Evaluation and optimization of work postures of female workers engaged in home based industries and ergonomic intervention for modifying a workstation

Thesis submitted for the award of the Degree of

Doctor of Philosophy (Science)

By

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Certificate

This is to certify that **Payel Maity**, M. Sc., Vidyasagar University, Midnapore (West), West Bengal, has completed her research work entitled, **"Evaluation and optimization of work postures of female workers engaged in home based industries and ergonomic intervention for modifying a workstation"** for the fulfilment of the award for the degree of Doctor of Philosophy (Science). It is a bona fide record of research work carried out by her, under my supervision and guidance. Payel 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.

She is submitting the revised thesis after necessary modifications according to the adjudicator's suggestions.

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

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Declaration

I hereby declared that the research work presented in the thesis entitled **"Evaluation andoptimization of work postures of female workers engaged in home based industries and ergonomic intervention for modifying a workstation"**, has been carried out by me in the Ergonomics and Sports PhysiologyDivision of Department of Human Physiology with Community Health, Vidyasagar University, for the fulfilment 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.

I am submitting the revised thesis after the modification according to the suggestions given by the adjudicator.

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(PAYEL MAITY)

Dedicated

To

My Parents

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Introduction

Today is the era of women who have diverse role in society. Women in the contemporary society are often saddled with multitasking-the responsibility of a full-time professional job besides domestic chores. Now women have become a large workforce in the production sector. It is a fact that all women work. Some of their work goes unrecognized because they do a variety of jobs daily which does not fit into any specific ‘occupation’. Most of them are involved in arduous household work. Women work for longer hours and contribute substantially to family income. Women do more work than men is a known fact. The daily work schedule of rural women is very challenging and laborious. In addition to household work, the other time and energy demanding activity for woman is care of livestock. The resultant is that women are overburdened as well as at continuous health risk.

Women suffer from multiple musculoskeletal problems that significantly damage their activities of daily living. In the home and work places where women performs tasks even though sitting, standing, bending, twisting, awkward posture, duration of work and inadequate rest pause are associated with the occurrence of serious musculoskeletal problems and musculoskeletal disorders.

1.1 Women at work:

Women form a significant proportion of the workforce and this proportion continues to increase throughout the world. Out of the 3.0 billion people that were employed around the world in 2008, 1.2 billion were women (40.4%) (International Labour Organization, 2009).

India today engages more than 4.5 crores of women workers employed in the industrial work. A sharp increase in female labor force participation rates have occurred in India during past three decades (Census of India, 1991). According to the Registrar General of India(Census of India, 2001), it was 25.63 per cent in 2001, up from 19.67 per cent in 1981 and 22.73 per cent in 1991. whereas, At All-India level the percentage share of females as cultivators, Agricultural labourers, workers in the household industry and other workers stood at 32.93, 38.87, 6.46 and 21.75 respectively.(Census of India, 2011).

The study focused on those female workers engaged in home base industries. These enterprises perform a vital role in development and in many countries like India, they play an important role in employing the majority of the industrial workers.

Women are prone to the highest levels of stress and its consequent fallouts, stress related illnesses, burnout and depression. The impact of stress and its effects reaches far beyond the workplace, home and personal well-being of women (NUPGE, 2009).

To understand the issue of occupational health problems of women, it is necessary to make a detailed study of the women's work in terms of the actual activity undertaken, the hours of work and the extent of remuneration received. Often they handle two or more task simultaneously. For that reason they are prone to suffer from work related diseases. Roughly, 1 out of 300 female is suffering from some occupation related disease (Srivastav et.al, 2000).

It is therefore not surprising that much of the findings include widespread and well-expressed concerns for the double burden of women at work and at home (Kane, 2005; Artazcoz et al., 2004). However, there is a general perception that women's occupational health issues are understudied, despite the enormous magnitude of the problem, especially in the developing countries where such issues are perhaps more prevalent (WHO, 2003). Women form 50% of population and constitute 60 % of work force but earn only 10% of income.

They perform multifarious activities in the home, farm and allied activities, which include weeding, harvesting, milking of animal, cleaning animal sheds, mud plastering of house etc. This makes their life miserable as the activities are not only fatiguing but also time consuming (Jamal, 1994). Rural women rarely report their musculoskeletal problems at the right time, "having learned to live with pain" they commonly develop physical disability. Left unaddressed, musculoskeletal disorders can result in lifelong pain and permanent disability (Gupta and Nandini, 2015).A part from other medical problems, pregnancy and child bearing aggravate the complications in females (Koley et.al, 2008).

1.2 Work-related musculoskeletal disorders

Work-related musculoskeletal disorders (WMSDs) are musculoskeletal disorders (MSDs) that result from a work-related event. MSDs are common among the workers engaged in physical activities. WMSDs have been a worldwide issue in many countries. MSDs are a significant public health problem due to their high impact on disability, personal suffering, absence from work, disability, and their direct and indirect costs to the health care system (PicavetandShouten, 2003).Work related Musculoskeletal Disorders (WMSD) are injuries or dysfunctions affecting muscles, bones, nerves, tendons, ligaments, joints, connective tissue, cartilages, and spinal discs (Kumar, 2001) caused by occupational or non-occupational tasks involving bad posture, high frequency of exertion or high force levels. WMSDs have induced several social issues such as medical expenses, wage compensation and reduced productivity, along with physical and psychological pain, sprains, strains, tears, and soreness of different parts of the body (Ayoub and Mital, 1989; Chaffin and Andersson, 1991). WMSDs are globally concerned and distributed among both developed and developing industrial countries (Choobineh et al., 2010).

Musculoskeletal disorders (MSD) such as low back pain are the most common work related injuries in manual material handling (MMH) tasks. Causes of lower back pain are varied. Most cases are believed to be due to a sprain or strain in the muscles and soft tissues of the back (Henschke et al., 2009). Over activity of the muscles of the back can lead to an injured or torn ligament in the back which in turn leads to pain.

1.3 Factors associated with WMSDs:

Many factors are associated with WMSD such as repetitive motion, excessive force, awkward and/or sustained postures, prolonged sitting and standing (Moore and Garg, 1995; Hagberg et al., 1995). WMSDs due to forceful exertion, repetition and awkward posture are experiencing lack of data concerning to the relationship between the above factors and associated injury (Kumar, 2001). Dohyung et al. (2007) defined musculoskeletal disorders (MSD) using three criteria based on the frequency, duration and pain intensity of the symptoms. The results showed that prevalence of MSD in these three criteria were 56.8%, 53.7% and 45.7% respectively. Mukhopadhyay et al (2007b) concluded that WMSDs are a group of disorders affecting the bones, muscles, ligaments and tendons of the human body. There are certain risk factors like awkward posture, force, repetitive activities and inadequate rest. Presence of all these factors sets the stage for WMSDs. This eventually leads to a decline in the productivity and quality of work.

Work-related musculoskeletal disorders (WMSDs) are one of the greatest occupational health concerns today. Of the many types of WMSDs, low back disorders (LBDs) are the most prevalent and by themselves constitute a major health and socioeconomic problem. Decades of research has identified certain physical workplace factors that increase the risk for LBDs.

Table 1.1: Work related physical risk factors (NIOSH, 1997)

Body part	**Strong evidence**	**Evidence**	**Insufficient evidence**	**Evidence of no effect**
Risk factor	**(+++)**	**(++)**	**(+/0)**	**(-)**
Neck and Neck/shoulder				
Repetition				
Force				
Posture				
Vibration				
Shoulder				
Posture				
Force				
Repetition		✓		
Vibration				
Elbow				
Repetition			✓	
Force		✓		
Posture			✓	
combination		✓		
Hand/wrist Carpal tunnel syndrome				
Repetition		✓		
Force		✓		
Posture			✓	
vibration		✓		
combination	✓			
Tendinitis				
Repetition		✓		
Force		✓		
Posture		✓		
combination	✓			
Hand-arm vibration syndrome				
vibration	✓			
Back				
Lifting/forceful movement	✓			
Awkward posture		✓		
Heavy physical work		✓		
Whole body vibration	✓			
Static work posture				

A review by the National Institute for Occupational Safety and Health (NIOSH, 1997) of epidemiological studies related to MSDs in the workplace found evidence for an association between LBDs and the following workplace factors. 1) Heavy physical work,2) Lifting and forceful movements, 3) Bending and twisting (awkward postures), and4) whole-body vibration.

Musculoskeletal Disorders (MSDs) are a highly prevalent occupational health hazard in industry causing substantial costs. A close relationship has been shown between physical risk factors and MSDs, in particular, high levels of force, deviated postures and repetitiveness (NIOSH, 1997)(Table 1.1).There are also strong evidence for relationship between the combination of forceful griping or pinching, poor posture and repetition in the occurrence of MSD in upper arm (Finneran, 2010).

1.3.1 Posture

The human body can adopt various types of postures according to the need of their jobs. The home based workers are also required to adopt different postures for performing different tasks. Awkward work postures are responsible for lower back discomfort as well as different segmental pain which might be resultant of long term damage. Postures acquired by the workers at the tasks performed are of great importance. A good posture provides comfort to the worker, enhanced productivity and safety from injuries while awkward postures were recognized as key ergonomic risk factors for WMSDs (Lis et al., 2007; Armstrong et al., 1986a; Putz- Anderson, 1988; Muggleton et al., 1999; NIOSH, 1997). Keyserling et.al.,(1986) postulated that working posture is determined by the interaction of many factors in the workplace such as features of work station layout, hand tool design characteristics, work methods and anthropometric characteristics. For the trunk posture, it is shown that sustained static postures of the trunk such as prolonged sitting or forward bending is an increased risk of low back pain.

Indian women adopt different forms of sitting postures during work and leisure. Squatting is one of the most common postural patterns and has been a part of the traditional lifestyle in India and other Asian countries. Indian women are also found to adopt a traditional sitting posture, i.e., sitting on the floor with folded legs. Women adopt such posture to perform various activities, e.g., a variety of domestic tasks, handcrafting, a complete range of professional work, leisure activities etc.

An adaptation of such postures is frequently observed in small scale home based industries in India. Most of the manually energized operations in these industries are evidence of such postures. An industry is identified in central India,where operators are mostly women and 91% of them are suffering from work related MSDs (Metgud et al., 2008). The women adopt long static postures for some of the activities, which increase the static muscular effort resulting in high physiological cost and low productivity. They perform these activities in their own convenient posture like sitting, standing, squatting or bending without realizing the harmful effect on the body. The fact that by keeping the body of the worker in natural alignment, the stress and strain of the women can be minimized without any excessive human input is often ignored. Due to this ignorance women suffer from various musculoskeletal disorders and unnatural posture when adopted for any work induces hazards on the supporting system at the spine. Much ergonomics research on sitting has been conducted with subjects adapted to Western chair sitting postures with the assumption being sitting on the chair are the most suitable way to sit.

