia. Intake of iron rich food items may reduce the problem. Awareness program about low cost iron rich and other nutrient-dense foods among the workers may be another solution of the problem.

The potato cultivators had a number of musculoskeletal disorders. The lower back problem was highly prevalent among the workers and it was followed by upper back, waist, shoulder, hip and elbow. The prevalence of MSDs was comparatively higher in tunneling job compared to potato harvesting and seed planting operations. However, lower back problem was extremely prevalent in all types of tasks of potato cultivation. The higher prevalence of work related MSDs at different body segments of the agricultural workers might be related to their postural pattern, repetitive movements as well as longer duration of exposure in awkward posture. The predominant posture of different potato cultivation tasks were forward bending and squat sitting posture. Adopting these two awkward postures during performing the tasks might be one of the possible causes of back pain among the workers. The female workers were more prone to have MSDs than that of male workers. The female cultivators had to perform household chores including cooking in addition to the occupational work (agricultural activities), the cumulative effects of which might result a higher degree of musculoskeletal problems in comparison to male workers.

The following suggestions would be helpful for reducing some of the MSDs:

(i) The WRMSD can be reduced if the workers adopt appropriate posture, as far as practicable, during performing their jobs and follow the rules of manual material handling. For example, during handling the load the load should be taken as close to the body as possible and grasping the load between the knees, whenever possible. Load should be lifted with back straight and with bent knees.

(ii) Avoiding handling of loads during acute pain.

(iii) Bed-rest in case of acute-severe low back pain problems.

(iv) Relief from low back pain can be obtained by lying in the supine position, grasping the knees and then squeezing the thighs against the chest for about 5 seconds and obtained other types of exercise.

(v) Practice of “yogic” exercise regularly.

(vi) The conservative treatment of low back pain and other pain ultimately rests and education.

From the work-rest pattern of different tasks of potato cultivation it was observed that the total working hours was approximately 9 hours including rest pauses. The work-rest pattern showed that the duration prescribed rest was much greater than that of the work related rest. The total amount of rest required for a given period of work is important; however, the actual duration of the work before a rest period may be of even greater importance for adequate recovery. Few short breaks are better than one long break in a day’s work. This is because short and frequent breaks were much more effective in preventing excessive fatigue and possible injury than longer, less frequent breaks. This is probably a good general principle to keep in mind when scheduling work and rest to maximize recovery and to minimize strains. In the present study it was observed that the workers took a long duration rest (food break) for about 2½ hours. It may be more helpful if the longer continuous rest period is reduced and more number of short breaks is provided within work-time. According to their work load and energy requirement the 30-minute work and 5 minutes rest will be preferable for long durational potato cultivation jobs.

The forward bending and squatting postures were the dominating postures in potato cultivation jobs. The workers were found to twist and bend their body frequently during planting of seeds and potato harvesting tasks. The prolonged tasks performed in awkward postures (forward bend and squatting postures) might be the possible causes of pain at different segments of the body of the cultivators. According to the different posture analysis methods, the postures adopted by the workers have been categorized as having 'medium' to 'very high' risk levels in different tasks of potato cultivation. The workers suffered account of health problems, perhaps because of prolonged working hours, awkward posture and used less safety measures while working.

The following recommendations may be helpful for the workers to reduce some of the postural problems:

(i) The forward bend posture is a very strenuous posture. In case of tunneling task, the workers were spending more than 80% of total work time in forward bending posture. The problems will be reduced if the forward bend posture can be avoided. This may be achieved by using redesigned hand tool (small speed). The workers are required to use a small spade for tunneling operation. The length of the handle of the spade and the angle between the blade and handle were suggested to increase from the existing length. Such change may improve the postures of the workers when performing the spade operation.

(ii) They may lean backward for a few times during the short rest. This may be helpful for avoiding harmful effects of bend posture for a long time.

(iii) They may walk for a few steps within the working area during taking brief rest. Thus they may be relieved from the continuous static load imposing on the legs in case of working under squatting posture.

(iv) The workers should have to avoid twisting their body as far as practicable. Instate of twisting under squat posture they can move their whole body to the lateral side whenever required.

(v) Training and awareness programme are required for educating the workers about the appropriate posture for different tasks and about bad effects of inappropriate posture.

According to the work category classification on the basis of mean working heart rate, the potato cultivation tasks ware categorized as moderate work category. According to the classification of physical work in terms of working heart rate, the planting of potato seeds and potato harvesting operation were considered as the moderate work. But tunneling operations were belonged to the heavy work category. According to CSI classification, all the task of potato cultivation has been classified as stressful category except planting of potato seeds (male). The working blood lactate level of the workers was also high. A significant physiological stain was exerted on the potato cultivators, as shown by increased heart rates, cardiovascular stress index and blood lactate accumulation. Variation of cardiovascular strain in different phases of potato cultivation tasks might be due to the difference in the amount of work load imposed on the workers. Proper designing of work-rest schedule, as mentioned earlier, may help to reduce the problem.

In the present study ergonomic intervention was made by redesigning a small spade and making a new design for ground nut plucking tool. Such intervention became useful for solving some of the work related health problems.

A small spade is very much useful for different tasks of potato cultivation. In case of designing of small spade, modifications of handle dimensions (length and diameter) and of the angle between handle and blade were incorporated. Such change caused betterment of postures of the workers when performing the spade operation. Length and width of the blade of the spade is an important criterion as it is concerned with the productivity. Long length blade may be more productive than short blade as experienced by the workers who were engaged in potato cultivation task. The length of the blade was increased from that of existing one. The width of the blade was also increased for improving the surface area of the blade. Such modification in the tool caused an improvement in the productivity. The weight of the spade was decreased from the existing spade. The lighter tool enables the workers to work with ease, as evident from the results of the subjective study. To ensure a good grip a rubber pad was wrapped on the handle. The final design was settled after a lot of trials and consultations with workers. The redesigned small spade became more comfortable in handling than the existing spade. The prevalence of pain / discomfort in different segments of the body became lowered during using the redesigned small spade than that of existing spade. The physiological strain of workers was decreased while working with the redesigned spade. There was an increase in productivity by about 11% in male and by about 9% in male workers respectively. However, it may be expected that after regular use of the redesigned small spade, the productivity would significantly be increased. Thus, it can be concluded that redesigned small spade was better than that of existing spade from the view point of productivity. The cost of the redesigned spade was a little higher than existing spade. On the other hand, redesigned small spade lowered the risk of injury among workers and provides better workers comfort.

A nut plucking hand tool was proposed instead of manual plucking. The tool was designed by considering the human factors. The final design was settled after a lot of trials and consultations with workers. In case of designing of nut plucking tool, main emphasis was given on hand –handle interface and plucking interface. A handle was attached to the main body of the tool and to ensure a good grip a rubber pad was wrapped on the handle. For separating the nuts from the plant, sharp finger like projections was made in front of the tool. The newly designed nut plucking tool was better than that of conventional system (manual) from the view point of productivity and safety. The prevalence of pain / discomfort in different segments of the body was lower during use of the nut plucking tool than the conventional system. The physiological strain of workers was decreased while working with newly designed nut plucking tool and there was a significant increase in productivity.

The potato cultivators should be aware about the advantages of using ergonomically designed hand tools and encouraged to use the tools on regular basis. The use of those tools would be better from the economic point of view because there are ample chances of increasing productivity. The occurrence of work related health problems would be reduced and thereby the medical cost.

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Appendix

APPENDIX – I

WORKSHEET FOR DETERMINE SOCIO-ECONOMIC STATUS (Modified Kuppuswami's Scale)

Name: Age: Sex: M / F

A	**Education**	**Score**
1	Profession or Honours	7
2	Graduate or post graduate	6
3	Intermediate or post high school diploma	5
4	High school certificate	4
5	Middle school certificate	3
6	Primary school certificate	2
7	Illiterate	1

B	**Occupation**	**Score**
1	Profession	10
2	Semi-Profession	6
3	Clerical, Shop-owner, Farmer	5
4	Skilled worker	4
5	Semi-skilled worker	3
6	Unskilled worker	2
7	Unemployed	1

C	**Monthly family income in Rs**	**Score**	**Modified for 1998 in Rs**	**Modified for 2012 in Rs**
1	≥ 2000	12	≥ 13500	≥32050
2	1000-1999	10	6750 - 13499	16020 – 32049
3	750-999	6	5050 - 6749	12020 – 16019
4	500-749	4	3375 - 5049	8010 – 12019
5	300-499	3	2025 - 3374	4810 – 8009
6	101-299	2	676 - 2024	1601 – 4809
7	≤ 100	1	≤ 675	≤ 1600

Total Score	**Socioeconomic class**
26-29	Upper (I)
16-25	Upper Middle (II)
11-15	Lower middle (III)
5-10	Upper lower (IV)
<5	Lower (V)

APPENDIX – II

OWAS: Posture analysis work sheet

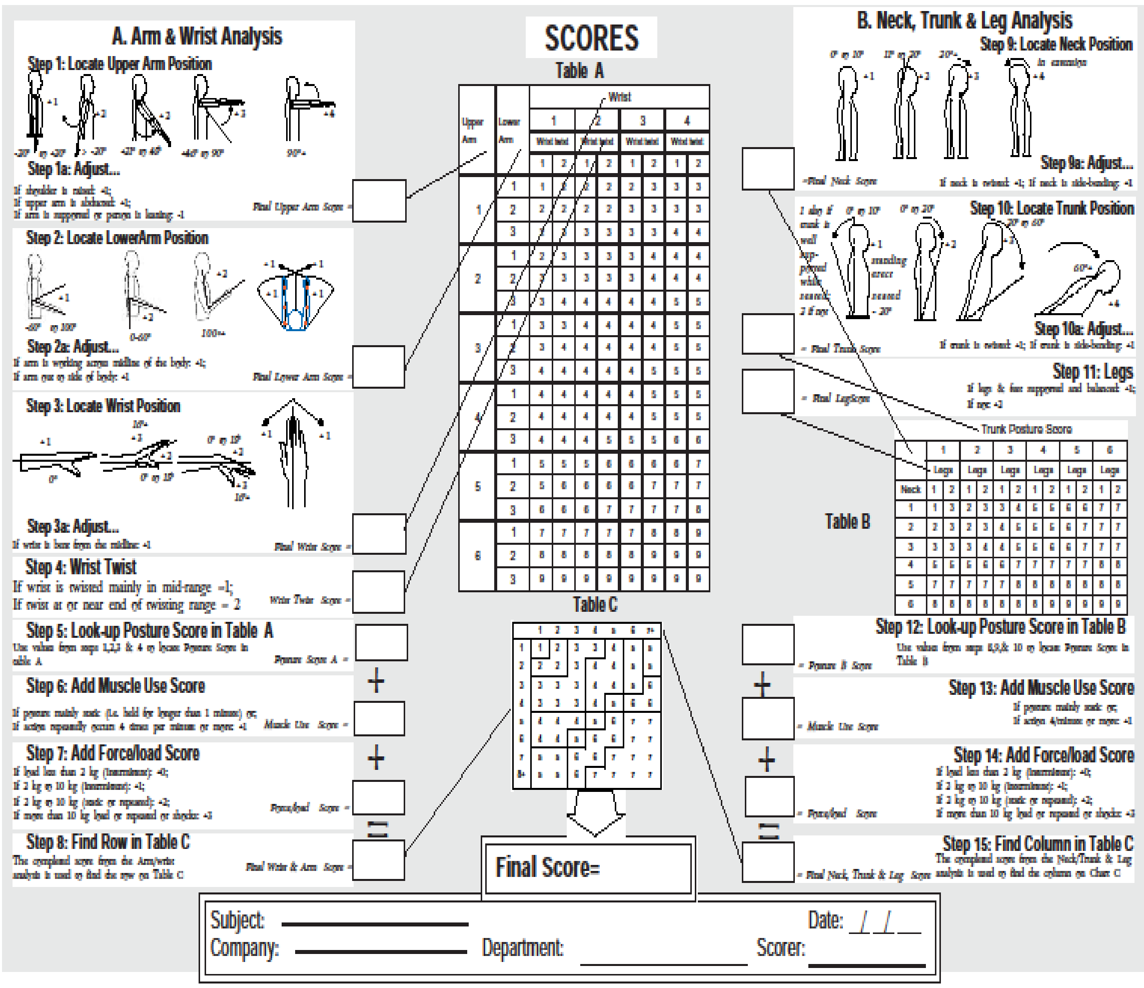
Cod	Body part and load used			
	Back	**Arms**	**Leg**	**Load or use of force**
1	Straight	Both arms are below shoulder level	Sitting	Weight or force needed is 10 kg or less
2	Bent forward, back forward.	One arm is at or above the shoulder level.	Standing with both legs straight.	Weight or force needed exceeds 10 kg but is less than 20 kg.
3	Twisted or bend sideway.	Both arms are at or above the shoulder level.	Standing with the weight on one straight leg.	Weight or force needed exceeds 20 kg.
4	Bent or twisted or bend forward and sideway.	-	Standing or squatting with both knees bend.	-
5	-	-	Standing or squatting with one knee bend.	-
6	-	-	Kneeing on one or both knees.	-
7	-	-	Walking or moving.	-

BACK	ARMS	1			2			3			4			5			6			7			LEGS
		1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**USE OF FORCE**
1	**1**	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2	
2	**1**	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3	
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4	
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4	
3	**1**	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1	
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1	
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1	
4	**1**	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4	
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	

ACTION CATEGORIES

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

APPENDIX – III



RULA Employee Assessment Worksheet

Complete this worksheet following the step-by-step procedure below. Keep a copy in the employee's personnel folder for future reference.