However, a substantial proportion of the world's population is not habituated to chair sitting suitable in some extends. Due partly to cultural traditions, Asian and African people more frequently adopt sitting on the floor with squatting, crossed legs or on their knees in their works and daily activities. It has been identified that adopting squatting postures without any proper support would gradually cause postural stress.

Back pain problem has been a culprit to many occupational safety and health problems. Lack of ergonomics knowledge and interventions in daily activities of the workers as well as excessive manual material handling are among the many factors contributing to study related disorders (Koda and Ohara, 1999; Yeung et al., 2003).Sitting posture has often been discussed with respect to back pain. Mandal (1994) suggests that a seated person has a hip joint flexion of about 600 and the pelvis has a sloping axis, so that the lumbar region then exhibits a convexity, or kyphosis.

1.3.2 Duration of Work /Rest

Work duration, exertion cycle time and rest periods plays important role in reducing the risk of WMSDs. Certain studies have emphasized the importance of work rest duration for controlling WMSDs (Cook and Burgess-Limerick, 2004; Garg et al., 2006;Finneran and Gallwey, 2010). The work / rest pattern in the work cycle time may be important factor in assessing the risk for developing MSD caused by repetitive monotonous work (Christensen et al., 2000). Proper task analysis and work rest pattern is useful to lessen the mental fatigue and improve work efficiency. Work-rest schedules also influence the physiological and postural workload as exposed by the differences in working heart rate and postural discomfort. Suthar and Kaushik (2011) found that long hours of work, continuous attention, precision, job diversity, extreme postures, scanty nutrition and poor health apparently indicate that the farm women, whether tribal or non-tribal, are under serious physical stress.

1.3.3 Repetitive monotonous work

High repetition, excessive forces and awkward postures are a major cause of musculoskeletal disorders and complaints (Genaidy et al., 1994; Vanwonterghem, 1996; Westgaard, 2000) in industry and industrializing countries. Women in monotonous and repetitive work are more prone to get problems or ailments in the neck and upper limbs than men; for example, women were found to have twice the rate of men (Dimberg et al., 1985), and to take sick leave more often than men (Brulin et al., 1990).

Linton and Kamwendo (1989) compared medical secretaries with a poor or good psycho-social work environment, and found that those who worked in a poor environment reported neck and shoulder ailments three times as often as those who worked in a good environment. Levi et al., (1986) reported that stress was highest among workers with highly repetitive work tasks who maintained the same position during work and who found it impossible to influence the pace of their work. The findings of these studies suggest that both physical and psychological work demands result in physiological stress.

Finally, in a survey of studies using the Nordic questionnaires for musculoskeletal diseases, Kuorinka et al., (1990) stated that there appeared to be an increased risk of problems in the neck, shoulders and arms in monotonous and tensed work tasks performed in a sitting position. Christmansson et al., (1999) observed that organizational redesign of manual repetitive assembly jobs mostly impaired the psychosocial work environment and increased the physical stress and risk of MSDs.

1.4 Job description

The home based industries covered under the present study were essentially labor intensive and they are prone to suffer from work related health problems. Every industry plays a significant role in development of a country by contributing immensely to employment generation, production of goods and subsequent wealth creation. The production of these industries very often becomes the chief means of livelihood in a society. The employment provides sustenance to the societal members, and their daily requirements are satiated by the earnings.

In the present study three different job categories were selected. These are as follows:

1.4.1 Craft work:

Plate-1.1:Female workers are engaged in making different craft products

The craft work is a common small home based industry, which are performed in different districts of West Bengal e.g., Purulia, Bankura, Paschim and PurbaMedinipur etc. Female craft workers usually make different craft items, viz., soft toys, gift bags, decorating materials and other handloom products with different material like far, jute, synthetic cord, beads, grass, etc. in those workplaces (Plate 1.1). However, the workers especially who are engaged with knitting and making soft toys and bags were included in our study.During work they have to perform their tasks by using both hands simultaneously in sitting posture. The workers are ought to work for a long time in a static posture with repetitive movements.

1.4.2 Mat weaving:

Mat weaving is one of the important crafts of West Bengal providing seasonal employment to thousands of artisans spread over several districts of the state. Among the several varieties of mat woven "Madur" a type of reed mat woven mainly in Medinipur is the most popular.

Plate-1.2: Different phasesof weaving mat
Phase-I: Taking and preparing one single mat stick
Phase-II: Weaving the mat stick into the frame of rope
Phase-III: Making knots in the mat stick with rope
Phase-IV: Pulling the weaved stick close to previously weaved stick with the help of a shuttle

Weaving of mat (“Madur”) is a rural household industry with active participation of female family members. The looms take up a little space and are placed inside their own homes. The process of mat production involves a number of labour intensive activities. Mat requires two persons for the weaving. One person places the specially selected reeds and starts the process left to right by placing one thread down while the second person performs the same from right to left. The threads are then turned at the end and the process continued. The shuttle carries two threads. Different phases of this job have been described in Plate-1.2.

1.4.3 Golden thread (“jori”) work:

Plate-1.3: Different phasesof golden thread work performed by female workers.
Phase-I: Insert the golden thread into the hoops of sewing needle
Phase-II: Picking up the beads by using needle for stitching them by one after another
Phase-III: Knitting the cloth by raising the right hand upwards and keeping left hand downwards.

The golden thread (“jori”) work is one of the major home based industries in rural West Bengal. This industry is also run by mainly female workers with their extensive physical effort.In this work, the workers stitch on the cloth (‘sharees’) by golden thread to make it attractive and decorative. Different predefined art designs are made on the cloth piece with the help of golden thread. The workers have a definite workstation in which they have to perform this work. There was a working platform made up wooden frame having a certain height, length and breadth. The cloth piece is set in the frame in certain height. This platform facilitates the workers to work simultaneously by forming a small group (4-6 persons) who sit on floor in both sides of the platform. The entire work is done by the workers adopting sitting on the floor. During work the workers are using both horizontal and parallel ends to stich the cloth simultaneously. Different phases of this job have been presented in Plate-1.3.

1.5 Problem statement:

In the present study efforts were taken to evaluate different job related stresses of female workers of different home based industries from the viewpoints of ergonomics. Home based industrial work is one of the most tedious professions, requiring long hours of static work. It is also a high risk occupation for developing MSDs as awkward posture, repetitive movements, long working hours and inadequate rest pauses are associated with those jobs. The prevalence of WMSDs has been well recognized in occupational tasks with awkward postures. In the present investigation three jobs, viz., craft work, mat weaving, and golden thread work (‘jori’) were selected for ergonomics study. Most of the workers perform their task by sitting on the floor. The workers are found to adopt three different postures, viz., a) sitting on the floor with folded legs, b) squatting posture, and c) sitting on the floor with stretched legs.

They do not follow scientific methods, in most of the cases, to execute the tasks. Female workers are exposed to different types of stresses, e.g., physiological stress, postural stress and biomechanical stress during performing those tasks. As a result the female workers may suffer from work related drudgery. In the present study efforts have been made to evaluate the postural stress in different tasks and to find the suitability of different posture adopted by the workers.

In spite of the national and international importance there is a little ergonomic study on the effect of postural stress on female workers in home based industries. The present study has therefore, been carried out on some selected jobs of home industries with the objectives of determining the prevalence of musculoskeletal symptoms and other posture related problems.

Poor design of workstation also imposes postural stress which in turn adds to physiological stress. Musculoskeletal disorders and job related health problems may be associated with the drawbacks in the existing design of workstation. This may affect the productivity. In golden thread work a locally made work station is used for performing the task. The said workstation may not be compatible with the need of the workers. For example, the height of the workstation has been made arbitrarily by the owner of the factory or sometimes by the workers. Therefore, such workstations had no standard height. There was a wide variation in the physical dimension of work station. Therefore, the workers were sometimes required to bend or raise their shoulder for long time and remained in static posture which might cause biomechanical stress in different muscles and bone joints Therefore, an effort has been made to redesign the workstation for golden thread work considering ergonomics principle to minimize the strain on the human body by reducing job stress.

Chapter-II

Literature Review

Ergonomics studies may solve many of the human factor related problems of workers engaged in home based industry. Ergonomics investigation as well as application is also required on female workers. In India a good number of women workers, engaged in home based industries, are performing various tasks by acquiring squatting and Indian traditional posture, i.e., sitting on the floor with folded or stretched legs.The information regarding the home based industry and the workers engaged in this industry are limited. Not much ergonomics study is found in the literature. However, some of the ergonomics studies in home based industries and related jobs are pointed out below.

2.1Work-related musculoskeletal disorders

The work-related musculoskeletal disorders (WMSDs) denote health problems of the locomotor apparatus i.e., muscles, nerves, tendons, joints, cartilages, a spinal disc and related tissues, which have been empirically shown or are suspected to have been associated with exposures to risk factors at a workplace (Luttmann et Al., 2003). MSDs include a wide range of inflammatory and degenerative conditions affecting the muscle, tendon, ligament, joint, peripheral nerve, and supporting blood vessels (Punnet and Wegman, 2004). It is one of the leading causes of occupational injury and disability in both developed and developing countries (World Health Organization, 1985). Body regions most commonly involved are the lower back, neck, shoulder, forearm, and hand, although recently the lower extremity has received more attention (PunnetandWegman, 2004).

A high prevalence of the WMSDs has been recordedamong workers who are exposed to manual labor, work in unusual and restricted postures, repetitive and static work, vibrations and poor psychological and social conditions

(Watersetal.,2007).Musculoskeletal disorders have been described as the most notorious and common causes of severe long term pain and physical disability that may affect hundreds of millions of people across the world (Glover et al., 2005). They have also been recognized as one of the leading causes of significant human suffering, loss of productivity and economic burdens on society (Glover et al., 2005).

2.1.1 Common MSDs in Women

Differences in physiology between men and women, including hormonal effects on the connective tissues and decreased total muscle cross-sectional area, may play an important role for the differences in the injury rates of men and women (Knapiket al., 2001; Bell et al., 2000). Also, anatomical differences in women, such as the wider pelvis as well as their increased valgus angulation at the knee and increased foot pronation, may increase their risk of injury of the lower extremity (Knapiket al., 2001; Kowal, 1980). Some common MSDs in women are osteoporosis, spine disorders (particularly low back pain), disorders of the knee, shoulder, adhesive capsulitis and disorders of the foot. Men have more workplace accidents, but women report more illnesses such as ‘sick building syndrome’ and upper limb MSDs (Stenberg and Wall, 1995).