A. Arm & Wrist Analysis

Step 1: Locate Upper Arm Position

-20° to +20° (+1); > -20° (+2); +20° to 45° (+2); +45° to 90° (+3); 90°+ (+4)

Step 1a: Adjust…

If shoulder is raised: +1;
If upper arm is abducted: +1;
If arm is supported or person is leaning: -1

Final Upper Arm Score =

Step 2: Locate Lower Arm Position

+60° to 100° (+1); 0-60° (+2); 100°+ (+2)

Step 2a: Adjust…

If arm is working across midline of the body: +1;
If arm out to side of body: +1

Final Lower Arm Score =

Step 3: Locate Wrist Position

0° (+1); 0° to 15° (+2); 15°+ (+3)

Step 3a: Adjust…

If wrist is bent from the midline: +1

Final Wrist Score =

Step 4: Wrist Twist

If wrist is twisted mainly in mid-range = 1;
If twist at or near end of twisting range = 2

Wrist Twist Score =

Step 5: Look-up Posture Score in Table A

Use values from steps 1,2,3 & 4 to locate Posture Score in table A

Posture Score A =

+

Step 6: Add Muscle Use Score

If posture mainly static (i.e. held for longer than 1 minute) or;
If action repeatedly occurs 4 times per minute or more: +1

Muscle Use Score =

+

Step 7: Add Force/load Score

If load less than 2 kg (intermittent): +0;
If 2 kg to 10 kg (intermittent): +1;
If 2 kg to 10 kg (static or repeated): +2;
If more than 10 kg load or repeated or shocks: +3

Force/load Score =

=

Step 8: Find Row in Table C

The completed score from the Arm/wrist analysis is used to find the row on Table C

Final Wrist & Arm Score =

SCORES

Table A

Upper Arm	Lower Arm	Wrist 1 – Wrist twist 1	Wrist 1 – Wrist twist 2	Wrist 2 – Wrist twist 1	Wrist 2 – Wrist twist 2	Wrist 3 – Wrist twist 1	Wrist 3 – Wrist twist 2	Wrist 4 – Wrist twist 1	Wrist 4 – Wrist twist 2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	6	6	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C

	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Final Score=

B. Neck, Trunk & Leg Analysis

Step 9: Locate Neck Position

0° to 10° (+1); 10° to 20° (+2); 20°+ (+3); in extension (+4)

Step 9a: Adjust…

If neck is twisted: +1; If neck is side-bending: +1

Final Neck Score

Step 10: Locate Trunk Position

1 also if trunk is well supported while seated; 2 if not; 0° to 10° (+1); 0° to 20° (+2); 20° to 60° (+3); 60°+ (+4)

Step 10a: Adjust…

If trunk is twisted: +1; If trunk is side-bending: +1

Final Trunk Score

Step 11: Legs

If legs & feet supported and balanced: +1;
If not: +2

Final Leg Score

Table B

Trunk Posture Score

Neck	1 – Legs 1	1 – Legs 2	2 – Legs 1	2 – Legs 2	3 – Legs 1	3 – Legs 2	4 – Legs 1	4 – Legs 2	5 – Legs 1	5 – Legs 2	6 – Legs 1	6 – Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B

Use values from steps 9,10,& 11 to locate Posture Score in Table B

Posture B Score

+

Step 13: Add Muscle Use Score

If posture mainly static or;
If action 4/minute or more: +1

Muscle Use Score

+

Step 14: Add Force/load Score

If load less than 2 kg (intermittent): +0;
If 2 kg to 10 kg (intermittent): +1;
If 2 kg to 10 kg (static or repeated): +2;
If more than 10 kg load or repeated or shocks: +3

Force/load Score

=

Step 15: Find Column in Table C

The completed score from the Neck/Trunk & Leg analysis is used to find the column on Chart C

Final Neck, Trunk & Leg Score

Subject: ______ Date: / /
Company: ______ Department: ______ Scorer: ______

FINAL SCORE: 1 or 2 = Acceptable; 3 or 4 investigate further; 5 or 6 investigate further and change soon; 7 investigate and change immediately

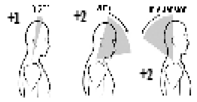
APPENDIX – IV

REBA Employee Assessment Worksheet

based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

A. Neck, Trunk and Leg Analysis

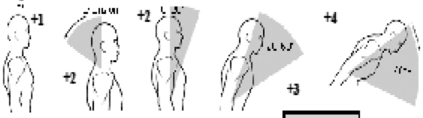
Step 1: Locate Neck Position



Neck Score

Step 1a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

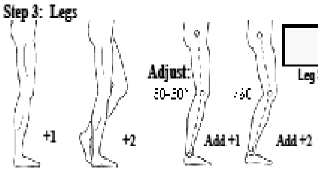
Step 2: Locate Trunk Position



Trunk Score

Step 2a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

Step 3: Legs



Leg Score

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, locate score in Table A

Posture Score A

\+

Step 5: Add Force/Load Score
If load < 11 lbs : +0
If load 11 to 22 lbs : +1
If load > 22 lbs: +2
Adjust: If shock or rapid build up of force: add +1

Force/Load Score

=

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A.
Find Row in Table C.

Score A

Scoring:
1 = negligible risk
2 or 3 = low risk, change may be needed
4 to 7 = medium risk, further investigation, change soon
8 to 10 = high risk, investigate and implement change
11+ = very high risk, implement change

SCORES

Table A

	Neck	1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B

	Lower Arm	1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Table C

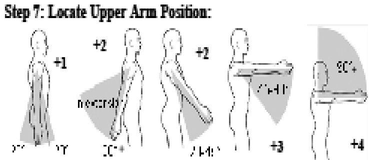
Score A (score from table A +load/force score)	Score B, (table B value +coupling score)											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score + Activity Score

Final REBA Score

B. Arm and Wrist Analysis

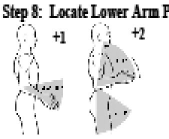
Step 7: Locate Upper Arm Position:



Step 7a: Adjust…
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 8: Locate Lower Arm Position:



Lower Arm Score

Step 9: Locate Wrist Position:

Wrist Score

Step 9a: Adjust…
If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

Posture Score B

\+

Step 11: Add Coupling Score
Well fitting Handle and mid rang power grip, ***good: +0***
Acceptable but not ideal hand hold or coupling acceptable with another body part, ***fair: +1***
Hand hold not acceptable but possible, ***poor: +2***
No handles, awkward, unsafe with any body part, ***Unacceptable: +3***

Coupling Score

=

Step 12: Score B, Find Column in Table C
Add values from steps 10 &11 to obtain Score B. Find column in **Table C** and match with Score A in row from step 6 to obtain Table C Score.

Score B

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Task name: ______________________ Reviewer:______________________ Date: ____/____/____

provided by Practical Ergonomics

This tool is provided without warranty. The author has provided this tool as a simple means for applying the concepts provided in REBA .

rbarker@ergosmart.com (816) 444-1667

APPENDIX – V

Worker's name ______________________ Date ____________

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)

- A1 Almost neutral?
- A2 Moderately flexed or twisted or side bent?
- A3 Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?

- B1 No
- B2 Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back

- B3 Infrequent (around 3 times per minute or less)?
- B4 Frequent (around 8 times per minute)?
- B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)

- C1 At or below waist height?
- C2 At about chest height?
- C3 At or above shoulder height?

D Is the shoulder/arm movement

- D1 Infrequent (some intermittent movement)?
- D2 Frequent (regular movement with some pauses)?
- D3 Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)

- E1 An almost straight wrist?
- E2 A deviated or bent wrist?

F Are similar motion patterns repeated

- F1 10 times per minute or less?
- F2 11 to 20 times per minute?
- F3 More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?

- G1 No
- G2 Yes, occasionally
- G3 Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?

- H1 Light (5 kg or less)
- H2 Moderate (6 to 10 kg)
- H3 Heavy (11 to 20kg)
- H4 Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?

- J1 Less than 2 hours
- J2 2 to 4 hours
- J3 More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?

- K1 Low (e.g. less than 1 kg)
- K2 Medium (e.g. 1 to 4 kg)
- K3 High (e.g. more than 4 kg)

L Is the visual demand of this task

- L1 Low (almost no need to view fine details)?
- *L2 High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for

- M1 Less than one hour per day or Never?
- M2 Between 1 and 4 hours per day?
- M3 More than 4 hours per day?

N At work do you use vibrating tools for

- N1 Less than one hour per day or Never?
- N2 Between 1 and 4 hours per day?
- N3 More than 4 hours per day?

P Do you have difficulty keeping up with this work?

- P1 Never
- P2 Sometimes
- *P3 Often

* *If Often, please give details in the box below*

Q In general, how do you find this job

- Q1 Not at all stressful?
- Q2 Mildly stressful?
- *Q3 Moderately stressful?
- *Q4 Very stressful?

* *If Moderately or Very, please give details in the box below*

* *Additional details for L, P and Q if appropriate*

*** L**

*** P**

*** Q**

Exposure Scores Worker's name ______________________ Date ____________

Back

Back Posture (A) **& Weight** (H)

	A1	A2	A3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1

Back Posture (A) **& Duration** (J)

	A1	A2	A3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2

Duration (J) **& Weight** (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3

Now do **ONLY** 4 if static
OR 5 and 6 if manual handling

Static Posture (B) **& Duration** (J)

	B1	B2
J1	2	4
J2	4	6
J3	6	8

Score 4

Frequency (B) **& Weight** (H)

	B3	B4	B5
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 5

Frequency (B) **& Duration** (J)

	B3	B4	B5
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 6

Total score for Back
Sum of scores 1 to 4 **OR**
Scores 1 to 3 plus 5 and 6 ______

Shoulder/Arm

Height (C) **& Weight** (H)

	C1	C2	C3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 1

Height (C) **& Duration** (J)

	C1	C2	C3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2

Duration (J) **& Weight** (H)

	J1	J2	J3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 3

Frequency (D) **& Weight** (H)

	D1	D2	D3
H1	2	4	6
H2	4	6	8
H3	6	8	10
H4	8	10	12

Score 4

Frequency (D) **& Duration** (J)

	D1	D2	D3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 5

Total score for Shoulder/Arm
Sum of Scores 1 to 5 ______

Wrist/Hand

Repeated Motion (F) **& Force** (K)

	F1	F2	F3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 1

Repeated Motion (F) **& Duration** (J)

	F1	F2	F3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 2

Duration (J) **& Force** (K)

	J1	J2	J3
K1	2	4	6
K2	4	6	8
K3	6	8	10

Score 3

Wrist Posture (E) **& Force** (K)

	E1	E2
K1	2	4
K2	4	6
K3	6	8

Score 4

Wrist Posture (E) **& Duration** (J)

	E1	E2
J1	2	4
J2	4	6
J3	6	8

Score 5

Total score for Wrist/Hand
Sum of Scores 1 to 5 ______

Neck

Neck Posture (G) **& Duration** (J)

	G1	G2	G3
J1	2	4	6
J2	4	6	8
J3	6	8	10

Score 1

Visual Demand (L) **& Duration** (J)

	L1	L2
J1	2	4
J2	4	6
J3	6	8

Score 2

Total score for Neck
Sum of Scores 1 to 2 ______

Driving

M1	M2	M3
1	4	9

Total for Driving ______

Vibration

N1	N2	N3
1	4	9

Total for Vibration ______

Work pace

P1	P2	P3
1	4	9

Total for Work pace ______

Stress

Q1	Q2	Q3	Q4
1	4	9	16

Total for Stress ______

Interpreting the scores

Exposure scores for body areas
The total score for each body area is determined from the interactions between the exposure levels for the relevant risk factors (see table below), and their subsequent addition.

Important risk factors	
Back	Wrist/hand
• load weight • duration • frequency of movement • posture	• force • duration • frequency of movement • posture
Shoulder/arm	Neck
• load weight • duration • task height • frequency of movement	• duration • posture • visual demand

It is important to take note of which interactions contribute most to the overall score for each body area.

The exposure scores for the back, shoulder/arm, wrist/hand and neck have been categorised into 4 exposure categories: Low, Moderate, High or Very High.

	Exposure level			
Score	Low	Moderate	High	Very High
Back (static)	8-15	16-22	23-29	29-40
Back (moving)	10-20	21-30	31-40	41-56
Shoulder/arm	10-20	21-30	31-40	41-56
Wrist/hand	10-20	21-30	31-40	41-46
Neck	4-6	8-10	12-14	16-18

Even if the exposure score is Low, it is important to note that one or two interactions may be contributing disproportionately to the score (i.e. a score of 8 or more).

For Moderate, High and Very High scores, there are likely to be several interactions that should be identified and reduced. It is also possible that one or two interactions are at the highest levels (i.e. 10 or 12) of exposure. These should be addressed urgently to reduce the level of exposure for these factors.

These interactions should be monitored and reviewed as injury to the body could occur if exposure continues.

Exposure scores for other factors
The exposure scores for driving, vibration and work pace have been categorised into three exposure categories: Low, Moderate, High. Stress has a fourth category: Very High. Where scores are Moderate or High, or Very High, the level of exposure should be reduced.

	Exposure level			
Score	Low	Moderate	High	Very High
Driving	1	4	9	-
Vibration	1	4	9	-
Work pace	1	4	9	-
Stress	1	4	9	16

APPENDIX –VI

Work Sheet for Determining the Whole Body CG

Body Segment	Proportion of Body weight	X-ordinate value	Product	Y-ordinate value	Product
1. Head & Neck	0.079				
2. Trunk	0.486				
3. Right thigh	0.097				
4. Right Lower leg	0.045				
5. Right. Foot	0.014				
6. Left Thigh	0.097				
7. Left Lower leg	0.045				
8. Left Foot	0.014				
9. Right Upper Arm	0.027				
10. Right Forearm	0.014				
11. Right Hand	0.006				
12. Left Upper Arm	0.027				
13. Left Forearm	0.014				
14. Left Hand	0.006				
X,Y Resultants for the whole body CG					

APPENDIX –VII

QUESTIONNAIRE: Evaluation of Existing Small Spade

Please put (✓) mark in the appropriate place for your answer:

1. Do you feel any trouble (ache, pain, numbness or discomfort) during use of spade? Yes/ No

2. In which part of your body do you feel discomfort?
   Neck/Shoulder / elbow/ wrist / palm / fingers / upper back/lower back/ Hip / other

3. How bad was the pain/discomfort duding the work episode?
   Mild pain / Severe/ Very Severe

4. Is the discomfort continuous? Yes / No

5. Is the problem persists even after the work? Yes / No

6. Whether the discomfort is due to use of the existing spade? Yes / No

7. Whether any accident occurred due to using existing spade? Yes / No

8. Any problem on existing spade? Yes / No
   Please mention the problem………………………………………………………

9. Do you prefer any change of existing spade? Yes / No

If yes, What change do you suggest? ....

10. Do you prefer the present weight of existing spade? Yes / No
    If no, What change do you suggest?
    Increase / Decrease by _____________ Kg.

11. Do you prefer present length of handle of existing spade? Yes / No
    If no, What change do you suggest?
    Increase / Decrease by _____________ cm.

12. Do you feel any difficulty in gripping of the handle of existing spade? Yes / No
    If yes, i) what problem you face in gripping during work?
    a) Slippery b) Diameter not suitable
    ii) What is your suggestion to prevent slip problem?
    a) Rubber band in grip area

b) Change of diameter of grip area: Increase / Decrease by ________ cm

13. Do you prefer present diameter of handle of existing spade? Yes / No

    If no, What change do you suggest?

    Increase / Decrease by __________ cm.

14. Do you prefer present length of blade of existing spade? Yes / No

    If no, What change do you suggest? Increase / Decrease by __________cm.

15. Do you prefer present breadth of blade of existing spade? Yes / No

    If no, What change do you suggest? Increase / Decrease by __________cm.

16. Do you prefer present angle between handle and blade? Yes / No

    If no, What change you suggest?

    Increase / Decrease by __________(°).

17. Do you prefer present shape of blade of existing spade? Yes / No

    If no, What change do you suggest?

    Flat / Inwards curved / Backwards curved/Any other

18. Do you prefer present shape of blade at the cutting area of existing spade? Yes / No

    If no, What change do you suggest?

    Flat/ Curved/Any other

19. Any other problem on existing spade?

20. Any special suggestion for modification of existing spade?

List of Publications

FULL PAPER Publication:

1. **Pal A.**, De S., Sengupta P., Maity P., Mahata H., Shaikh S., Dhara P.C. (2015): Physiological strain among the women potato cultivators in West Bengal, India. J. Human Ergol.; **44 (2)**. [in press]
2. **Pal A.**, De S., Sengupta P., Maity P., Dhara P.C. (2015): Evaluation of work related musculoskeletal disorder and postural stress among female potato cultivators in West Bengal, India. Ergonomice SA.; **27(1)**: 46-64.
3. **Pal A.**, De S., Sengupta P., Maity P., Dhara P.C. (2014): Ergonomic evaluation of work related musculoskeletal disorders and postural stress among male potato cultivators of West Bengal, India. International Journal of Occupational Safety and Health. [in press]
4. Maity P., **Pal A**.; Dhara P.C. (2015): Evaluation of work related musculoskeletal disorder and postural stress of brick kiln workers during performing brick making tasks. In: Ergonomics for rural development. Dhara P.C. (ed), Vidyasagar University, Midnapore, pp-375-386.
5. Maity P., De S., **Pal A**.; Mahata H., Chatterjee M., Dhara P.C. (2015): Identification of a suitable working posture for female workers engaged in golden thread work. International Journal of Occupational Safety and Health. [Accepted]
6. **Pal A.**, De S., Sengupta P., Maity P., Dhara P.C. (2014): An investigation on prevalence of anemia in relation to BMI and nutrient intake among adult rural population of West Bengal, India. Epidemiology, Biostatistics and Public Health; **11(2)**: E8915- 1-10.
7. **Pal A.**, De S., Sengupta P., Maity P. and Dhara P.C. (2014): Relationship of body compositional and nutritional parameters with blood pressure in adults. J Hum Nutr Diet., **27(5):** 489-500.
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10. Dhara P.C., De S., Sengupta P., Maity P., **Pal A.** (2014): An Ergonomic approach for designing Indian traditional vegetable cutter. Work; **50:** 177- 186.
11. Sengupta P., De S., Maity P., **Pal A**., Banerjee M., Chatterjee M., Dhara P.C. (2014): A comparative study of hand grip strength and body composition among the population of eastern India. In: Humanizing work and work environment- Ergo: Safety for all. Vinay D. (ed), Astral Publishing Pvt. Ltd., New Delhi, pp 371-377.

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Abstract Publication:

1. **Pal A.**, Mollick A.N., Parvin B., Dhara P.C. (2015): A case-control study on pulmonary parameters and the occurrence chronic obstructive pulmonary diseases among the rubber factory workers. UGC sponsored National seminar on current trend of research in human physiology and community health. Organized by Dept. of Human Physiology with Community Health, 27th March.

2. **Pal A.**, Santra A., Goswami S., Dhara P.C. (2014): An ergonomic study on the prevalence of musculoskeletal problems and postural stress among female cultivators engaged in different post harvesting jobs in west Bengal, India. International Ergonomics Conference, HWWE-2014, organized by Department of Design, Indian Institute of Technology, Guwahati, 3-5 December.

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Reprints

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Evaluation of work related musculoskeletal disorder and postural stress among female potato cultivators in West Bengal, India

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Abstract

Apart from cereal production (rice, wheat, etc.) agricultural labourers are engaged in different vegetable cultivations in West Bengal, India, of which potato cultivation is one of the more important vegetable cultivations. Potato cultivation requires manual work and workers are exposed to extreme postural stresses. The present study was aimed at evaluating the musculoskeletal disorder and postural stress experienced by female workers engaged in potato cultivation. The study was conducted on 155 female cultivators in different districts of West Bengal state (India). A modified Nordic Questionnaire and Body Part Discomfort Scale were applied to identify musculoskeletal disorders (MSDs) in different body parts. The postural stress was analyzed by four methods, viz. OVAKO Working Postures Analysis System (OWAS), Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), and Quick Exposure Check (QEC). From the results it was revealed that the prevalence of MSDs among the female workers was very high and the most affected areas were the back and upper extremities. Stooping and squatting postures were the dominating postures in potato cultivation jobs. Postural analysis indicated that during potato harvesting the workers were subjected to greater postural stress than that of other tasks. Postural stress might be the reason for the occurrence of MSDs. Thus, immediate ergonomic interventions are needed to reduce work stress of the women potato cultivators by correcting awkward postures.

Keywords: Potato cultivation, Female cultivator, Posture analysis, MSD

1 Introduction

India is an agricultural-based country and agriculture plays an important role in the economic development of the country. A large number of women in India are involved in agricultural activities and perform manual labour for crop production. A census conducted in 2011 highlighted that 42.95% of women are engaged in agricultural work in India (Census, 2011). In West Bengal the participation of women in agriculture is about 46.3% (Census, 2011). Most of these women workers come from rural and economically disadvantaged areas where employment opportunities are limited.

Agricultural work requires manual labour and, perhaps more than any other occupational group, agricultural workers are exposed to tremendous postural stresses that are potentially harmful to their health and well-being (Sabharwal and Kaushik, 2011). They face many job-related health problems during work. Kar *et al.,* (2012) studied occupational problems of female cultivators and stated that the female agricultural workers have job related problems other than musculoskeletal disorders. Among them fatigue, digestive disorders and headaches were prevalent. They also reported indigestion and pain in the abdomen. Kar *et al.,* (2012) also stated that different types of eye related problems such as pain and burning sensation in the eyes, watering and blurred vision were evident among the women workers engaged in agricultural tasks. In addition to cereal production (rice, wheat, etc.), agricultural labourers also performed different vegetable cultivation. Potato cultivation is one of the more important vegetable cultivations in India. There are different tasks in potato cultivation, which are performed in different phases. The potato cultivation tasks, viz., planting of seeds, tunneling and harvesting potatoes are repetitive in nature and are carried out through manual efforts. Most of the tasks of potato cultivation performed by the cultivators are monotonous, strenuous, physiologically demanding as well as time-consuming (Gangopadhyay *et al.,* 2005; Das and Gangopadhyay, 2012). Due to adopting different inappropriate postures whilst performing different potato cultivation tasks, workers are exposed to postural stress and may suffer from pain in different parts of the body. In different phases of potato cultivation tasks different patterns of work are performed. Some of the activities are dominated by static muscular contractions and some other tasks involve tasks repeated dynamic activities. Pascal (2003) noted that prolonged static muscle loads have appeared as a major risk factor in the development of load-related illnesses. A constant repetition of movements imposes a cumulative work-load which can cause pain and weakness and impaired function of the muscles and other soft tissues (Gangopadhyay *et al.,* 2007; Girish *et al.,* 2012). The predominant posture of different potato cultivation jobs are the stooping and squat postures. Workers sometimes adopt stooping and twisting postures during tunneling jobs and squatting postures while harvesting of potatoes for long durations. All these postures may produce discomfort in different body parts of the body. In potato cultivation jobs, continuous movement of upper limbs also occurs during tunneling jobs. In many parts of the agricultural sector, upper extremity injuries are prevalent and are related to several common risk factors, viz., awkward posture and repetitive movement (Meyers *et al.,* 2000; Struttmann and Reed, 2002; Gomez *et al.,* 2003; Goswami *et al.,* 2012). High repetitions, excessive forces and awkward postures are major causes of musculoskeletal disorders and complaints in industries (Westgaard, 2000; Singh, 2010). Competition and increased work demands have also increased farmers' exposure to risk factors through increased work pace and duration.

In labour intensive countries like India, not many studies are available on agricultural workers. Das and Gangopadhyay (2011) studied posture-related discomfort and occupational health problems among rice cultivators. Kar *et al.,* (2010) studied work-rest patterns and work components of different rice cultivation tasks. Nag *et al.,* (2004) studied drudgery, accidents and injuries in Indian agricultural workers. Kar and Dhara

(2007) studied musculoskeletal disorders and socioeconomic status of farmers in West Bengal. Das and Gangopadhyay (2012) also studied musculoskeletal disorders and physiological stress among male potato cultivators in West Bengal. Dewangan *et al.,* (2010) measured hand dimensions of male agricultural workers in North-Eastern India.

Investigations of male participants predominate, although it is actually females who comprise the majority of subsistence farmers in developing countries (F.A.O., 1995; De *et al.,* 2006; Goswami *et al.,* 2012). Therefore, an ergonomic study was undertaken on to assess the occupational health hazards of female potato cultivators in the West Bengal area. Efforts have been made to evaluate different musculoskeletal disorders and postural stresses of female workers performing different tasks of potato cultivation.

2 Methods

2.1 Site and participants

The study was conducted on 155 female cultivators having an age range of 18-60 years. Ethical approval and prior permission was obtained from the Institutional Ethics Committee before commencement of the study and the experiment was performed in accordance with the ethical standards of the committee and with the Helsinki Declaration. A two stage sampling method was utilized. In the first stage, the cluster sampling method was used to identify 5 clusters in each district e.g., Midnapore (East and West), Bankura, and Howrah of West Bengal, India. In the second stage, a systematic random sampling method was used to identify 12 households per cluster. The total number of samples was divided by the required number to get the sampling interval. The first household was selected randomly by using the lottery method and the subsequent households were identified by adding the sampling interval to the random number. The selected households were approached during field visits and the protocol of the study was explained verbally in local language (Bengali) and the available adult female members were selected as participants. Informed consent was obtained from the participants during field visits. During field visits, complete information on the experience of the work of the participants was noted on the basis of a questionnaire. According to the nature of work performed by participants, the potato cultivation jobs were divided into the three tasks, viz. potato plantation, tunneling and potato harvesting.

After ploughing the land, weeding is performed. The land surface is then levelled after which potato seeds (cut pieces of potato) are sown in rows by making a shallow dig with the hand. During sowing, a regular distance is maintained and the seeds are covered with soil. The seeds are sown in several rows keeping gaps (40-45 cm) between each row. After germination, when the saplings have grown, tunnels are made in the gap between the two rows with the help of a small sized spade. These tunnels are used for irrigation purposes. Such tunnels are re-made after every phase of irrigation. After a few months, when the crop is fully grown under the ground, harvesting activities begin. The soil along the rows of plants is dug by with the use of a spade. Care is taken to avoid cutting the potato under the soil. Once the soil beneath the plants becomes loose the potatoes are collected by the hand. The collected potatoes are kept in a sac or a basket.

2.2 Physical parameters

Anthropometric measurements were taken from the participants according to standard technique and appropriate landmarks (Ermakova *et al.*, 1985). Stature was measured to the nearest 0.1 cm using an anthropometer (Hindustan Minerals, The Hindustan Mineral Products Co. Ltd., Kolkata, India) and mass to the nearest 0.1 kg using a portable weighing machine (Libra, Libra Weighing Machine Limited, Bangkok, Thailand). From measures of stature and mass of the participants the Body Mass Index (BMI) was calculated using the following standard equation: BMI = weight (kg)/height (m^2) (WHO, 1995).