Work-related musculoskeletal disorders (WMSDs) affect the muscles, tendons, joints and nerves when they are stressed, or traumatized on a repetitive basis over an extended period of time.(Bryant, 2005). Back problems affected millions of people worldwide, i.e. 70-80% of people during their lifetimes. (VanVuuren et al., 2007). Neck pain occurred in between 15-44% of the general community, but was reported as affecting between 50-60% of office workers.(Hush et al.,2009) Carpal tunnel syndrome

(CTS) was one of the most common and disabling WMSDs,(Turner et al.,2007) affecting up to 25% of active workers.(Werner et al.,1998).

Low back pain (LBP) is one of the most frequent occupational health problems and accounts for a large number of losses in working days and disability for workers in modern industrialized societies. This accounted for about 20% to 30% of compensation claims by workers and up to 50% of all direct compensation costs (Spengler et al., 1986; Burdorf and Sorock,1997; Davis and Heaney, 2000; Elders et al., 2003; Hansson and Jensen,2004).

In India, Nag et al., (1992) examined the work stresses of women who were engaged in sewing machine operation in small garment manufacturing units. The short cycle sewing work involves repetitive action of hand and feet. The women had to maintain a constant seated position on a stool without backrest and the body inclined forward. Long-term sewing work had a cumulative load on the musculoskeletal organization, including the vertebral column and reflected in the form of high prevalence of discomfort and pain in different body parts. About 68% of the women complained of back pain, among which 35% reported a persistent low back pain.

A number of reviews have examined the evidence of work stress factors, working as perilous cause for back pain in past years (Davis and Heaney, 2000; Hoogendoorn et al.,2000; Vingard,2000; Hartvigsen etal., 2004).Ghaffari etal., (2000) showed that employees with high demands, low control, job strain, poor job satisfaction have higher incidence of LBP. Tissot etal., (2009) in their study showed that high job strain was significantly associated with LBP in women who usually sat at work. Hoogendoorn etal., (2002) described low job satisfaction as a risk factor for sickness absence due to low back pain.

Choobineh et al.,(2007) in their study on carpet weavers showed that these workers performed most tedious profession, requiring long hours of static work and suffer from LBP. According to Nag and Nag (2010), female weavers were more prone to developing MSDs in the lower back. Gangopadhyay et al., (2014) evaluated the low back pain among female 'Chikan' Embroidery workers of West Bengal, They concluded that low back pain was the most experienced pain symptom among the workers. It was significantly associated with prolonged work hours, static sitting posture and rigid work pattern.

Strain-inducing postures affect mainly manual workers, such as skilled tradespersons but also those employed (predominantly women) in sales jobs or domestic services. Tiring positions tend more to affect industrial manual workers. Female industrial manual workers are particularly affected by repetitive movements, while female professionals and managerial workers are prone to vertebral stress.

Cumulative trauma disorder (CTD) was identified by Gangopadhyayet al., (2003) among the workers who were engaged in highly repetitive jobs involving continuous hand exertion, vibration and localized mechanical pressure. An experiment performed on meat cutters, typists, tailors, visual display terminal (VDT) operators & weavers found that high repetitiveness, prolonged work activity and remaining in static posture for a prolong period of time can be regarded as the causative factors in the occurrence of CTD. A study by Desai (1994), on women in small scale industries also showed a significantly higher body pain and discomfort, attributable to their prolonged sitting postures.

Basuet al., (2008) performed a study on female workers engaged in the manual brick manufacturing industry in West Bengal. A questionnaire study was conducted among such female workers. Results revealed that a large number (81%) of workers complained of pain in different body parts. The main complaints concerned low back pain (50%), neck pain (38%) and shoulder pain (29%). The causes were the workers' awkward postures and heavy workload. Other health complaints included gynecological problems (56%), skin diseases (38%) and respiratory problems (42%). The workers' body mass index revealed that 28% of them were suffering from chronic energy deficiency.

Maity et al.,(2013) investigated work related musculoskeletal disorder and postural stress on brickmoulders in West Bengal, India. The study revealed that primary illnesses amongst the sample population was essentially musculoskeletal disorders, including shoulder pain, back pain, neck pain, and knee pain.

Another study on nurses of South-west Nigeria was made by Tinubuet al., (2010) and found that 84.4% of nurses had WMSDs once or more in their occupational lives and work related MSDs occurred mostly in low back (44.1 %), neck (28.0 %), and knees (22.4 %). Working in the same positions for long periods, lifting or transferring dependent patients and treating an excessive number of patients in one day were the most perceived job risk factors for WMSDs. Prevalence of WMSDs were found to be associated with years of work experiences in these nurses.

WMSDs have been a worldwide issue in many countries. In the U.K., the Health and Safety Executive (HSE, 2006) showed that Upper Limb Disorders are not confined to any one particular group of workers or industrial activity over recent years, but are widespread in the workforce.Furthermore, the HSE reports that WMSDs were the most common occupational illnesses, affecting 1.0 million people a year, with problems including lower back pain, joint injuries and repetitive strain injuries of various types.

In Taiwan, the Institute of Health and Safety began developing a work injury prevention strategy and health and safety standards for the Government, employers and employees in 2002 (Lin, 2003). Moreover, a nationwide study indicated (Guo et al., 2004) that 37.0% of 18,942 people who returned a questionnaire had WMSDs. In the U.S., the Annual Survey of Occupational Injuries and Illnesses conducted by the Bureau of Labour Statistics (2001) reported that there were 522,528 WMSDs cases, with a total of 329, 920 total employees from the service industries, resulting in absence from work. In fact, MSD cases are increasing every year; however, there is no worldwide scheme of prevention against these conditions (Lin, 2003).English et al., (1995) studied 580 cases and 996 controls; the diagnoses of the cases included soft tissue conditions affecting the shoulder, elbow, forearm, wrist, thumb, hand, and fingers; the controls included traumatic, degenerative, and inflammatory conditions, mostly of the legs and lower back, and found the risk highest for shoulders cases amongst female hairdressers. In 1988, an investigation reported through the National Health Interview Survey was analysed by Guo (2002), who pointed out that female Hairdressers and Cosmetologist are the third highest risk of the top 15 major occupations for lower back pain attributable to RA at work. Furthermore,

Lin (2003) pointed out that WMSD cases claiming compensation from labour insurance between 1999 and 2001 showed the highest levels of compensation being granted to Taiwanese workers in the Hairdressing and Barber industry for upper limb disorders. One year later, Wu et al, conducted a questionnaire survey given to 36 hairdressers from thirteen hair salons as part of a study of the musculoskeletal disorders in employees working in beauty salons in Kaohsiung, Taiwan. As a result, Wu et al, revealed that most of the discomfort comes from the shoulders (94.4%), lower back

(80.6%), and neck (77.8%). Moreover, a similar result from a quantitative study (n=360) by Chuang (2005), found that 94.4% of hairdressers voted that their shoulders were the most uncomfortable body region, followed bythe lower back and neck. In short, it isobvious that most research into WMSDs indicates that hairdressers suffer fromdiscomfort in their upper limbs, neck, shoulders, lower back and wrists.

Another study was done by Gupta and Nandini (2015), on Prevalence of low back pain in non-working rural housewives of kanpur, India. They suggest that 83% of the non-working rural housewives have low back pain and activity restriction due to their pain. They have significant impact of social burden on their low back pain. High prevalence (83%) of low back pain among rural housewives is an alarming sign for our society. Better health-care measures to enhance rural housewives education about good posture, ergonomic measures, health schemes, health awareness, and activity pacing could help rural housewives.

Low back pain imposes a considerable social and economic burden on the community and is one of the most common reasons for presentations to primary health care providers (Atlas and Deyo,2001,DeyoandWeinstein, 2001).

Musculoskeletal disorders (MSDs) are pain or discomfort of the muscles, nerves and tendons regions including other soft tissues (NIOSH, 1997). MSDs are the major work-related health issue among the industrial workers (Waters, 2004). The MSDs problems are associated with work related physical risk factors such as repetitiveness, work environment and psychosocial factors (Escorpizo, 2008). The WMSDs problems are the major complaints received from the workers performing repetitive task (Bernard, 1997; Linton andKamwendo, 1989; PunnettandWegman, 2004;Walker-Bone and

Cooper, 2005) in various industries (Aghilinejad et al., 2012; Balogh, et al., 2009; de Looze et al.,2009; Gooyersand Stevenson, 2012).

WMSDs problems result in low worker productivity (Xu et al., 2012), causing approximately 34% of the annuallost time (Ontario Ministry of Labour, 2009). It is because workers are not only more likely to be injured due towork related musculoskeletal disorders but they also tend to slow down (Resnick and Zanotti, 1997). WMSDscontribute 7% of the overall productivity loss (Medibank, 2011).

WMSDs are diseases related and/or aggravated by work that can affect the upper limb extremities, the lower back area, and the lower limbs. WMSD can be defined by impairments of bodily structures such as muscles, joints, tendons, ligaments, nerves, bones and the localized blood circulation system, caused or aggravated primarily by work itself or by the work environment (Nunes, 2009a).

2.2 Factors associated with WMSDs:

Many factors are associated with the MSD. The socioeconomic status of the workers may be responsible for different types of musculoskeletal disorders (MSD). Low education showed a significantly positive association with MSD at the bivariate level; however, it was not related in the multivariate model. Several studies have reported a non-significant association between education and MSD (Alexopoulos et al., 2003; Barnekow-Bergkvist et al., 1998), while Guo et al., (2004) found an inverse association between education and MSD in Taiwanese women.

The back pain, especially low back pain, was prevalent in more or less all categories of jobs. There were different risk factors for the occurrence of back pain. Staal et al., (2003) reported that the socioeconomic status was also one of the causes of the lower back pain. Other investigators (Kar et al., 2007, Gjesdal et al., 2009, Boyer et al.,

2009) also stated the same opinion that WRMSDs were influenced by socio economic condition of the workers.

These have each been associated with increased operator discomfort in occupational and non-occupational tasks involving deviated postures. Ergonomic interventions reducing the effects of these risk factors have been demonstrated to lower discomfort and also increased productivity with cost benefits (HSE, 2006). Other studies have also identified that occupational risk factors leading to MSD were repetitive motion, forceful exertions with limited opportunity for recovery (Armstrong, 1986a & b), poor and awkward postures (Hertzberg, 1955).

Literature survey reported the associations between MSDs and work-related psychosocial factors such as high workload/demands, high perceived stress levels, low social support, low job control, low job satisfaction and monotonous work (Deeney and Sullivan 2009, Caicoya and Delclos, 2010). Personal and behavioral risk factors, including increased age, female sex, increased weight, and lifestyle factors also affect the musculoskeletal system (Kaergaard& Anderson, 2000, Cassou, et al., 2002,Tsuritani et al., 2002, Palmer et al., 2003, Peltonen et al., 2003, Gjesdal et al., 2009). De Vries et al., (2011) suggested some success factors for staying at work and reducing MSD by some psychological intervention. Such interventions may be helpful in rehabilitation and occupational medicine and to prevent absenteeism, or to promote a sustainable return to work.