2.3 Evaluation of work rest patterns

The human body shows a rhythmic balance between energy consumption and energy replacement during work and rest periods. This dual process is an integral part of the operation of the muscles of the heart. Work-rest is therefore indispensable as a physiological requirement if performance and efficiency are to be maintained. As postural stress depends on the duration of adopting the posture, it is necessary to determine the actual work time within the work shift.

The work-rest patterns of potato cultivators were determined by directly observing the work as well as interviews with the workers (Wilson and Corlett, 1985). The work-rest cycle of different tasks of potato cultivation was studied by noting the actual work time and rest time. The total work shift was divided into work cycle and rest cycle. The rest period is the sum of prescribed rest pauses (rest for a food break) and job related rest pauses (rest taken by the worker for self-requirement during working hours). The actual work time was calculated by subtracting the rest pause from the total work shift. It was recorded carefully from beginning to end of the work shift by direct observation employing videography of the job. For this purpose, the whole day work of the workers was video recorded in DVD mode and analysed by using the software Xing MPEG player (Version 3.30). After a careful and repeated observation, the whole shift was evaluated and the duration of work time and different rest pauses of the workers were noted.

2.4 Determination of postural pattern

For evaluating postural stresses, the postural patterns of the workers performing their jobs were studied. The analysis of posture at different phases of potato cultivation jobs was made by direct observation employing video-photography (Wilson and Corlett, 1985). The posture of each participant was studied for each type of job for the whole working period. The postural changes while performing the work were noted carefully and the durations for adopting each posture were recorded. The observations were achieved by employing a "one participant per day" strategy.

2.5 Musculoskeletal disorders

The musculoskeletal disorders of the workers were evaluated by the modified Nordic Questionnaire technique (Kuorinka *et al.*, 1987). The questionnaire emphasized individual details, type of work and the occurrence or frequency of pain felt in different parts of the body.

2.6 Discomfort Rating

The intensity of pain or different types of discomfort was evaluated by utilizing the Body Part Discomfort (BPD) scale (Jacquelin *et al.,* 1994). The scale consisted of marks from 1 to 10 and ranged from just noticeable discomfort to intolerable discomfort. A '0' on the scale meant no discomfort at all and '10'on the scale indicated intolerable discomfort. The mean value of scores (perceived rating of discomfort) of all segments was taken as the overall discomfort rating of the workers.

2.7 Postural analysis

The postures adopted by the workers depend upon the type of work, personal characteristics, the tools required to perform the particular work and also the duration and frequency of the work cycle. Postural analysis can be a powerful technique for assessing work activities as the risk of musculoskeletal injury is associated with the posture (Kee and Karwowski, 2007). So, various techniques have been applied for postural analyses to identify the stress of different phases of work. Working postures were evaluated using the OVAKO Working Postures Analysis System (OWAS) method (Heinsalmi, 1986). Hignett and McAtamney (2000) pointed out that the OWAS method has a wide range of use but the results can be poor in detail because some body parts were not included in the analysis. Therefore, the Rapid Entire Body Assessment (REBA) method (Hignett and McAtamney, 2000), Rapid Upper Limb Assessment (RULA) method (McAtamney and Corlett, 1993) and Quick Exposure Check (QEC) method (Li and Buckle, 1999) were also applied for analysis work posture of the workers. Researchers (Sahu and Sett, 2010; Mukhopadhyay and Srivastava, 2010) have used several posture analysis methods viz. OWAS, RULA, REBA etc. simultaneously for posture analysis. This was the reason for applying four methods for posture analysis. In all the jobs of potato cultivation continuous movement of upper limb was noted. Thus, the RULA method was applied for posture analysis.

2.8 Statistical analysis

Data were analysed using STATISTICA (Vr. 6.0) for Windows. Age, anthropometric measures and work experience were described by their means and standard deviations. To test the significance of different parameters, the students' t-test was performed. Chi-square analysis was done to determine the differences in the prevalence of MSDs among different categories.

3 Results

The physical characteristics and experience of the work of the female cultivators are shown in Table 1. Nutritional status of the participants was assessed from their BMI value (WHO, 1995) and it was revealed that about 60.64% of the subjects had 'normal' weight (BMI 18.5 to 24.9 kg/m^2). The prevalence of underweight was high (32.26%) among the female cultivators, while a low percentage (7.1%) of them were classified as overweight.

Before the follow-up, complete information on the experience of work was noted on the basis of a questionnaire and the participants were divided into three groups: Gr.-A (work experience ≤5 years); Gr.-B (work experience 6-15 years) and Gr.-C (work experience >15 years). From the results it was revealed that about 36.13% workers had work experience durations of ≤5 years, 46.45% durations of 6 to 15 years and 17.42% had work experience of at least 16 years.

Table 1. The physical characteristics and experience of work for female cultivators

Parameters	Mean ± SD	Range
Age (years)	32.70±10.27	18-60
Stature (cm)	150.14±5.35	134-162
Mass (Kg)	44.84±7.27	29.5-69.5
BMI (Kg/m^2)	19.88±2.99	13.75-29.43
Experience (Years)	11.60±8.95	1-35

The work-rest patterns of female cultivators were studied and have been presented in Table 2. The workers started work by 7 a.m. and worked for about two hours. After this, they took a break for breakfast for about 30 to 40 minutes. They would resume the work after this break and continued the work for about 2 to 2½ hours. They would then take a lunch break for about 1½ to 2 hours. During this break they would also take a bath and rest for some time. The workers would also perform their household work like; cooking, cleaning, and washing clothes and dishes during this period. After this break they had to start work at 14:30 p.m. and it would continue for 3 hours.

Table 2. Mean ± SD of work time and rest time (min) of female cultivators in different potato cultivation tasks. The figures in the parentheses indicate the percentage of total time

		Different potato cultivation tasks		
		Plantation	**Tunneling**	**Potato Harvesting**
Work time		355.49±22.07 (65.25%)	350.35±34.52 (64.26%)	363.48±10.38 (63.81%)
Rest time	Work related rest	36.66±7.52** (19.36%)	39.68±9.29* (20.36%)	47.08±8.02 (22.83%)
Rest time	Prescribed rest (Food breaks)	152.67±9.1 (80.64%)	155.13±11.86 (79.64%)	159.07±14.17 (77.17%)
Rest time	Total rest	189.32±9.67*** (34.75%)	194.82±15.01* (35.74%)	206.15±14.58 (36.19%)
Work shift		544.81±25.21**	545.16±35.34*	569.62±19.94

w.r.t Potato harvesting * p<0.05, ** p<0.01, *** p<0.001

From the observed results it was revealed that the work rest patterns vary in different tasks of potato cultivation. The work time varied from 63.81% to 65.25% of the total work shift and rest time varied from 34.75% to 36.19% in different tasks of potato cultivation. The rest period of the cultivators included the food break. The results also indicate that total work time was the highest in potato harvesting (approximately 6 hours) followed by plantation and tunneling jobs. However, there was no significant difference in work time among the groups (potato plantation, tunneling and potato harvesting). From the study of rest period of the workers, it was noted that the rest period was significantly lower among the potato plantation ($p<0.05$) and tunneling ($p<0.001$) groups compared to potato harvesting group. The prescribed rest (food breaks) was more or less same for all the groups. However, the work related rest was significantly lower among the potato plantation ($p<0.01$) and tunneling ($p<0.05$) groups compared to potato harvesting group. The work shift was significantly higher among the potato harvesting group compared to potato plantation ($p<0.01$) and tunneling ($p<0.05$) groups.

The direct observation method was used for the analysis of postural patterns and results are shown in Table 3. In potato cultivation, the female workers were found to adopt three major types of postures, viz., squatting, stooping (where trunk leans forward) and walking (Figure 1).

It was noted from the results that stooping was the dominant posture in potato cultivation jobs. The workers were compelled to adopt a stooping posture for about 84.98% of the work-time when performing the tunneling job and about 51.79% and 47.61% during potato harvesting and plantation jobs respectively. The workers engaged in potato plantation and harvesting jobs were compelled to adopt a squat sitting posture for about 39.49% and 35.03% of the work-time respectively. From the results it was noted that the time for adopting stooping posture in tunneling job was significantly higher ($p<0.001$) than the potato plantation and harvesting jobs.

Table 3. Mean±SD and percentage (%) of time (min) for adopting different postures in a work shift by female cultivators performing different potato cultivation jobs

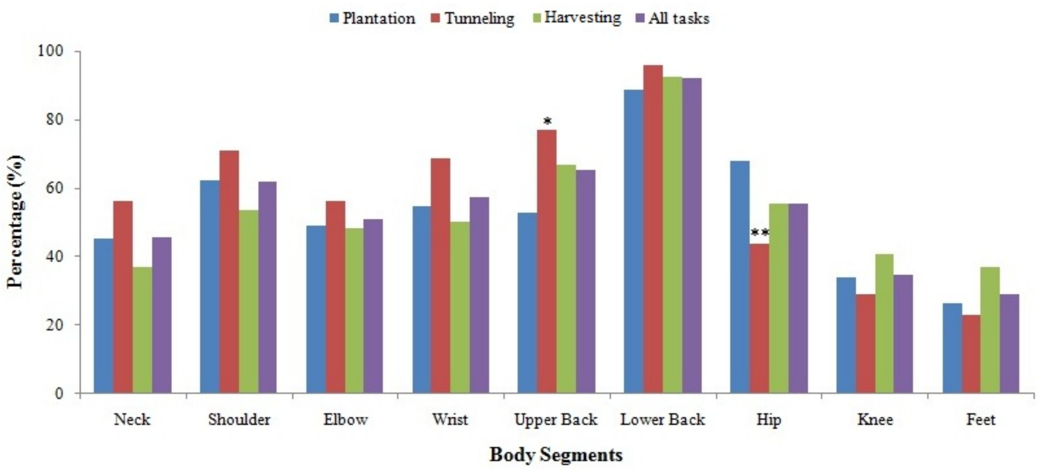
Different working posture	**Different potato cultivation tasks**		
	Plantation	**Tunneling**	**Potato Harvesting**
Squatting	140.4±46.6 (39.49%)	-	127.33±30.36 (35.03%)
Stooping	169.26±58.28* (47.61%)	297.59±41.68 (84.94%)	188.26±29.33* (51.79%)
Walking	45.83±15.29 (12.89%)	52.76±16.93 (15.06%)	47.76±13.09 (13.14%)
Total working period	355.49±22.07	350.35±34.52	363.48±10.38

w.r.t Tunneling * $p<0.001$

The prevalence of musculoskeletal disorders of the workers was evaluated using the modified Nordic Questionnaire method and the occurrence of musculoskeletal disorders (MSDs) is presented in Figure 2. From the results it was revealed that the prevalence of MSDs was very high among the workers. It was noted that the most affected body parts were the lower back (92.26%) and upper back (65.16%) when all tasks were considered together. These were followed by problems of the shoulder (61.94%), waist (57.42%), hip (55.48%) and elbow (50.57%). The workers performing tunnelling activities had a significantly higher prevalence of MSD in the upper back ($p<0.05$) than that of potato plantation. In addition, the tunnelling workers had a higher percentage of other segmental discomfort than that of potato plantation, except for the hip, knees and feet.

Figure 1. Photographs of the female workers engaged in different activities in potato cultivation: - (a) stooping posture, (b) in squat sitting posture, (c) Tunneling in stooping posture, (d) Walking during tunneling operation (e) Potato harvesting in stooping posture, (f) Potato harvesting in squat sitting posture

During potato plantation the workers had a higher percentage of discomfort in different body segments (neck, shoulder, elbow, wrist and hip) than during harvesting potato, except for the upper back, lower back, knees and feet. During performing tunnelling activities the workers showed a higher percentage of discomfort in different body segments than those workers in potato harvesting except for the hip, knees and feet. The occurrence of discomfort in the lower back was almost the same in all groups of female workers.

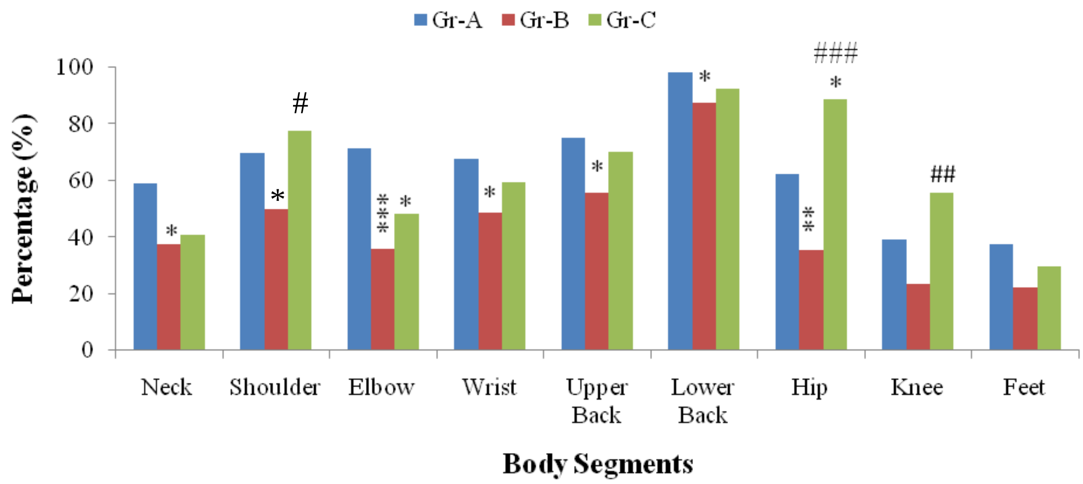


w.r.t. Plantation * $p<0.05$, ** $p<0.01$

Figure 2. Percentage (%) of female cultivators reported problems in different body parts performing different potato cultivation jobs

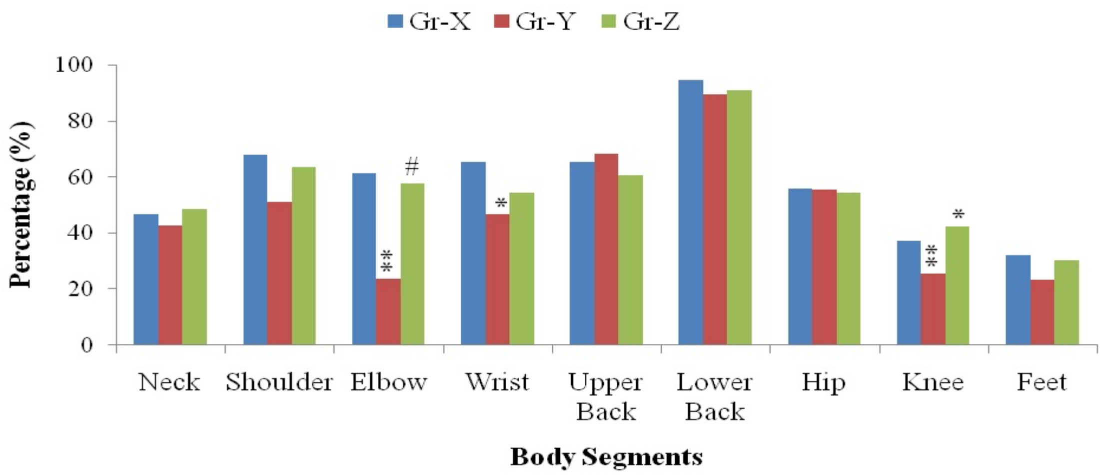
The occurrence of MSDs among the female workers having different levels of experience was also studied and the results have been presented in Figure 3. It was revealed that the occurrence of MSDs was significantly higher in subjects of Gr.-A in different segments of the body [in neck ($p<0.05$), shoulder ($p<0.05$), elbow ($p<0.001$), wrist ($p<0.05$), upper back ($p<0.05$), lower back ($p<0.05$) and hip ($p<0.01$)] than that of Gr.-B. It was also significantly higher in the elbows ($p<0.05$) than that of Gr.-C. The subjects of Gr.-C also showed significantly higher percentage of MSDs in shoulder ($p<0.05$), hip ($p<0.001$) and knee ($p<0.01$) than that of the Gr.-B workers and in hip ($p<0.05$) than the Gr.-A workers.

The subjects were also divided into three groups according to age viz., Gr.-X (age: ≤ 30 years); Gr.-Y (age: 31-40 years) and Gr.-Z (age: >40 years) and the occurrence of MSDs in different age groups were studied. A comparison of prevalence of MSDs among different age groups of female workers has been presented in Figure 4. The results reveal that the subjects of lower age groups (Gr.-X) had significantly higher prevalence of MSDs in different segments of the body [in the elbow ($p<0.001$), the wrist ($p<0.05$) and the knee ($p<0.001$)] than the subjects of the middle age group (Gr.-Y). The subjects of the higher age group (Gr.-Z) showed significantly higher percentages of MSDs in the knee ($p<0.05$) than the lower age groups (Gr.-X) and in the elbow ($p<0.05$) than the subjects of the middle age group (Gr.-Y) respectively.



Gr.-A: work experience ≤5 years; Gr.-B: work experience 6-15 years; Gr.-C: work experience >15 years
w.r.t. Gr.-A * p<0.05, ** p<0.01, *** p<0.001
w.r.t. Gr.-B # p<0.05, ## p<0.01, ### p<0.001

Figure 3. Prevalence of MSD of female workers on the basis of their work experiences

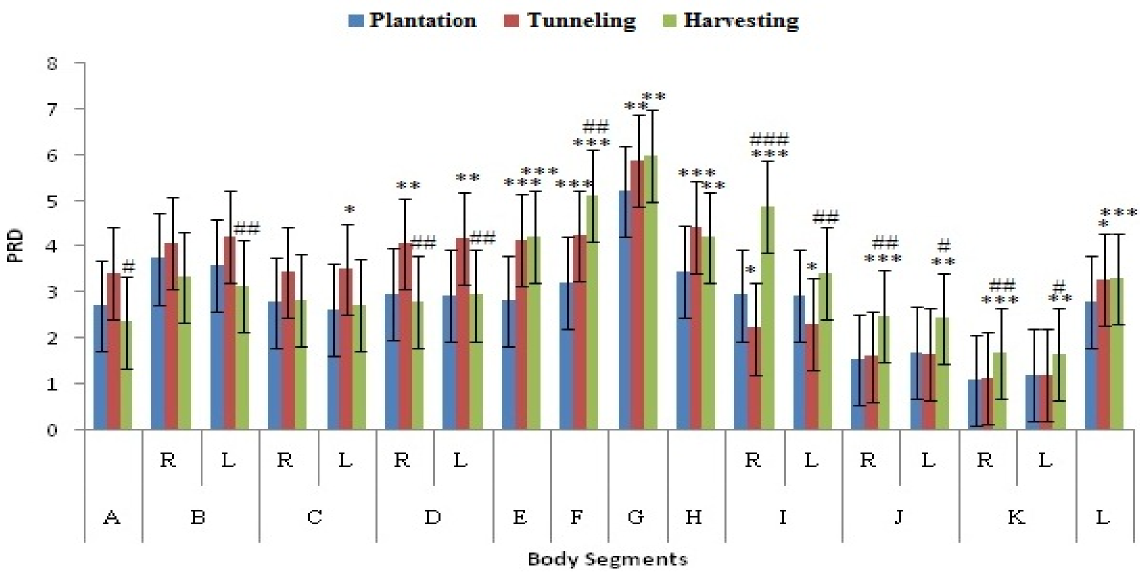


Gr.-X: Age ≤30years; Gr.-Y: Age 31-40years; Gr.-Z: Age >40 years

w.r.t. Gr.- X * p<0.05, ** p<0.001
w.r.t. Gr.-Y # p<0.05

Figure 4. Prevalence of MSDs in female workers in different age groups

The quantitative assessment of the discomfort of the workers was also examined. The perceived rating of discomfort of the workers was studied using a 10-point scale and the results showed that the workers who were engaged in different phases of potato cultivation tasks had different degrees of perceived exertion (Figure 5). It was revealed that there was a severe degree of discomfort (>4 to ≤7) in the lower back, upper back and buttocks among the female cultivators when all the tasks were considered together. The female tunnelling workers suffered a significantly higher degree of discomfort in left upper arm ($p<0.05$), lower arm ($p<0.01$), upper back ($p<0.001$), middle back ($p<0.001$), lower back ($p<0.01$) and buttock ($p<0.001$) than that of potato plantation workers and they also had significantly higher degree of discomfort in neck ($p<0.05$), shoulder (left $p<0.01$) and lower arms ($p<0.01$) than that of potato harvesting workers. The potato harvesting workers had significantly higher degree of pain in upper back ($p<0.001$), middle back ($p<0.001$), lower back ($p<0.01$), buttock ($p<0.01$), right thigh ($p<0.001$), calf ($p<0.01$) and feet ($p<0.01$) than that of the potato plantation workers. On the other hand, a significantly higher degree of pain was noted at middle back ($p<0.01$), thigh ($p<0.01$), calf ($p<0.05$) and feet ($p<0.05$) in the potato harvesting workers than that of the tunnelling workers. From the results of overall discomfort rating of the body, it was noted that higher degree of pain or discomfort was found among the workers engaged in potato harvesting than that of the workers performing tunnelling and potato plantation tasks.



w.r.t Plantation * p<0.05, ** p<0.01, *** p<0.001
w.r.t Tunneling # p<0.05, ## p<0.01, ### p<0.001
A- Neck; **B**- Shoulder; **C**- Upper Arm; **D**-Lower Arm; **E**- Upper Back; **F**-Middle Back; **G**- Lower Back; **H**- Buttock; **I**- Thigh; **J**-Calf, **K**- Feet; **L**- Over all discomfort rating of the body; **PRD**- Perceived Rating of Discomfort

Figure 5. The perceived rating of discomfort (Mean ±SD) in different body segments of female cultivators during performing different potato cultivation jobs

In the present study, different postures adopted by female cultivators while performing different tasks of potato cultivation were analyzed by four methods, viz., OWAS, RULA, REBA and QEC and represented in detail, along with the maximum discomfort zone and rating (Table 4). The dominant postures adopted by the workers during potato plantation were stooping and squat sitting postures. From the results of postural assessment of potato plantation job by OWAS method, it was found that the stooping posture needed corrective measures as soon as possible and squat sitting posture needed corrective measures in the near future. Similarly, from the results of postural assessment by RULA and REBA methods, it was found that the stooping posture of potato plantation has been categorized as high risk and needed further investigation and immediate change. The squat sitting posture has been categorized as medium risk and it needed further investigation and change soon.

Table 4. Results (action and risk levels) of postural analysis of the female potato cultivators in different potato cultivation tasks

Tasks		OWAS		REBA		RULA		Maximum discomfort in body parts	Maximum Discomfort Rating
		Action Level	Risk level	Action Level	Risk level	Action Level	Risk level		
Plantation	Stooping	3	Corrective measures as soon as possible	10	High risk, investigate and implement change	7	Investigate and change immediately	Lower back	5.21 ±2.53
	Squatting	2	Corrective measures in the near future	7	Medium risk, further investigation, change soon	6	Investigate further and change soon		
Tunneling		3	Corrective measures as soon as possible	11	Very high risk, implement change	7	Investigate and change immediately	Lower back	5.88 ±2.21
Harvesting	Stooping	3	Corrective measures as soon as possible	12	Very high risk, implement change	7	Investigate and change immediately	Lower back	5.98 ±2.48
	Squatting	3	Corrective measures in the near future	11	Very high risk, implement change	7	Investigate and change immediately		

The analyses of potato plantation tasks using the QEC indicated the risk level to specific body parts including the back, shoulder/arm, wrist/hand, and neck (Table 5). From the results it was revealed that the risk level was high in the back and neck regions and moderate in the shoulder/arm and wrist/hand regions while adopting both stooping and squat sitting postures.

Postures adopted in tunneling jobs were analyzed by four posture analyses methods. From the results of postural assessment of tunneling job by OWAS method, it was found that the posture needed corrective measure as soon as possible. Similarly, from the results of postural assessment by RULA and REBA methods, it was found that the posture for tunneling jobs has been categorized as very high risk and needed change immediately. The results of the posture analysis by QEC method indicated that the risk levels were high in the back and neck regions and moderate for the shoulder/arm as well as at wrist/hand regions while performing tunneling task.

The postures adopted by the female cultivators while harvesting potatoes were the stooping and squat sitting postures. From the results it was found that both stooping and squatting needed corrective measures as soon as possible. Similarly from the results of postural assessment by RULA and REBA methods it was found that both the stooping and squatting postures were categorized as high risk and needed change of posture immediately. The results of the posture analysis by QEC method indicated that the risk levels were high at the back, shoulder/arm and neck and moderate at the wrist/hand while performing potato harvesting job in stooping posture. In case of adopting squatting posture the risk levels were high at back, wrist/hand and neck and moderate at shoulder/arm.

Table 5. Results (scores and risk level) of postural analysis by QEC method of the female potato cultivators in different potato cultivation tasks

Tasks		Back		Shoulder/Arm		Wrist/Hand		Neck		Driving		Vibration		Work pace		Stress	
		Score	Risk level	Score	Risk level	Score	Risk level	Score	Risk level	Score	Risk level	Score	Risk level	Score	Risk level	Score	Risk level
Plantation	Stooping	34	High	30	Moderate	30	Moderate	14	High	1	Low	1	Low	4	Moderate	9	High
	Squatting	32	High	28	Moderate	30	Moderate	14	High	1	Low	1	Low	4	Moderate	7	Moderate
Tunneling		34	High	30	Moderate	30	Moderate	14	High	1	Low	1	Low	4	Moderate	9	High
Harvesting	Stooping	40	High	34	High	30	Moderate	14	High	1	Low	1	Low	4	Moderate	9	High
	Squatting	34	High	26	Moderate	34	High	14	High	1	Low	1	Low	4	Moderate	9	High

4 Discussion

Female cultivators had to adopt different awkward postures while performing different jobs of potato cultivation. Thus, assessment of work postures is one of the starting points to address the problem of work-related body pain. The direct observation method was used for the analysis of posture and it was noted that the stooping posture was the dominant posture in potato cultivation jobs. The workers engaged in tunnelling jobs were compelled to adopt a stooping posture for most of the work-time. In the case of the plantation and potato harvesting jobs the workers were also compelled to spend maximum time in a flexed posture. The prolonged stooping posture imposes high static muscular load particularly in the trunk region (Gangopadhyay *et al.,* 2007; Goswami *et al.,* 2012). So, a flexed posture in different phases of potato cultivation jobs was generally stressful to the musculoskeletal structures, including the vertebral column. This is consistent with the past studies that have shown that stooping and twisting of the back impose higher postural strain than the straight back postures which are important risk factor of origin of discomfort (Kothiyal and Yuen, 2004; Chaffin *et al.,* 2006; Drake and Callaghan, 2008).