Some investigators mentioned psychosocial condition as risk factors of the occurrence of MSD. In Sweden an ergonomics study on animal production revealed that the livestock workers were contented with their psychosocial work environment; however, they reported high frequencies of MSD. The prevalence of MSD seemed to be associated with the physical rather than the psychosocial work environment (Lundqvist, 2010).

In many countries, the prevention of MSDs among the work force is considered a national priority (Spielhoiz et al., 2001). Several studies have demonstrated a relationship between certain jobs and risk factors that are associated with increased risks of developing MSDs (Bernard, 1997; Spielhoiz, et al., 2001; da Costa and Vieira, 2010). Psychosocial factors such as high job demands, low social (coworker) support, low job control, high and low skill discretion and low job satisfaction have been implicated as risk factors for MSDs (Ariëns, et al., 2001).

Besides the physical demand of the jobs, the ageing of the workforce was also a contribution to the widespread of WMSD, since the propensity for developing a WMSD was related more to the difference between the demands of work and the worker's physical work capacity that decreased with age (Okunribidoand Wynn, 2010).

2.2.1 Posture

Many jobs and activities in people's daily lives have them in squatting postures. Jobs such as housekeeping, farming and welding require various squatting activities. It is speculated that prolonged squatting without any type of supporting stool would gradually and eventually impose musculoskeletal injuries on workers. Workers who adopt unusual or restricted postures appear to be at higher risk of musculoskeletal complaints and often exhibit reduced strength and lifting capacity (Gallagher, 2005). Borah et al., (2014) studied on women workers engaged in cashew nut processing industry and observed that the workers had high prevalence of MSDs due to adoption of unnatural squatting posture on the ground for a long time.Poor postural working conditions and the absence of effective work injury prevention programs have resulted in a very high rate of MSDs as well (Bernard, 1997).

Carey and Gallwey (2002) evaluated the effects of wrist posture, pace, and exertion ondiscomfort. They concluded that extreme flexion caused greater discomfort than the othersimple types of deviation, and the combination of flexion and ulnar deviation resulted ingreater discomfort than the other combinations of deviation. In a study, HaqueandKhan (2009) found that if the ulnar deviation and wrist extension would be reduced by thedesign change in the pliers it reduces discomfort and increases productivity.

Khan et al., (2009) examined the influence of wrist deviation combined with forearm rotation angle on subjective discomfort and found that the discomfort rating increased rapidly while both the wrist deviation and forearm rotation were greater than 30% joint range of motion. Griecoet al., (1998) reported that, along with other postural problems, pronation and supination of the forearm were related to upper extremity disorders. Mukhopadhyay et al., (2007a) investigated the effect of forearm rotation, elbow flexion, task frequency and forearm torque exertion on perceived discomfort score. Discomfort was found higher at 45^0 (elbow flexion) as compared to 90^0 and 135^0, and also higher in forearm pronation as compared to forearm supination or neutral posture. Similarly, awkward elbow posture may be caused due to extreme pronation and/or supination of the forearm, particularlywhen the motions are highly repetitive (Mukopadhyay et al., 2007b).Cook and Burgess-Limerick (2004) proposed using a computer keyboard with the forearms unsupported as a causal factor for neck/shoulder and arm/hand diagnoses.

Kilbom and Persson (1987) demonstrated the relation of upper arm abduction to the onset of symptoms for WMSDs. In a handmade brick manufacturing plant, Trevelyan and Haslam (2001) also found 45^0 medial rotation of the humerus accompanied by 45^0abduction and 45^0 forward flexion of the upper arm were at the risk of developing WMSDs.

Like Korean workers, home based industry workers were also more frequently adopt squatting postures in their work and daily activities, compared to Western workers. Women in housekeeping activities regularly adopt this posture. This may be due to cultural traditions where the people of Korea and some of Asian countries commonly sit on the floor with crossed legs or on their knees(Chung et al., 2003). In contrast, Western culture promotes sitting in a chair. Therefore, a squatting posture is one of the most awkward postures commonly adopted by many workers in some parts of Asian countries.

Developments of new ergonomically designed model can improve many jobs and activities in people's daily lives have been performed in squatting postures. Jobs such as weaving, housekeeping, farming and welding require various squatting activities. It is speculated that prolonged squatting without any type of supporting stool would gradually and eventually impose musculoskeletal injuries on workers (Wu et al., 2008).

Workers reported complaints about musculoskeletal problems after adopting the squatting posture since they were supported with non-suitable facilities (Manuaba, 1997; Tirtayasa et al., 2003). Although this phenomenon is common in discussions about occupational safety and health, there have been a few in-depth studies about squatting postures from the viewpoint of physical human behavior (Bridger, 1995).

Chung et al., (2001) indicated that the stool height of 10 cm contributed to a low level of discomfort for those who often performed their job above the ground level. The discomfort feeling rating of the squatting posture was found to increase rapidly after 6 min of work. Despite the variability of typical seat-heights, little has been known about how a sitting posture changes in the population in terms of different body types and seat height alteration. Working on the ground level in a squatting posture is suspected to gradually cause the health risk of musculoskeletal injuries and to contribute to a higher rate of discomfort (Keyserling, 1988). During performing a dynamic motion task in lower level seating, the strategy of body angular movement can be quite different for those with functional limitations (Hughes et al., 1994).

Disorder and pain in the arm have been related to the gripping an instrument and awkward posture. Several factors which were considered to influence the static activity of the shoulder muscles were horizontal distance between the worker and the working place, position of the task, height of the working table, shoulder joint flexion, abduction/adduction and the posture etc. (Westgaard et al., 1988).Mukhopadhyay et al., (2007a) explored that industrial jobs involving upper arm abduction have a strong association with musculoskeletal disorders and injury. Awkward working postures, repetitive use of body segments, previous or existing injuries, long periods of standing, and genetic makeup of the individual and demographic factors were known to be important predictive variables of MSDs (Kivi and Mattila, 1991; Mani and Gerr, 2000; OccupationalSafety and Health Administration (OSHA), 2000; Fenske and Simcox, 2000).

Other groups of scientist reported that there was significant association of awkward postures with back pain (Burdorf et al., 1991). Prolonged flexion posture causes shortening of soft tissue, reduced back muscle endurance, physical inactivity and muscle weakness (O'Sullivan et al., 2006, Krisner and Colby, 2002).

In machine manufacturing plant (Xiao et al.,2004) and textile weavers (Singh et al.,2005), high physical demands, poor postures and insufficient recovery time are the contributing factors to develop low back pain.Study of Granata et al., (2005) found that work activities requiring static lumbar flexion for 15 minute periods contributed to changes in the reflex behavior of the paraspinal muscles, leads to decreases spinal stability, leaving the spine more vulnerable to injury. Abnormal posture creates a strain on ligaments and muscles that indirectly affects the curvature of the lumbar spine. Chronic low back pain affected the lower lumbar spine and limits the maximal range of lumbar extension (Evcik and Yucel, 2003).

Marschall et al., (1995) demonstrated subjects had significantly less latissimusdorsi activity when with less neck flexion (<350) and significantly larger hip angle (>1000). One study (Lee and Chiou, 1994) found that ‘‘poor sitting habits’’ were statistically associated with low back pain. MSDs are strongly associated with specific physical when they are intense, prolonged and also strongly associated with poor posture. There was also strong evidence for low back pain being associated with lifting/forceful movement and evidence for low back pain being associated with awkward posture and heavy physical work.

Cooper et al., (1994) and Thambyah et al. (2005) showed the evidence that osteoarthritis and cartilage damage can occur in the knee as a result of frequent or high contact stresses. Gallagher (2005) stated that the squatting posture appears to be the least stable of the restricted postures.

As shown by the comparative analysis on knee joint pressure between lying down with legs stretched out and various other postures, squatting causes the most pressure while kneeling applies the second-most pressure (Lee, 2004). Zelle et al., (2007) also showed that the average maximal contact forces for each leg were 34.2% bodyweight during squatting and 30.9% bodyweight during kneeling.

Literature study revealed that there are number of methods for assessment of postural stress in working condition. A systematic review was made by Osborne et al., (2012) some of which in this regard is mentioned here. All these methods was based on a postural classification (McAtamney and Corlett, 1993;Keyserling,1986b). The direct observation method was proved to be a good method for studying work postures when there was requirement of whole body movement. The validity of visual observation to assess posture in a laboratory-simulated material-handling task (Loozeet al.,1994) was established. However, continuous direct observation of individual workers was not only very laborious and expensive but was likely to lead to changes in working patterns and habits on the part of those being observed. There are several observational techniques include OWAS (Karhu et al., 1977), TRAC (van der Beek et al.,1992), PATH (Buchholz et al., 1996), RULA (McAtamney and Corlet, 1993), REBA (Hignett and McAtamney, 2000), LUBA (Kee and Karwowski, 2001) etc. Of these techniques OWAS, RULA, and REBA are widely used for body posture assessment of the workers.

2.2.2 Work and Rest Schedule

The work and rest cycle is a very important to eliminate the mental and physical boredom of the workers.So proper task analysis and along with work rest pattern is useful to alleviate the mental fatigue and improve work efficiency, life satisfaction

(Chen et al., 2008; Kar et al., 2010). Different studies also show that optimal work-rest schedule minimize segmental fatigue and reduce WRMSD prevalence.

Karam et al., (2009) stated in their study that every function of the human body can be seen as a rhythmical balance between energy consumption and energy replacement, or between work and rest. This dual process is an integral part of the operation of different agricultural activities. Turner (2004) affirmed that instituting micro pausing might reduce discomfort and pain by muscles, of the heart and of the organism as a whole. Rest pauses are indispensable for farm workers as they do more back breaking job and repetitive motions during agricultural activities. Farm workers are exposed bending, squatting, stooping or standing posture for long periods during their work. Lifting or carrying heavy loads are also part of agricultural activities. These awkward postures and heavy work cause musculoskeletal disorders. It was suggested that appropriate rest periods should be allowed to the farm workers to prevent musculoskeletal injuries.

Brulin et al., (1990) concluded that the fact that women worked more often in repetitive, monotonous work tasks than men was more important than gender per se. Dimberg et al., (1985) found that short stature was as important as gender in this regard. Repetitive work and static work with arms abducted or elevated at more than 60 degrees are associated with shoulder disorders (Bernard, 1997; Walker-Bone and Cooper 2005).

Task analysis along with work rest pattern is useful to alleviate the mental fatigue and improve work efficiency, life satisfaction (Chen et al., 2008). Studies also showed that optimal work-rest schedule might minimize segmental fatigue (Woodet al.,1997), and reduce WRMSD prevalence.