From the studies of work-rest patterns of female cultivators, it was found that total work time was approximately 6 hours in all jobs. Thus the prolonged tasks performed in awkward postures (stooping posture) may be possible causes of pain at different body segments of the female cultivators. The workers would also perform their household work such as, cooking, wiping, washing clothes and dishes during the lunch break and they were not able to avail adequate rest during this period. This might be one of the reasons for higher prevalence of MSDs. Al-Rahamneh *et al.,* (2010) also pointed out that prolonged tasks have been positively associated with body part discomfort. According to Caicoyal and Delclos (2010), those performing highly repetitive tasks for longer duration reported pain at different segments of their body.

Female cultivators were compelled to adopt different awkward postures for prolonged periods while performing different jobs of potato cultivation. Ergonomic assessment of work postures is one of the starting points to address the problem of work related body pain. Researchers proposed different methods for ergonomic assessments of working posture and quantification of ergonomic risk factors. From the results of the posture analysis it was revealed that all postures adopted by the workers during potato cultivation jobs were categorized as moderate to very high risk and that corrective measures were needed as soon as possible. Similar findings were also obtained from a posture analysis via the QEC method on all three jobs of potato cultivation. The greatest discomfort rating was noted in the lower back region in all the tasks because the cultivators spent most of the work time in stooping and squatting postures. Discomfort ratings revealed that the workers performing different tasks suffered from stress in the lower back and buttocks, which might be related to their postural patterns as well as the duration of work in awkward postures. Osborne *et al.,* (2012) studied farmers and reported that lower back pain was the most common MSD among the farmers, followed by upper and then lower extremity MSDs. They also suggested that the prevalence of MSDs in farmers was greater than in non-farmer populations. Long term adoption of bend and twist posture has been associated with postural stress. Investigators have suggested that awkward stooping and twisting of the back and working in the same position were significantly associated with prevalence of lower back problem and the workers judged those conditions to be the most problematic job factors contributing to pain and injury (Roffey *et al.,* 2010; Merlino *et al.,* 2003). Goldsheyder *et al.,* (2002) reported that there was a significant association of awkward postures with back pain. Das and Gangopadhyay (2012) studied potato cultivators and reported that prolonged work activity, high repetitiveness and remaining in an awkward posture for a prolonged period of time may lead to MSDs. The lower back pain (LBP) was commonly associated with decreases in muscular strength, spinal flexibility, incapacity and eventually activity limitation due to sick leave and corresponding high costs to the society, which was also reported by Van Tulder *et al.,* (1995). The higher prevalence of work related MSDs at different segments of the body of the workers might be due to use of significant force, repetitive movements and longer duration of exposure (Chaffin *et al.,* 2006). A constant repetition of movements imposes a cumulative work load which can cause pain and weakness and impaired function of the muscles and other soft tissues (Gangopadhyay *et al.,* 2007). The physiological problems that arose from repetitive work or overuse of certain muscles, tendons and soft-tissue structures, were addressed in terms of muscle fatigue, tissue density changes and tissue strain (Valachi and Valachi, 2003). Physiologic evidence shows that the rate and degree of tissue damage depends on the amount of force, repetition and duration of exposure (Geronilla *et al.,* 2003). The prevalence of shoulder problems was very high among the workers. In all tasks of potato cultivation, workers had to repetitively move their arms. This may evoke shoulder muscular tenderness disorder. This is due to the static fatigue of the trapezius muscle and multifactorial identification including static and awkward posture and work practices (Hayes *et al.,* 2009).

The occurrence of MSDs in most of the body segments was higher in the lower age group than that of the middle and upper age group of workers. The occurrence of MSDs also exhibited variation in the participants having different work experience. This difference might be due to involvement of less skill workers in the lower age group. As the workers were newly recruited they were untrained and possessed little knowledge to operate the hand tools. From the study of Häkkänen *et al.,* (2001) it has been revealed that among trailer assembly workers a higher rate of sick leave due to disorders of the upper limbs was found for new workers compared with experienced ones. On the other hand, the higher incidence of MSDs in the workers of upper age group might be due to reduced muscle strength and endurance with the advancement of age (Holmström and Engholm, 2003). Guo *et al.,* (2004) noted in their studies that MSDs significantly increased with age. From the findings of the Alexopoulos *et al.,* (2003) and Habib *et al.,* (2005) it was revealed that age was associated with chronic complaints.

5 Conclusions

According to the different posture analysis methods, the postures adopted by the female cultivators have been categorized as ‘moderate’ ‘to ‘very high’ risk levels in different tasks of potato cultivation. The workers suffered health problems, perhaps because of prolonged working hours, awkward postures and used less safety measures while working. The female cultivators had to start their day before dawn to finish off their household chores and cooking before they moved off to the fields, which altogether results in a higher degree of musculoskeletal problems. The prevalence of MSDs was higher in the lower age group compared to middle and upper age group of workers. The prevalence of MSDs also exhibited variation in the participants having different work experience. Moreover, ergonomic interventions such as modifying work-rest schedules would improve the work conditions and postures of the female cultivators and reduce their MSDs. From this study it is recommended that workers avoid awkward work postures as far as possible and take adequate rest during their work for reducing job related health hazards. The strenuous posture is one of the major problems in potato cultivation jobs. This problem may be solved by designing new equipment, which can relieve them from adopting harmful bend postures. Avoiding loads during acute pain and performing specific exercises can reduce the low back pain. Awareness and training programs about the correct work posture, personal protective devices and using proper work methods among the women cultivators may be another solution of the problem.

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To
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Dear Author,

An edited and formatted version of your Original article "**Ergonomic Evaluation of Work Related Musculoskeletal Disorders and Postural Stress among Male Potato Cultivators of West Bengal, India**", which is accepted and scheduled for publication in a forthcoming issue of IJOSH.

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We value your support to our journal and look forward for your valuable contribution in future.

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Original Article

Ergonomic Evaluation of Work Related Musculoskeletal Disorders and Postural Stress among Male Potato Cultivators of West Bengal, India

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Abstract:

Background: Apart from cereal production (rice, wheat, etc.) agricultural labourers are engaged in vegetable cultivation in West Bengal, India. Potato cultivation is one of the important vegetable cultivation in India. The potato cultivation tasks are repetitive in nature and those are carried out mainly by manual efforts. Most of the tasks of potato cultivation are monotonous, strenuous, physiologically demanding as well as time-consuming. **Objective:** The present study was aimed to evaluate musculoskeletal disorders (MSDs) and postural stress among male workers engaged in different potato cultivation jobs. **Methods:** The study was conducted on 163 male potato cultivators in different districts of West Bengal state. A modified Nordic Questionnaire and Body Part Discomfort scale were applied to identify MSDs in different body parts. The postural pattern was assessed by direct observation method. The postural stress was analyzed by OWAS, REBA and QEC methods. **Result:** The results show that the prevalence of MSDs was very high among the workers and the most affected areas were back and upper extremity. Postural analysis indicated that the subjects had to adopt different stressful postures during performing different potato cultivation jobs. During potato harvesting operation the workers were subjected to greater postural stress than that of other tasks. **Conclusion:** Postural stress might be the reason of the occurrence of MSDs. From this study it has been recommended that workers should avoid bad work postures as far as possible during work for reducing job related health hazards.

Key Words: MSDs, Work Posture, Posture Analysis, Work Experience, Potato Cultivation Jobs

Introduction

Agricultural work is the most primitive type of employment in the world. India is an agricultural-based country and agriculture plays an important role in the economic development of India. A census conducted in 2011 in India highlighted that 58.4% of the total population in the country are engaged in agricultural work [1]. According to the Census report [1] it has been found that in West Bengal state about 43.35% of male and 46.3% of the female population are engaged in agricultural work.

A large number of people of this state, especially of Midnapore (East and West), Bankura, Purulia, Howrah district etc. are engaged in agriculture throughout the year. Most of these workers, those are involved in agricultural works are coming from rural and economically backward areas where employment opportunities are limited. Because of their poverty, farmers are obliged to undertake most agricultural tasks relying solely on their own efforts. Even today, Indian agriculture depends to a very large extent on manual labour, although modernization has reached some parts of the subcontinent. Though the agricultural workforce is by far the major work forcing the third world countries, its work organization has not received much attention.

Apart from cereal production (rice, wheat, etc.) agricultural labourers are engaged in vegetable cultivation. Potato cultivation is one of the important vegetable cultivation in India. Both male and female workers are involved in this job and expend a great extent of their physiological cost. The potato cultivation is a seasonal work. The potato is cultivated in one season (November-March). Potato cultivation totally depends upon irrigation from rivers, canals and underground water. There are different tasks in potato cultivation, which are performed in different phase viz., plantation of potato, tunneling and harvesting of potato. Prior to potato cultivation, weeding is done to remove unwanted weeds. After this the land surface is level. Then potato seeds (cut pieces of potato) are sown in rows by making a shallow dig with the hand. During sowing a regular distance is maintained. The seeds are covered with soil. The seeds are sown in several rows, keeping some gaps (40-45 cm) between two rows. For this activity, agricultural workers adopt a very awkward posture for a prolonged time. After germination when the saplings are grown tunnels are made in the gap between two rows with the help of a small sized spade. These tunnels are used for irrigation purpose. Such tunnels are re-made after every phase of irrigation. Spading is another very strenuous activity whereby the workers have to work in a constantly bent posture. After a few months when the crop is fully grown under the ground, harvesting activities begin. The soil along the rows of plants is dug by the help of a spade. Care is taken to avoid the cutting of potato under the soil. Once the soil beneath the plants become loosens the potatoes are collected by the hand. The collected potatoes are kept in a sac or a basket. The potato cultivation tasks are repetitive in nature and those are carried out mainly by manual efforts. Most of the tasks of potato cultivation performed by the cultivators are monotonous, strenuous, physiologically demanding as well as time-consuming [2-3]. They have to face many job related health problems during work. Agricultural works are executed by manual labour and perhaps more than any other occupational group; agricultural workers are exposed to a tremendous variety of postural stress [4]. These manual operations may be physically demanding through postural requirements and are commonly regarded as a source of the drudgery that is potentially harmful to their health and well being. They may therefore be considered to be suitable for ergonomics intervention.

In labour intensive countries like India, few studies were done on agricultural workers. Das and Gangopadhyay [5] studied on posture related discomfort and occupational health problems among rice cultivators. Kar et al. [6] studied on work-rest patterns and work component of different rice cultivation tasks. Nag et al. [7] studied on drudgery, accidents and injuries in Indian agricultural worker. Kar and Dhara [8] studied on musculoskeletal disorders and socioeconomic status of farmers in West Bengal. Goswami et al. [9] studies on the work related musculoskeletal disorder and postural stress among female cultivators engaged in post harvesting tasks in India. However, studies on vegetable cultivation tasks, particularly in potato cultivation are scanty. Therefore, an ergonomic study was undertaken to assess the occupational health hazards of the male potato cultivators. Efforts have been made to evaluate different musculoskeletal disorders and postural stress of male workers during performing different tasks on potato cultivation job.

Methods

Site and subject : The study was conducted on 163 male workers having the age group of 18-50 years. Ethical approval and prior permission were obtained from the Institutional Ethics Committee before commencement of the study and the experiment was performed in accordance with the ethical standards of the committee and with the Helsinki Declaration. Prior to the experimental trial, the protocol was explained verbally in local language (Bengali) and informed consent was obtained from the subjects during field visits and the available adult males were randomly selected as subjects from different districts of West Bengal state, India. During field visits, complete information on the experience of the work of the workers was noted on the basis of a questionnaire. According to the nature of work performed by the workers, potato cultivation jobs were divided into the three tasks, viz. potato plantation, tunneling and potato harvesting.

Physical Parameters: Anthropometric measurements were taken from the subjects following standard technique and appropriate landmarks[10]. Height was measured to the nearest 0.1 cm using anthropometer (Hindustan Minerals) and weight to the nearest 0.1 kg using a portable weighing machine (Libra). From measures of height and weight of the subjects the body mass index (BMI) was computed using the following standard equation: BMI = weight (kg)/height (m^2).

Evaluation of Work Rest Patterns: The work-rest patterns of potato cultivators was determined by directly observing their work as well as by taking interview of the workers [11]. The work -rest cycle of different tasks of potato cultivation was studied by noting the actual work time and rest time. The total work shift was divided into work cycle and rest cycle. The rest period is the sum of prescribed rest pause (rest for food break) and job related rest pause (rest taken by the worker for self requirement during working hour). The actual work time was calculated by subtracting the actual rest pause from total work time. It was recorded carefully from beginning to end of the work by direct observation employing videography of the job. For this purpose, whole day works of the workers were video recorded in DVD mode and analyzed by using the software Xing MPEG player (Version 3.30). After a careful and repeated observation, the whole day work was evaluated and the duration of work time and different rest pauses of the workers were noted.

Determination of Postural Pattern: For evaluating the postural stresses, the postural pattern of the workers during performing their jobs was studied. The analysis of posture at different phases of potato cultivation jobs was made by the direct observation method employing video-photography [11]. The work posture of each subject was studied for each type of job for a whole working period. The postural change during performing the work was noted carefully and the time for adopting each posture was recorded. The observation was made by employing one subject one day strategy.

Musculoskeletal Disorder: The musculoskeletal disorders of the workers were evaluated by the modified Nordic questionnaire technique [12]. The questionnaire emphasized their individual details, type of work and the occurrence or frequency of pain felt in different parts of their body.

Discomfort Rating: The intensity of pain or different types of discomfort was evaluated by utilizing the body part discomfort (BPD) scale [13]. The scale consisted of marks from 1 to 10 and ranges from just noticeable discomfort to intolerable discomfort. A ‘0’ in the scale meant no discomfort at all and ‘10’ in the scale indicated intolerable discomfort. The mean value of scores (perceived rating of discomfort) of all segments was taken as the overall discomfort rating of the workers.

Postural Analysis: The postures adopted by the workers in their working place depends upon the type of work, personal characteristics, the tools required to perform the particular work and also the duration and frequency of the work cycle. Postural analysis can be a powerful technique for assessing work activities as the risk of musculoskeletal injury associated with the posture [14]. So, various techniques have been applied for postural analyses to identify the stress of different phases of work. Working postures were evaluated by using OWAS (OVAKO Working postures Analysis System) method [15]. Although the OWAS method has a wide range of use, but the results can be low in detail [16]. Therefore, the REBA (Rapid Entire Body Assessment) method [16] and QEC (Quick Exposure Check) method [17] were also applied for analysis of work postures of the workers.

Statistical Analysis: Data were analyzed using STATISTICA (Vr. 6.0) for windows. Results for the general information items here expressed as mean±SD. Among the different groups of parameters 't'-test had also been made. The chi - square test was used for comparison of categorical variables.

Results

The physical characteristics of the workers have been shown in Table I. Nutritional status of the subjects was assessed from their BMI value and it was found that the mean value of BMI of subjects was within the normal range.

Before follow-up, complete information on the experience of the work of the workers was noted on the basis of a questionnaire and the subjects were divided into three groups based on their work experiences viz., Gr. -A (work experience ≤5 years); Gr. -B (work experience 6-15 years) and Gr. -C (work experience >15 years). From the results it was revealed that about 14.72% workers had their work experiences for ≤5 years, 54.60% workers had their work experiences for 6 to 15 years and 30.68% workers had experience of at least 16 years.

Table I The physical characteristics of the male cultivators

Parameters	Mean ± SD	Range
Age (yrs)	33.24 ± 10.33	18 - 50
Height (Cm)	162.06 ± 5.35	145.7 - 75.0
Weight (Kg)	53.36±7.77	39.6 - 77.4
BMI (Kg/m^2)	20.28±2.49	15.9 - 28.21
Work Experience (yrs)	12.04±9.18	1 - 37

The work-rest patterns of the potato cultivators were studied and have been presented in Table II. The workers started work by 7 a.m. and continued the work for about two hours. After this, they took a breakfast break for about 20 to 40 minutes. They would resume the work after this break and continue the work for about 2 to 2½ hours. Then they used to take another meal break (lunch) for a longer duration than the former break. It would continue for about 1½ to 2 hours. During this break they would also take a bath and rest for some time. After this break they had to start work from 2.30 p.m., which would continue for 3 hours.

From the observed results it was revealed that the work rest patterns were found to vary in different tasks of potato cultivation. The work time varied from 67.38% to 68.77% of the total work shift and rest time varied from 31.23% to 32.62% of the total work shift in different tasks of potato cultivation. The rest period of the cultivators included the food break. The results also indicate that the total work shift was significantly (p<0.05) higher in potato harvesting operation than potato plantation and tunneling jobs. The total work period was also significantly (p<0.05) higher in potato harvesting operation than the tunneling job. It was noted that the total working hours of the all groups of workers were approximately 9 hours including rest pause.

Table II: Mean ± SD of work time and rest time (min) of the cultivators in different potato cultivation tasks (The figures in the parentheses indicate the percentage of total time)

Different potato cultivation jobs	Total work time (min)	Total rest time (min)	Total duration of work shift (min)
Plantation (n=19)	380.74±28.98 (68.77%)	172.87±11.67 (31.23%)	553.60±30.71*
Tunneling (n=22)	373.12±25.25* (67.38%)	180.60±13.70 (32.62%)	553.73±29.93*
Potato Harvesting (n=20)	391.68±25.90 (67.79%)	186.06±14.27 (32.21%)	577.74±32.91
All categories	380.87±27.31 (67.96%)	179.56±14.01 (32.04%)	560.43±32.38

w.r.t Potato harvesting * p<0.05

The direct observation method was used for the analysis of postural patterns and results are shown in Table III. It was noted from the results that the workers had to adopt forward bending posture throughout the work time. The workers were found to twist and bend their body frequently during potato plantation and potato harvesting jobs. They had also to adopt forward bending posture for about 89.31% of the work-time in case of tunneling job and it were about 51.53% and about 56.54% in case of plantation and potato harvesting jobs respectively. The workers engaged in potato plantation and potato harvesting jobs were compelled to adopt squat sitting posture for about 39.17% and 34.25% of the work-time respectively.

According to the nature of work performed by workers, the potato cultivation jobs were divided into the three tasks, viz. potato plantation, tunneling and potato harvesting, which already mansion earlier. The prevalence of MSDs of three categories of working groups was studied and compared between the categories and showed in Table IV. The results indicated that the occurrence of MSDs was significantly different in different sites of the body between the workers engaged in different jobs of potato cultivation (potato plantation, tunneling and potato harvesting jobs). The workers engaged in tunneling activities had significantly higher percentage of MSDs in the shoulder (p<0.001), upper back (p<0.001) and lower back (p<0.05) than the workers engaged in potato plantation. In addition to those workers engaged in tunneling activities also had a higher percentage of other segmental discomfort than those of potato plantation workers excepting wrist, knee and feet. From the results it was revealed that the workers engaged in potato harvesting had significantly higher percentage of MSD in the shoulder ($p<0.01$), upper back ($p<0.01$) and lower back ($p<0.05$) than the workers engaged in potato plantation. In addition to those workers engaged in potato harvesting activities also had a higher percentage of other segmental discomfort than those of potato plantation workers excepting elbow and wrist. Whereas, potato harvesting workers had significantly lower prevalence of MSD in elbow ($p<0.001$) than the potato planting workers. The results also indicated that potato harvesting workers had significantly higher percentage of discomfort in the knee ($p<0.05$) and feet ($p<0.01$) compared to the workers engaged in tunneling activities.

Table III: Mean±SD and percentage (%) of time (min) for adopting different postures in a work shift by the cultivators during performing different potato cultivation jobs.

Different working posture	Different potato cultivation tasks		
	Plantation (n=19)	Tunneling (n=22)	Potato Harvesting (n=20)
Sitting (squatting)	149.12±49.36 (39.17%)	-	134.15 ±51.66 (34.25%)
Forward bends	196.19±60.95* (51.53%)	333.22±22.84 (89.31%)	221.47 ±48.28* (56.54 %)
Walking	35.43±12.44 (9.31%)	39.90±14.25 (10.69%)	36.06 ±10.60 (9.21 %)
Total working period	380.74±28.98	373.12±25.25	391.68±25.9

w.r.t Tunneling * $p<0.001$

Table IV: Comparison of MSDs of male workers between different groups of potato cultivation.

Body Segment	Plantation (n=51)	Tunneling (n=60)	Harvesting (n=52)
Neck	13 (25.49)	22 (36.67)	22 (42.31)
Shoulder	12 (23.53)	38 (63.33)***	27 (51.92)**
Elbow	24 (47.06)	37 (61.67)	15 (28.85)###
Wrist	34 (66.67)	30 (50.00)	34 (65.38)
Upper Back	21 (41.18)	45 (75.00)***	38 (73.08)**
Lower Back	43 (84.31)	58 (96.67)*	51 (98.08)*
Hip	19 (37.25)	29 (48.33)	24 (46.15)
Knee	16 (31.37)	11 (18.33)	18 (34.62)#
Feet	10 (19.61)	5 (8.33)	16 (30.77)##

w.r.t. Plantation * $p<0.05$, ** $p<0.01$, *** $p<0.001$
w.r.t. Tunneling # $p<0.05$, ## $p<0.01$, ### $p<0.001$

The occurrence of MSDs in different experience groups had also been studied and a comparison was done in MSDs among different experience groups and presented in Table V. Gr.-A (work experience ≤5 years) had significantly higher percentage of MSDs in the shoulder ($p<0.001$), elbow ($p<0.05$), upper back ($p<0.05$), hip ($p<0.001$) and feet ($p<0.05$) than Gr. B workers (work experience 6-15 years) and significantly higher percentage of MSDs in shoulder ($p<0.01$) and hip ($p<0.05$) than Gr. C workers (work experience >15 years) respectively. Gr. C workers have significantly ($p<0.05$) higher prevalence of discomfort in the shoulder than Gr. B workers.

Table V: Prevalence of MSD of male workers on the basis of their work experiences (the values in parenthesis indicate the percentage of MSD).

Body segment	Gr-A (≤5 yrs.) (n=24) f (%)	Gr-B (6-15 yrs.) (n=89) f (%)	Gr-C (>15 yrs.) (n=50) f (%)
Neck	11 (45.83)	28 (31.46)	18 (36.0)
Shoulder	21(87.5)	30 (33.71) ***	26 (52.0) **#
Elbow	16 (66.66)	36 (40.45)*	24 (48.0)
Wrist	17 (70.83)	51 (57.30)	30 (60.0)
Upper Back	19 (79.16)	50 (56.18)*	35 (70.0)
Lower Back	24 (100.0)	80 (89.88)	48 (96.0)
Hip	18 (75.0)	30 (33.71)***	24 (48.0)*
Knee	10 (41.66)	20 (22.47)	15 (30.0)
Feet	8 (33.33)	13 (14.61)*	10 (20.0)

w.r.t. Gr. A * $p<0.05$ ** $p<0.01$, *** $p<0.001$
w.r.t. Gr. B # $p<0.05$

The quantitative assessment of the discomfort of the workers engaged in different potato cultivation jobs had also been done. The perceived rating of discomfort of the workers was studied by using a 10-point scale which was graded from Grade 0 (no pain) to Grade 10 (very severe pain). According to the degree of severity, the scores of the 10-point scale were divided into three subgroups, i.e., mild (1–4), severe (>4–7) and very severe (>7). The results showed that the workers engaged in different phases of potato cultivation tasks were reported to suffer from different degrees of perceived exertion. It was revealed that severe degree of discomfort (>4 to ≤7) was observed in lower back among the cultivators of all potato cultivation tasks (Table VI). The comparison between the work groups showed that the tunneling workers had a significantly higher degree of pain at shoulder ($p<0.001$), upper arm ($p<0.001$) and upper back ($p<0.05$) region than that of the plantation workers and had a significantly higher degree of pain at upper arm ($p<0.05$) than that of the harvesting workers. The harvesting workers had a significantly higher degree of pain at shoulder ($p<0.01$), upper back ($p<0.01$) and middle back ($p<0.001$) region than that of the plantation workers and had a significantly higher degree of pain in middle back ($p<0.01$), calf (right $p<0.05$) and feet (right $p<0.05$; left $p<0.01$) than that of the tunneling workers.

Table VI: The perceived rate of discomfort (Mean ±SD) in different body segments of potato cultivators during performing different potato cultivation jobs .

Body Segment		Plantation	Tunneling	Harvesting
Neck		1.37±2.49	2.13±2.98	2.40±3.04
Shoulder	R	1.27±2.36	3.58±3.0###	2.67±2.95##
	L	1.25±2.27	3.57±2.98###	2.67±2.98##
Upper arm	R	1.43±2.47	3.52±3.16###	2.26±2.69$
	L	1.47±2.48	3.62±3.09###	2.30±2.77$
Lower arm	R	3.33±2.36	2.60±2.84	3.50±2.9
	L	3.25±2.56	2.68±2.95	3.48±2.93
Upper back		2.67±3.29	3.95±2.66#	4.31±2.91##
Middle back		2.61±2.39	3.32±2.11	4.62±2.01###$$
Lower Back		4.92±2.64	5.37±2.0	5.58±2.03
Buttock		3.18±2.34	3.80±2.26	3.42±3.01
Thigh	R	1.84±2.58	2.43±2.62	2.19±2.47
	L	1.94±2.65	2.37±2.57	2.12±2.37
Cuff	R	1.63±2.50	0.83±1.8	1.58±2.15$
	L	1.59±2.46	0.80±1.73	1.52±2.16
Feet	R	0.96±2.01	0.38±1.33	1.17±1.84$
	L	0.98±2.05	0.42±1.41	1.33±2.06$$
Over all discomfort rating of the body		2.22±0.97	2.67±1.18#	2.69±2.53

w.r.t Plantation # p<0.05, ## p<0.01, ### p<0.001
w.r.t Tunneling $ p<0.05, $$ p<0.01

A comparative study of reported mild, severe and very severe discomfort rating has been worked out and the results are presented in Table VII. The results reveal that percentages of workers expressed severe rating of discomfort were higher than that of mild rating in different segment of the body.

In the present study, different postures adopted by the cultivators while performing different tasks of potato cultivation were analyzed by three methods, viz., OWAS, REBA and QEC and represented in detail, along with the maximum discomfort zone and rating (Table VIII and Table IX). The dominant postures adopted by the workers during potato plantation were forward bending and squat sitting postures. From the results of postural assessment of potato plantation job by OWAS method, it was found that the forward bending posture needed corrective measure as soon as possible and squat sitting posture needed corrective measures in the near future. From the results of postural assessment by REBA method, it was noted that both forward bending and squat sitting posture of potato plantation job has been categorized as high risk . The analyses of potato plantation tasks using the QEC indicated the risk level to specific body parts including the back, shoulder/arm, wrist/hand, and neck (Table IX). From the results it was revealed that the risk level was high in back, wrist/hand and neck regions and moderate in shoulder/arm regions while adopting forward bending posture. While adopting squat sitting posture, the risk level was high in back and neck regions and moderate in shoulder/arm and wrist/hand regions.