The effect of work rest schedule on posture and physiological parameters was studied by Tiwari and Gite (2006). They conducted an experiment with five subjects to study the influence of four work-rest schedules on physical workload during power tiller operation. The study indicated that the work-rest schedules did influence the physiological and postural workload as evidenced by the differences in working heart rate and postural discomfort. It was concluded that to avoid excessive postural discomfort the minimum duration of rest pauses should be of 15 min. The duration of the lunch break should be more than 45 min.

Faucett et al., (2007) concluded that the introduction of frequent, brief rest breaks may improve symptoms for workers engaged in strenuous work tasks. Micro pausing may be beneficial for the health of the workers. Turner (2004) affirmed that instituting micro pausing might reduce discomfort and pain by reducing muscle and nerve tension. Micro pausing to prevent fatigue is more effective than resting than to recover from it. micro pauses may be passive where the employee rests and active where the employee undertakes a range of stretching type exercises.

2.3 Workstation design

Several work place factors, such as repetitive work, awkward and static postures, have been identified as being associated with upper extremity pain and discomfort (Putz-Anderson et al., 1997, Ohlsson et al., 1995, Punnett et al.,2000). Studies in Iranian hand woven carpet industry have reported high prevalence of musculoskeletal problem amongweavers due to constraints of seat type and other factors, e.g., working postures poordesign of loom, working time, and repetitive work (Choobineh et al.,2004 and Choobineh et al.,2007).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, 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. 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).

Study of Shin et al (2008) suggested a practical and simple process for model designing consisting of 8 stages: needs assessment, ergonomics guidelines, anthropometry, brainstorming and idea sketch, preliminary model, drafting and rendering, working prototype, and user trials.

It appears from the above discussion that awkward postures, repetitive work or handling heavy loads are amongst the risk factors that may damage the bones, joints, muscles, tendons, ligaments, nerves and blood vessels, leading to fatigue, pain and musculoskeletal disorders (MSDs). Work-related MSDs are mostly cumulative, resulting from repeated exposure to loads at work over a period of time. Upper limbs (the hand, wrist, elbow and shoulder), the neck and lower back are particularly vulnerable to MSDs.

Squatting is one of the posture patterns under the influence of the traditional lifestyle in Asian countries. The workers typically adopt their jobs in prolonged squatting postures in various fields to handle objects on the ground in furniture assembling, agriculture, metal welding and trimming, shoe making, homemade-food industries and other areas of small-scale industries like crafting, weaving etc.

From the literature review it emerges that there is still a lack of data about the home based industry in India. This sector generates employment for the local youth, household women. However, currently there are no statistical data on injury rates, diseases or disorders prevalent in this sector. Therefore there is a need to investigate the effect of awkward posture in development of risk regarding WMSDs.

Literature survey did not reveal very much recent study available regarding the occupational and postural stress and other general health status of home based industryworkers in West Bengal and even in India.So ergonomic intervention are very much requiring for assessing the occupationaland postural stress level among home based industry worker in West Bengal.

The design of workstation, which is particularly used by the golden thread workers, should be designed from the viewpoints of ergonomics studies. No such studies have been noted in the literature. It was concluded from the above review that there is a real lacuna in this field. The present study has been planned to fill some of these lacunae. It focuses to the evaluation of existing workstation as well as redesigning the workstation.

Chapter-III

Aim & Objectives

3.0 Aim and Objectives

The main aim of the proposed investigation was to find scope of ergonomic application in different jobs where sitting on floor and squatting postures are adopted by the women workers. Efforts have been made to evaluate the postural stress of the workers in different jobs and to find their relationship with physiological response. A job specific suitable work postures may be suggested from the viewpoint of ergonomics. A suitable workstation may be redesigned, to assure better work posture.

To fulfill the aim followings are the main objectives:

3.1 General objectives:

1. To evaluate general health problems of female craft workers, mat weavers and golden thread workers
2. To evaluate work related health problems of female craft workers, workers, mat weavers and golden thread.

3.2 Specific objectives:

3. To find the suitability of existing work posture adopted by the women workers engaged in different jobs mentioned above
4. Optimization of work posture in relation to job and work
5. Ergonomic intervention by redesigning the workstation for golden thread work

Chapter-IV

Methodology

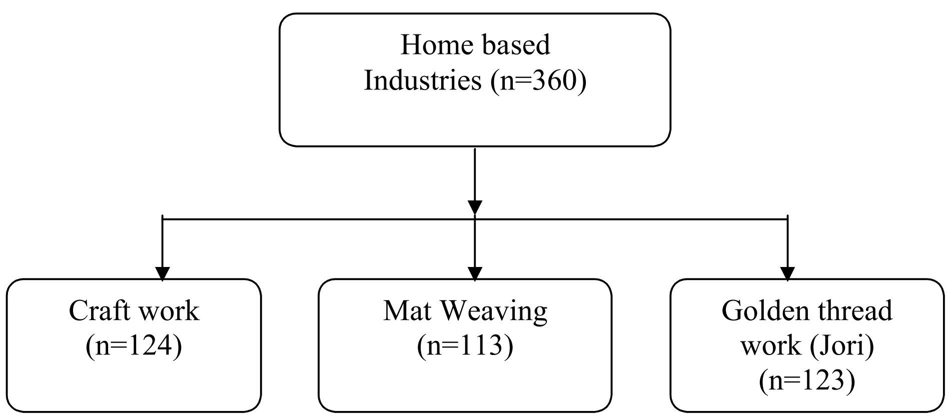
4. 0 Methodology

4. A Experimental planning

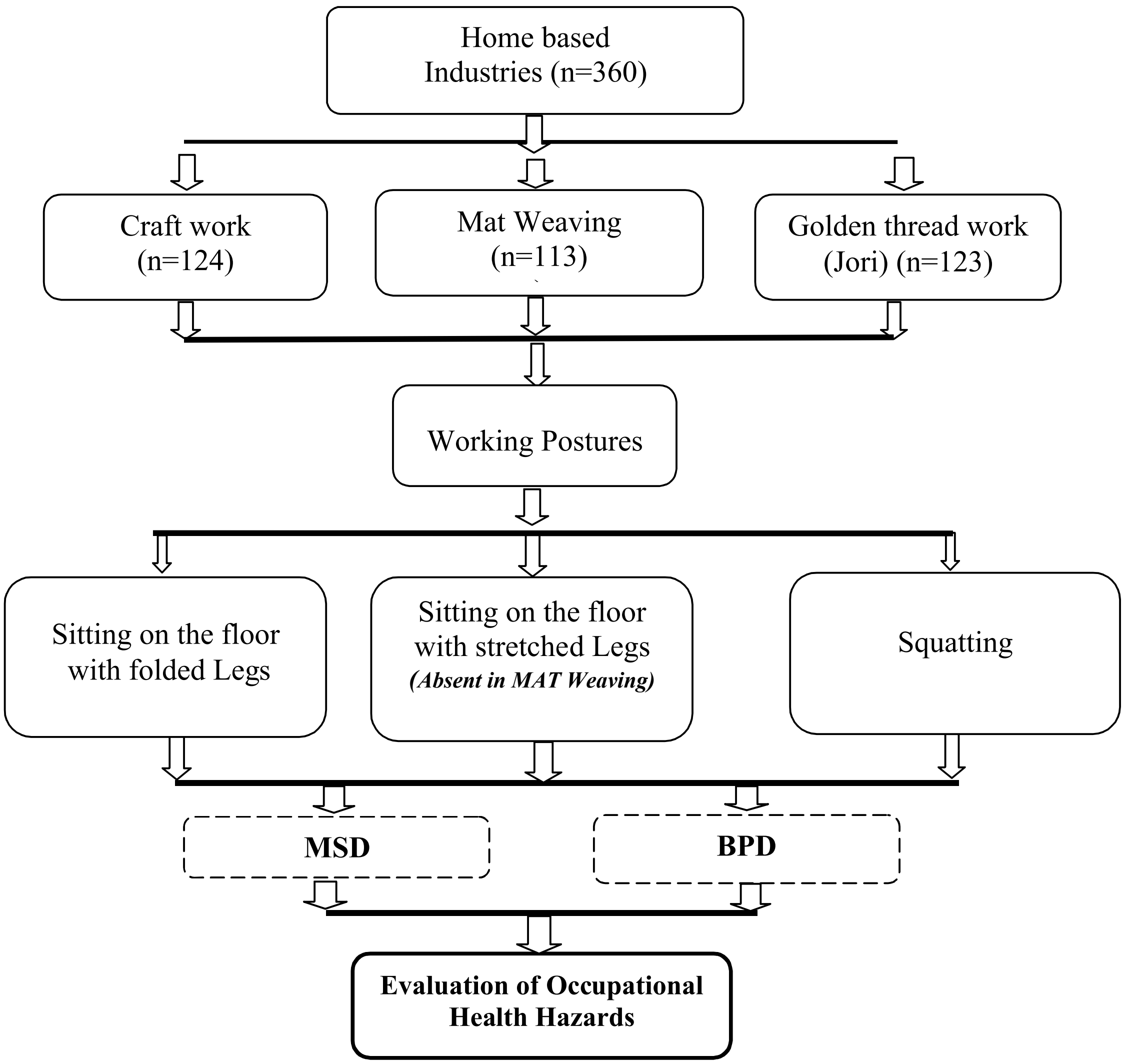
To fulfill the above aim and objectives the following experimental design has been made for 3 different jobs of home based industries i.e., craft work, mat weaving and golden thread work. A cross sectional study has been done for all three groups to assess the occupational, physiological and postural stresses of the workers. It has been divided into three phases. After that from the base line data an experimental study was done on golden thread workers to redesign the workstation height for golden thread work. The experimental designs are as follows:

4. B Experimental design

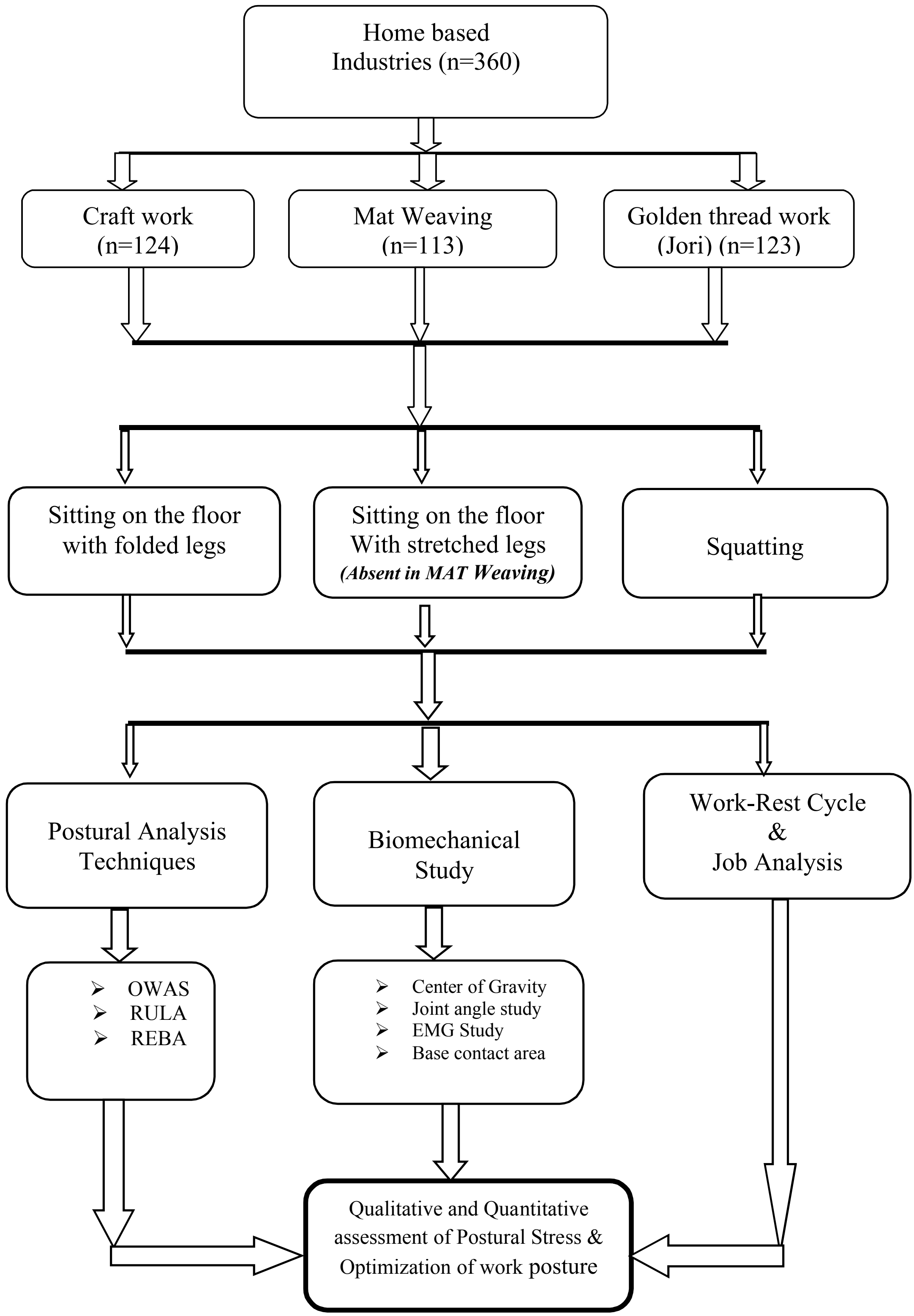
Phase 1-Selection of job



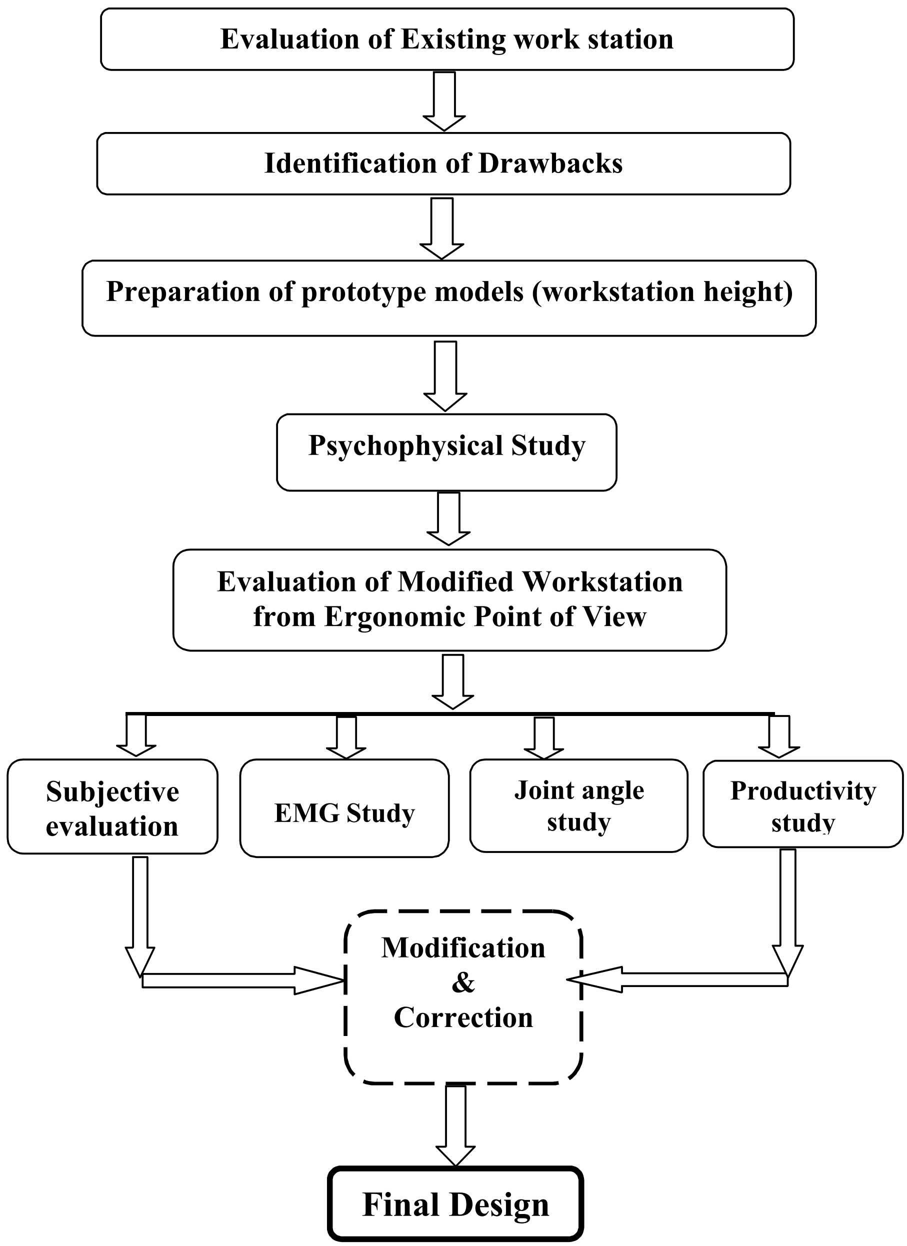
Phase 2- Evaluation of occupational health hazards



Phase 3-Evaluation of postural stress and job analysis



Phase 4-Redesigning of workstation height for golden thread (jori) work



4.1 Selection of Site

The study was conducted on female workers engaged in different home based industries in different districts of West Bengal, viz.,PurbaMedinipur, PaschimMedinipur,Purulia, and Bankura.The engagement of a large number of women in home based industries was the main criteria for selecting these districts.The sampling targeted specifically those female workers who were engaged in knitting, making soft toys, bags, mat weaving and golden thread work.

4.2 Selection of Subjects

The present study was carried out on 360 randomly selected adult female workers from threedifferent home based Industries where they habituated to perform their tasks in sittingposture, especially sitting on floor and squatting postures.

The exclusion and inclusion criteria are:

4.2.1 *Inclusion criteria:*

- Female subjects with not less than 4 years' experience in home based industry
- Subjects having age 18 years to 55 years
- Apparently healthy subjects

4.2.2 *Exclusion criteria:*

- Male subjects
- Pregnant and lactating female
- Subjects below 18 years
- Subjects above 55 years
- Subjects with physical deformities

- Subjects having acute cardiovascular, serious arrhythmias, chronic addiction and other major diseases.

The distribution of selected female workers in different jobs has been shown in Table 4.1.The workers who have been engaged in the profession for not less than 4 years, were only selected .The age range of the subjects was 18–55 years. The subjects were further subdivided into three subgroups according to the age for studying the prevalence of musculoskeletal problems. The age groups were divided the selected population as – younger adults (Group A: 18 -30 years), middle aged adults (Group B: 31 – 45 years) and relatively older adults (Group C: > 45 years).

Table 4.1a: Distribution of selected female workers in different jobs

Jobs	Number of subjects participated in the study
A. Craft workers	124
B. Mat weavers	113
C. Golden thread worker	123

Plate 4.1: Three working posture adopted by female workers:a) Sitting on the floor with folded legs b) Squatting posture and c) Sitting on the floor with stretched legs

The women workers had to adopt different working postures under sitting condition as shown in Plate-4.1. The subjects were further divided into sub-groups on the basis of the posture(s) they adopted during work(Table-4.1b).

Table-4.1b:Frequency of selected female workers in different jobs according to their working posture

Jobs	Postures adopted by the workers		
	Sitting on the floor with folded legs	Squatting posture	Sitting on the floor with stretched legs
A. Craft workers	49	20	24
B. Mat weavers	48	60	-
C. Golden thread worker	68	28	18

Ethical approval and prior permission (Reff.no.-VU/R/Ethical/IEC-07/2012) was obtained from institutional Ethics Committee before commencement(Appendix-I)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 to the subjects verballyin local language (Bengali) and written informed consent (Appendix-II) was obtained from the subjects during field visits and the available workers of the above mention areas were randomly selected as subjects. They were measured on the same day or another as per their agreement by fixing prior appointments. A few parameters were studied on same number of subjects but some of the parameters like job analysis, postural analysis and parameters which were included in the redesigning of workstation, were studied on lesser number of subjects. The numbers of subjects selected for study of different parameters are mentioned in respective chapters and tables.

4.3 Study of Socio-economic Status

The socio-economic status of workers was evaluated by modified Kuppuswami scale (Gururaj and Maheshwaran, 2014). The educational level of the subjects was evaluated by questionnaire technique also. The subjects were classify intoilliterate, primary educated, secondary educated etc. The socio-economic status of the workers was determined by the scores suggested in this scale. The score obtained by each person in education, occupation and income was added to get the final score and accordingly the subjects were categorized. Five different categories from the lower to upper have been suggested in this scale. The questionnaire of modified Kuppuswami scale for Socio-economic status has been given in Appendix-III.

4.4 Measurement of Body Dimensions

4.4.1 Anthropometry

Different anthropometric dimensions of the subjects were taken by ananthropometer (Holtain) and steel tape by adopting proper landmark definition and standard measuring techniques (Ermakova et al., 1985; Weiner et al., 1969).The all data were taken with the mean of three consecutive trials. The following anthropometric measurements were taken:

- **Height:** The vertical distance from floor to the vertex was measuredby an anthropometric rod. The head was oriented in the eye-ear plane (Fig 4.1).

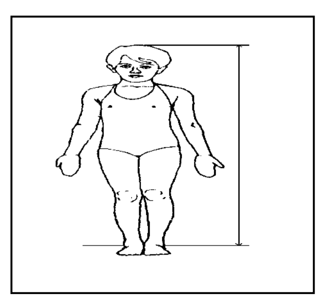


Fig 4.1: Measurement of height

Weight: The body weight of the subjects was measured by portable weighing machine with an accuracy of 0.5 kg. All subjects were asked to wear shorts and vestand were bare footed during measurements.

4.4.1.1 Anthropometric Index

Body Mass Index (BMI):

Body Mass Index (BMI) is the gold standard to be used in adults to assess the nutritional and anthropometric status of theworkers (Dorlencourt et al 2000) and it can be used in monitoring anthropometric changes and disease risk analysis for the population (Muñoz et al 2010). The BMI was computed by the following formula (Park 2005):

$$\text{BMI} = \text{Weight (kg)} / \text{Height}^2 \text{ (mt)}$$

Subjects were further classified by WHO BMI cut-offs in Asian and Pacific populations (WHO/IASO/IOTF 2000; James et al. 2002), as shown in table 4.2.

Table 4.2: Classification of weight status according to BMI in Asian Adults

Classification		BMI (kg/m2)
Underweight		< 18.5
Normal range		18.5 – 22.9
Obese	At Risk	23.0 – 24.9
	Obese class I	I 25.0 – 29.9
	Obese class II	> 30.0

4.5 General Health Status

4.5.1 Blood Pressure:

The systolic and diastolic blood pressure of the workers was measured during resting condition. The blood pressure was measured by auscultatory method, with the help of a sphygmomanometer (mercury type) and a stethoscope (Weiner and Lourie, 1981). Resting systolic and diastolic blood pressures of the subject were measured after taking rest in a sitting position for at least 15 min prior to measurement and again at least 10 min after the first reading.

Table 4.3: Classification of subject by systolic and diastolic pressure

Blood Pressure Classification	Blood Pressure level (mmHg)	
	Systolic blood pressure (SBP)	Diastolic blood pressure(DBP)
Normotensive	<120 mm Hg	<80 mm Hg
Hypertensive	≥140 mmHg	≥90 mmHg
Hypotensive	≤ 90 mmHg	≤ 60 mmHg

The mean values of three measures were used in analyses. The subjects were classified as normotensive, hypotensive and hypertensive according to the following the US Seventh Joint National Committee on Detection, Evaluation and Treatment of Hypertension (JNC VII) guidelines (Chobanian et al, 2003)(Table 4.3).

4.7 Evaluation of Occupational Health Hazards

4.7.1 Musculoskeletal Disorder:

The musculoskeletal disorder(s) (MSD) of the female workers were evaluated by modified ‘Nordic’ questionnaire (Kuorinka et al, 1987) during adopting the following sitting postures - sitting on the floor with folded legs, squatting posture, and sitting on the floor with stretched legs. Some of the disorders were assessed by direct observation method.

4.7.2 Body Part Discomfort (BPD) Rating:

To evaluate the segmental pain, the subjective assessment was employed. The intensity of pain or discomfort in different body segments was assessed by a 10 point scale which is a modified pain mapping scale of Wilson and Corlette(1985). The scale was graded from no discomfort at all to maximum discomfort. The discomfort was assessed in three sitting postures, i.e., sitting on the floor with folded legs, squatting, and sitting on the floor with stretched legs.

In present study, human body was divided into 10 segments (Fig.4.2). The subject was asked if she experiences discomfort from any part of the body. If so, the subject was asked to mention all body parts with discomfort, starting with the worst, the second worst and so on all parts have been mentioned. The overall discomfort level was computed as the mean value of the discomfort level assessed at various body Segments. 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 10 point scale arranged in the following way –

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

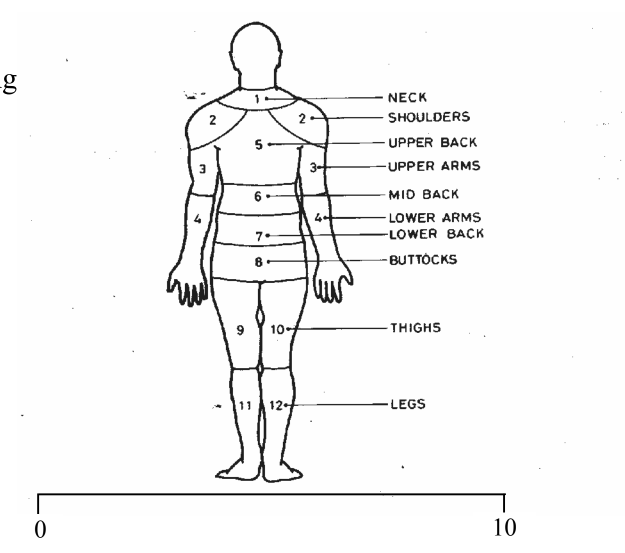


Fig.4.2: Different segments of the body

4.8 Evaluation of Work-Rest Cycle:

The work-rest pattern of the workers was determined by directly observing their work as well as by taking interviews of the workers. The work-rest cycle of different tasks of the workerswas 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 method employing video-photography of the task performed by the workers.

4.9 Job Analysis:

There are several cyclic tasks in home based industries, each cycle was analyzed and evaluated by applying time and motion study. For this purpose video photographic technique (Marschall et al, 1995) was used. The recording of each phase was done by a video camera (Sony Handicam, Model No.-DCR-HC40E). Postural changes of the workers were captured by the video camera and then the video records were transferred into a computer. Thenthe postural changes were analyzed by using the software XingMPEG player (Version 3.30). The time for each component or phase was recorded using software timer.

4.10 Evaluation of Postural Stress

4.10.1 Postural analysis:

The posture adopted by the workers in their working place depends upon the type of work, personal characteristics, to perform the particular work and also the duration and frequency of the work cycle.

The postures were chosen from the working images recorded with camera (Sony Handycam and Nikon SLR). When taking pictures of working postures, the camera was positioned at a suitable angle to the operator so that three-dimensional working postures could be identified during playback. The selected postures used in this study were those that the field observers classified as stressful to the human musculoskeletal system. Postural analysis can be a powerful technique for assessing work activities as the risk of musculoskeletal injury associated with the posture. So, various techniques have been applied for postural analyses to identify the stress of different phases of work.

4.10.1.1 Posture Analysis by Direct Observation: Postural pattern:

The postures adopted in different tasks of home based industries 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 for having food break was excluded from this study. 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.

The cautious and repeated observations were made for minimizing errors. The working postures were divided in to three major types – Sitting on the floor with folded legs, Squatting posture, and Sitting on the floor with stretched legs.

4.10.1.2 Postural stress analysis by OWAS, REBA and RULA methods

❖ **OWAS:**

The OWAS technique (Ovako Working Posture Analysing System) was developed by a Fininish steel company of OvakoOy (Karhu et al., 1977) and modified by Heinsalmi, P., 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 amount of force used. The technique classifiedcombinations 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(Table 4.4), which indicate the urgency for the required workplace interventions (Karhu et al., 1977 and Nevala, 1995).

Table 4.4: Action categories for OWAS technique

Score	Action categories	Corrective action
1	No corrective measures	Normal postures, which do not need any special attention
2	Corrective measures in the near future	Postures must be considered during the next regular check of working methods
3	Corrective measures as soon as possible	Postures need consideration in the near future
4	Corrective measures immediately	Postures need immediate consideration

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

❖ **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. The posture classification system, which includes the upper arms, lower arms, wrist, trunk, neck, and legs, is based on body part diagrams (Hignett and McAtamney, 2000). The method reflects the extent of external load/forces exerted, muscle activity caused by static, dynamic, rapid changing or unstable postures, and the coupling effect. Unlike OWAS and RULA, this technique provides five action levels(Table 4.5) for evaluating the level of corrective actions:

Table 4.5: Action categories for REBA technique

Score	Risk level	Corrective action
1	Negligible risk	corrective action including further assessment is not necessary
2-3	Low risk, change may be needed	corrective action including further assessment may be necessary
4-7	Medium risk, further investigation, change soon	corrective action including further assessment is necessary
8-10	High risk, investigate and implement change	corrective action including further assessment is necessary soon
11^{+}	Very high risk, implement change	corrective action including further assessment is necessary now

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

❖ **RULA:**

The RULA (Rapid Upper Limb Assessment) technique 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 exertedon the body. Based on the grand score of its coding system, four action levels,(Table 4.6) which indicate the level of intervention required to reduce the risks of injury due to physical loading on the worker, were suggested (McAtamney and Coriett, 1993):

Table 4.6: Action categories for RULA technique

Score	Risk level	Corrective action
1 or 2	acceptable posture	posture is acceptable
3 or 4	further investigation, changes may be needed	further investigation is needed and changes may be needed
5 or 6	further investigation change soon	investigation and changes are required soon
7	investigate and implement change	investigation and changes are required immediately

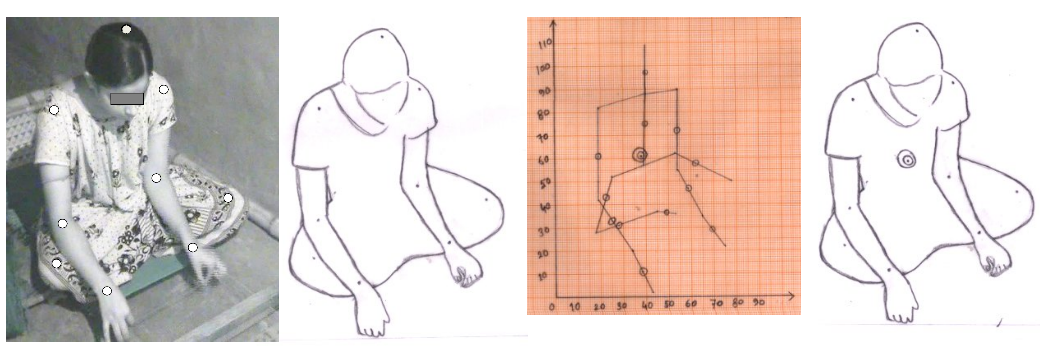
- The worksheet for RULA method has been given in Appendix-VI.

4.11Biomechanical Study

The biomechanical analysis is another component for the study of postural stress. The biomechanical studies were made by determining the center of gravity of the whole body, the joint angles study, the EMG study and base contact area of the female workers in different working posture.

4.11.1 Analysis of Center of Gravity

The whole body centers of gravity (CG) of the workers were determined by segmental method (Page, 1978) in normal erect posture, which was taken as reference posture, and in three different sitting postures. The location of CG was compared between normal erect and other sitting postures. For using this technique a photograph of the subject was used to finding the location of center of gravity of each 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.



(a) (b) (c) (d)

Fig.4.3: Steps of determination of CG by segmental method [(a) photograph with stickers at different body joints; (b) contour diagram; (c) stick diagram; (d) Location ofCG]

The following procedure was adopted for determining the CG:

Procedure:

(a) The location of the extremities of the individual segments was marked by placing white stickers of the following body joints: Supra sternum, acromion, elbow, wrist, waistandknee. Stickers were placed on both left and right joint except supra sternum as shown in Fig. 4.3(a).