Postures adopted in tunneling jobs were analyzed by three posture analysis methods. From the results of postural assessment of the tunneling job by OWAS method, it was found that the posture needed corrective measure as soon as possible. Similarly, from the results of postural assessment by REBA method, it was found that the posture for tunneling jobs has been categorized as very high risk. The results of the posture analysis by QEC method indicated that the risk levels were high in back and neck regions and moderate in the shoulder/arm as well as in wrist/ hand regions while performing tunneling task.

The postures adopted by the cultivators while harvesting potatoes were forward bending posture and squat sitting. From the results of postural assessment of the potato harvesting job by OWAS method, it was found that the both forward bending and squatting postures needed corrective measure as soon as possible. Similarly from the results of postural assessment by REBA

Table VII: Percentage distribution of individual according to severity of perceived rate of discomfort in different body segments during performing potato cultivation jobs.

Body Segment		Mild (1–4)	Sever (>4–7)	Very Sever (>7)
Neck		12.88	15.34	6.75
Shoulder	R	20.86	18.40	7.98
	L	19.63	21.47	6.13
Upper arm	R	12.27	28.83	4.91
	L	12.27	28.83	5.52
Lower arm	R	30.67	26.38	4.91
	L	25.77	29.45	4.91
Upper back		18.40	37.42	7.98
Middle back		42.94	30.06	1.84
Lower Back		37.42	38.04	17.79
Buttock		34.97	31.29	5.52
Thigh	R	21.47	21.47	1.84
	L	19.02	23.93	1.23
Cuff	R	13.50	14.72	0.00
	L	13.50	12.88	0.61
Feet	R	11.66	6.75	0.00
	L	10.43	8.59	0.00

Table VIII: Results (action and risk levels) of postural analysis of the male potato cultivators in different potato cultivation tasks

Tasks		OWAS Action Level	OWAS Risk level	REBA Action Level	REBA Risk level	Max. discomfort in body parts	Maximum Discomfort Rating
Plantation	Forward bending	3	Corrective measures as soon as possible	10	High risk, investigate and implement change	Lower back	4.92 ±2.64
	Squatting	2	Corrective measures in the near future	8	High risk, investigate and implement change		
Tunneling		3	Corrective measures as soon as possible	11	Very high risk, implement change	Lower back	5.37 ±2.0
Harvesting	Forward bending	3	Corrective measures as soon as possible	12	Very high risk, implement change	Lower back	5.58 ±2.03
	Squatting	3	Corrective measures as soon as possible	11	Very high risk, implement change		

Table IX: Results (scores and risk level) of postural analysis by QEC method of the male potato cultivators in different potato cultivation tasks.

Body parts / Stress	Score / Risk level	Plantation: Forward bending	Plantation: Squatting	Tunneling	Harvesting: Forward bending	Harvesting: Squatting
Back	Score	34	32	34	40	34
	Risk level	High	High	High	High	High
Shoulder/ arm	Score	30	28	30	32	26
	Risk level	Moderate	Moderate	Moderate	High	Moderate
Wrist/ Hand	Score	34	30	30	30	34
	Risk level	High	Moderate	Moderate	Moderate	High
Neck	Score	14	14	14	14	14
	Risk level	High	High	High	High	High
Driving	Score	1	1	1	1	1
	Risk level	Low	Low	Low	Low	Low
Vibration	Score	1	1	1	1	1
	Risk level	Low	Low	Low	Low	Low
Work pace	Score	4	4	4	4	4
	Risk level	Moderate	Moderate	Moderate	Moderate	Moderate
Stress level	Score	9	7	9	9	9
	Risk level	High	Moderate	High	High	High

method, it was found that the both forward bending and squatting postures of potato harvesting have been categorized as very high risk. The results of the posture analysis by QEC method indicated that the risk levels were high in back, shoulder/arm and neck regions and moderate in the wrist/hand regions while performing potato harvesting job in forward bending posture. While performing potato harvesting job in squat sitting posture the risk levels were high in back, wrist/hand and neck regions and moderate in shoulder/arm regions.

Discussion

The workers were habituated in different awaked postures while performing different jobs of potato cultivation. The change of posture was a common factor during dynamic work and in long term working condition. The cultivators were compelled to adopt in different awkward postures for prolonged periods of time while performing different potato cultivation jobs. Although awkward postures were most prevalent in the jobs, it was also noted that there were a lot of non-ergonomic postures of certain parts of the body which may be the possible contributing causes of pain in different body segments. A good posture becomes even more important when forceful tasks are performed. Posture is as important for the performance of tasks as it is for promoting health and minimizing stress and discomfort during work [18]. Thus, assessment of work postures is one of the starting points to address the problem of work-related body pain. There are many practical methods for evaluating postural workload based on a postural classification [19-20]. The direct observation method was proved to be a good method for studying the work postures in agricultural and other work when involved in whole body work requiring moving. The validity of visual observation to assess posture in a laboratory-simulated material-handling task [21] was established. Thus the direct observation method was used for the analysis of posture and it was noted that the forward bending posture was the dominant posture in potato cultivation jobs. The workers engaged in tunneling jobs were compelled to adopt forward bending posture throughout the work time. In case of potato plantation and potato harvesting jobs the workers were also spend maximum time in forward bending posture. The workers were found to twist and bend their body frequently during potato plantation and potato harvesting jobs. The prolonged forward bending posture imposes a high static muscular load, particularly in the trunk region. So, forward bending posture in different phases of potato cultivation jobs was generally stressful to the musculoskeletal structures, including the vertebral column. This is consistent with the past studies that have shown that forward bending and twisting of the back impose higher postural strain than the straight back postures which are important risk factors for origin of discomfort [22-24]. Meyers et al. [25] showed the relation between stressful work postures and functional disturbance of pain in various parts of the musculoskeletal system. The workers usually required moving forward (sometimes sideways) under squat posture and such movements were strenuous and cumbersome.

The work-rest cycle is dichotomized into work and rest periods. The human body shows a rhythmic balance between energy consumption and energy replacement during work and rest periods. This dual process is an integral part of the operation of muscles, of the heart and if we take all the biological functions into account of the organism as a whole. Work rest is, therefore, indispensable as a physiological requirement if performance and efficiency are to be maintained.

From the studies of work-rest patterns of the potato cultivators, it has been found that total duration of work shift was high (approximately 9 hours) in all jobs of potato cultivation. Thus the prolonged tasks performed in awkward posture (bend posture) may be possible causes of pain at different segments of the workers. Al-Rahamneh et al. [26] also point out in their studies that prolonged tasks have been positively associated with body part discomfort. According to Caicoyal and Delclos [27], those performing highly repetitive tasks for longer duration reported pain at different segments of their body.

Study of MSD and body discomfort revealed that the incidence of MSDs or pain was comparatively higher in tunneling job than that the workers engaged in potato plantation and potato harvesting jobs. However, lower back problem was found extremely prevalent in all types of job of potato cultivation. It was the highest in potato harvesting (98.08%) followed by tunneling job (96.67%) and potato plantation operation (84.31%). Upper back problem was also prevalent in all types of tasks of potato cultivation. It was the highest in tunneling job (75.0%) followed by potato harvesting (73.08%) and seed plantation operation (41.18%). Usually the workers of different potato cultivation jobs, adopt forward bending posture with frequent postural change and sometimes twisting posture also. Highest degree of pain / discomfort was observed in lumber region of the workers of all categories. This problem might be attributed to the prolonged forward bending and twisting postures with frequent postural change. Kothiyal and Yuen, [24]; Olendorf and Drury, [28] and Reneman et al. [29] strongly pointed that forward bending and twisting posture imposes higher postural strain among the workers which might be the cause of discomfort in different body parts [23, 30]. Osborne et al. [31] studied on farmers and reported that lower back pain was the most common MSD among the farmers, followed by upper and then lower extremity MSDs. They also suggested that the prevalence of MSDs in farmers was greater than in non-farmer populations. Long term adoption of forward bending and twist posture was associated with postural stress. Investigation suggested that bending and twisting of back awkwardly and working in the same position were both significantly associated with prevalence of lower back problem [9, 32-34] and both were judged by workers to be the most problematic job factors contributing to pain and injury. Goldsheyder et al. [35] reported that there was a significant association of awkward postures with back pain and the prevalence of lower back problems was significantly increased with work tasks described as “bending or twisting back in an awkward way”. Das and Gangopadhyay [3] studied on potato cultivators and reported that prolonged work activity, high repetitiveness and remaining constantly in an awkward posture for a prolonged period of time may lead to MSDs.

According to the report of NIOSH [36], the kneeling, squatting and non-neutral trunk postures are the awkward posture, which are responsible for lower back disorder. The National Research

Council (NRC) and Institute of Medicine [37] also reported that there is a clear relationship between back disorders and physical load. The lower back pain (LBP) was commonly associated with decrease muscular strength, spinal flexibility, incapacity and eventually activity limitation due to sick leave and corresponding high costs to the society, which also reported by Van Tulder et al. [38].

The higher prevalence of work related MSD at different segments of the body of the workers might be due to use of significant force, repetitive movements and longer duration of exposure [23]. A constant repetition of movements imposes a cumulative work load which can cause pain and weakness and impaired function of the muscles and other soft tissues [39]. The physiologic problems that arise from repetitive work or overuse of certain muscles, tendons and soft-tissue structures have been addressed in terms of muscle fatigue, tissue density changes, and tissue strain [40]. Physiologic evidence shows that the rate and degree of tissue damage depends on the amount of force, repetition and duration of exposure [41]. The results also indicated that MSDs was prevalent in different parts of upper limbs. It was also revealed that most of the workers of three different potato cultivation tasks reported disorders in wrist and shoulder. Wrist problem was highest in potato plantation operation (66.67%) followed by potato harvesting (65.38%) and tunneling job (50.0%). However, Disorder in the shoulder was highest in tunneling job (63.33%) followed by potato harvesting (51.92%) and seed plantation operation (23.53%). All these potato cultivation tasks required frequent movement of the shoulder, but the frequency of movement was very high in case of tunneling job due to spade operation. In case potato harvesting job, they collect potato and load the collected potato in a basket and the workers had to lift the loaded basket to the head of the carrier in a regular interval. Thus the frequency of upper arm movement was very high and this might be the reason for the occurrence of shoulder pain of the workers. This may evoke shoulder muscular tenderness disorder. This is due to the static fatigue of the Trapezius muscle and multifactorial identification, including static and awkward posture and work practices [42]. In all those potato cultivation tasks, major percentages of workers were affected bilaterally. This might be due to the fact that in all operations the workers were using both right and left arms almost equally during performing the job.

The occurrence of MSDs exhibited variation in the subjects of different work experienced groups. The occurrence of MSDs was higher in the subjects of Gr.-A and Gr.-C than the Gr.-B. The higher prevalence of MSD in the workers of Gr. -A might be due to lesser experience and skill. As the workers were newly recruited they were untrained and possessed a little knowledge to operate the hand tools. From the study of the Häkkänen et al. [43] it has been revealed that among trailer assembly workers a higher rate of sick leave due to disorders of the upper limbs was found for new workers compared with experienced ones. The higher incidence of MSDs in the workers of Gr.-C might be due to reduced muscle strength and endurance with the advancement of age [44]. Alexopoulos et al. [45]; Guo et al [46] and Habib et al. [47] noted in their studies that MSDs was significantly increased with age.

The potato cultivators were compelled to adopt in different awkward postures for prolonged period while performing different jobs of potato cultivation. Ergonomic assessment of work postures is one of the starting points to address the problem of work related body pain. Researcher proposed different methods for ergonomic assessment of working posture and quantification of ergonomic risk factors. In the present study, different postures adopted by the cultivators while performing different tasks of potato cultivation were analyzed by OWAS, REBA and QEC methods. From the results of posture analysis of three jobs of potato cultivation, it was revealed that all postures adopted by the workers during potato cultivation jobs has been categorized as moderate to very high risk and this posture was needed corrective measure immediately.

According to the different posture analysis methods, the postures adopted by the male cultivators have been categorized as having ‘moderate’ to ‘very high’ risk levels in different tasks of potato cultivation. The workers suffered account of health problems, perhaps because of prolonged working hours, awkward posture and used less safety measures while working. The prevalence of MSDs also exhibited variation in the subjects having different work experience. Moreover, ergonomic interventions such as modifying work-rest schedules would improve the work conditions and postures of the male cultivators and reduce their MSDs. From this study it has been recommended that workers should avoid awkward work postures as far as possible and take adequate rest during their work for reducing job related health hazards. The strenuous posture is one of the major problems in potato cultivation jobs. This problem may be solved by devising new equipment, which can relieve them from adopting harmful bend postures. Avoiding loads during acute pain and performing some special types of exercises can reduce the low back pain. Awareness and training programs about the correct work posture, personal protective devices and using proper work methods among the cultivators may be another solution of the problem.

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JHE ACCEPT [#565]

October 6, 2015

Dear Dr. Prakash C. Dhara;

It is a pleasure to inform you that your paper as shown below has been accepted for publication as an Original paper in *Journal of Human Ergology*. Your paper will appear in Vol. 44 No.2, 2015.

Manuscript JHE#565: Amitava Pal, Sujaya De, Piyali Sengupta, Payel Maity, Hiranmoy Mahata, Saijuddin Shaikh and Prakash C. Dhara, Physiological Strain Among The Women Potato Cultivation In West Bengal, India.

Sincerely yours,

Masahiro Shimoda, Ph.D.
Editor-in-Chief, *Journal of Human Ergology*