(b) The subject was asked to adopt his/her natural (relaxed) erect posture. In this posture, photograph of the subject was taken. Then the subject was asked to perform their work and the photographs were taken.

(c) On a good quality tracing paper a contour diagram of the photographs were traced and the marked body joints were traced on the tracing paper. The vertex, dactylion III and the end of second toe were also marked on the contour diagrams shown in Fig.4.3(b).

(d) The extremity limits were joined to form a stick diagram consisting of fourteen (14) segments (Fig.4.3c)

(e) The CG of each segment was then calculated by multiplying the percentage of that segmental weight. The percentages of segmental CG location from the proximal end (Clauser et al., 1969) are given bellow:

Head & Neck - 46.6%, Trunk - 38.0%, Upper arm - 51.3%,

Forearm - 39.0%, Hand - 48.0%, Thigh - 37.2%,

Calf – 37.1%, Foot - 44.9%

(f) Then the stick diagram was placed on the positive ordinate of the X and Y-axis in the transparent graph paper.

(g) The X and Y coordinates for each of the 14 segment mass centers (segmental CGs) were determined.

(h) A standard worksheet was used to record the X, Y coordinate values and the moments of those segments was computed by multiplying the coordinate values (X, Y) by the constants (proportion of body weight), as shown in Table-4.7.

(i) The algebraic sum of the X products represented the X- coordinate of the total body's mass center and the algebraic sum of the Y products was the Y-coordinate. Those values were located and marked on the tracing paper as shown in Fig. 4.3(d).

Table 4.7: Worksheet for computing segmental 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					

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

Percentage of location of Vertical CG=

(Length of the CG from the ground/ Total length of the body) **x** 100

Percentage of location of Horizontal CG=

(Distance of left leg from the projected point of whole body CG on the Base/ Distance between two legs) **x** 100

4.11.2 Joint angle study:

Different body joint angles were measured by a goniometer (Lafette, USA, Model No. - APM-I). The goniometer was placed at specific body joints (mentioned below) and reading was taken by proper placement of the arms of goniometer on the body parts. The angles were measured in normal erect posture as well as different working postures. The different joint angles, e.g., shoulder, elbow, wrist, hip and knee were measured. The joint angles were measured in the right and left sides of the body. During the measurement of joint angles of the body, the center of the goniometer was adjusted over the estimated center of the joint and the reference arms were aligned to the long axes of the adjoining body segments, which was taken as the reference position representing the zero angles.

In some cases particularly in working condition, photographic technique was employed. At first the photograph of the subject was taken, then the line was drawn on the both side of the joint and the angle was measured with the help of a protector.

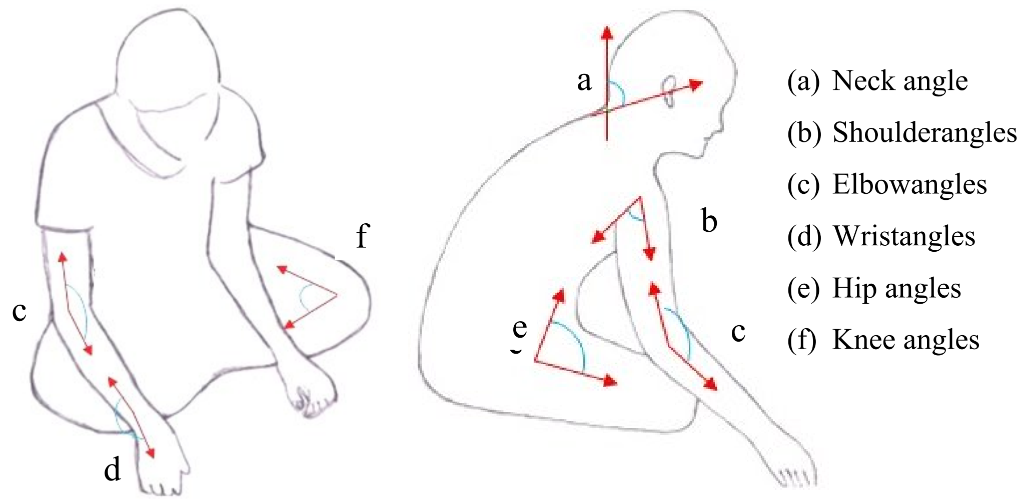


Fig 4.4: Differentbody joint angles adopting working posture

(a)**Neck angle:** It is the degree of forward head posture or neck protraction, typically defined as the angle between true vertical and a line connecting C7 (as shown in Fig. 4.4a).

(b)**Shoulder joint angle-** Itis the angle between the vertical trunk (lateral) line and the upper arm at acromial joint region(as shown in Fig. 4.4b). The line was drawn on the back where one arm of it was fixed (reference position) along the body line and the other line was drawn along the midline of the upper arm. The shoulder joint angle was measured in one plane, i.e., in sagittal plane.

(c**) Elbow joint angle-** It is the angle between the upper arm and lower arm (Fig 4.4c). The line was drawn on the elbow joint; one of the arms of the instrument was fixed in the mid line of the arm (reference position) and the other one was drawn at the mid line of the lower arm.

(d)**Wrist joint angle-** It is the angle between lower arm and hand(Fig 4.4d). The line was drawn on the wrist joint; one of the arms of the instrument was fixed in the midline of lower arm (reference position) of the subject and the other line was drawn at the midline of the backside of the palm.

(e) **Hip joint angle-** It is the angle between the trunk and the thigh(Fig 4.4e). The line was drawn on the waist line; one line was drawn on the vertical trunk (lateral) line (reference position) and another one was in the mid line of the thigh.

(f) Knee joint angle- It is the angle between the thigh and lower leg (Fig 4.4f). The line was drawn on the knee joint at the midline of the thigh (reference position) and the midline of the lower leg.

4.11.3 Measurement of Base contact area:

The base contact area of the body of the workers was determined in different postures, viz., squatting, sitting on the floor with folded legsand sitting on the floor with stretchedlegs. A white art papers were placed on the sitting surface on which the subjects was asked to sit andthe outer contour of the contact area was drawn on the white art paper. The drawn boundary areas were measured with a Planimeter by dividing the whole contact area into several subdivisions.

4.12 EMG Study:

The EMG of the shoulder (Trapezius) and back (Latissimusdorsi) muscles of female workers was recorded with the help of the BIOPAC system (USA). This laboratory study was carried out on 10 randomly chosen female workers from each job groups amongst previously selected subjects.

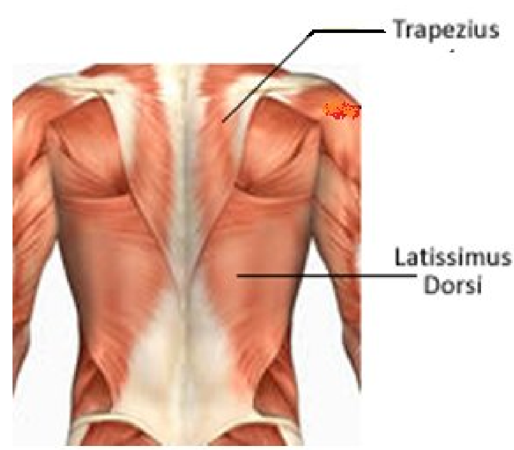


Fig 4.5: Anatomical location of selected muscles

The random selection was made according to the alphabetical order of the names of the selected subjects. The subjects were asked to sit in resting and relaxed condition by adopting normal Indian traditional sitting posture i.e., sitting on the floor with folded legs; this posture was taken as reference posture. Then they were asked to work in three different working postures, i.e., sitting on the floor with folded legs, squatting posture, and sitting on the floor with stretched legs. The EMG was recorded in those postures.

(a) Muscle selection: For the EMG study two muscles, viz., shoulder muscle (Trapezius) and back muscle (Latissimusdorsi) were selected (Fig.4.5) according the selection criteria deduced by Marchall et al., 1995.

Fig 4.6: EMG study of shoulder (a) and back muscle (b)

(b) Subject preparation: At first subjects were asked to wear minimum clothing, so that the muscle could be detected by anatomical landmarks, based on dominant bone areas and prominences or other structures that can easily be palpated from dorsal plane of body.

Then skin preparation was done by soft rubbing with a very fine sand paper to remove dead skin, sweat and dirt. Whenthe skin typically turned into a light red color, it was said to be ingood impedance condition. After this, skin preparation, silver / silver chloride pre-gelled disposable electrodes were placed over the muscles. The diameter of the conductive area of the electrode was 1cm.Electrodes were attached along the direction of the muscles fibers of the muscle .Three electrodes were placed in the required muscle with 2cmof inter-electrode gap (center point to center point) and electrodes are applied in parallel to the muscle fiber direction (Marschallet al, 1995).Then the leads (SS2L) were attached to electrodes.One of them was used for positive signal, another for negative signal and the rest was neutral.

- The locations of recording electrodes for shoulder muscle (Fig. 4.6a) were as follows (according to Villaneuva et.al, 1997):

1) At the level of the 2nd or 3rd vertebra (C2-C3),right paravertebral, over the cervical portion of the descending part of the trapezius muscle to record the activity of neck extensor muscle
2) At midpoint between the right acromion and the spine of the right 7th cervical vertebra (C7), to record the activity of the trapezius pars descendens muscle, and
3) The ground electrode ere attached lateral to the recording electrodes.

- The locations of recording electrodes for back muscle (Fig. 4.6b) were as follows :

1) At the proximal part of the muscle.
2) At the distal part of the muscle, and
3) The ground electrode ere attached lateral to the recording electrodes.

Instrument setup: At first the computerwas connected to the system was turned on and make sure that BIOPAC MP35 unit was switched OFF. Then electrode lead (SS2L) was plugged in Channel 3 (CH 3) and BIOPAC MP35 unit was switched on. After the preparation of the subject, the leads were connected to the BSL Data Acquisition Unit (MP35) which was further connected to the computer by using BSL Pro 3.7software of BIOPAC System (USA). Then the electromyography signal and the Root Mean Square (RMS) were recorded at the frequency range of 5-1000 Hz. Raw EMG signals were filtered using a band-pass filter (10-500 Hz bandwidth). RMS reflected the mean power of the signal (also called RMS EMG) and was the preferred recommendation forsmoothing (De Luca et al., 1997). The length of epochs for calculating the absolute EMG and the root-mean-square (RMS) was set in 1sec by setting the Delta T.

(d) Data Analysis: The saved data file was open and the scale was resized. The counter for displaying the magnitude of the EMG signal was activated. The I-Beam data selection tool was used for selecting the recorded EMG signal. The EMG value and RMS value were displayed in the counter when the respective selected record was clicked.

4.13 Study of Physiological Stress

Different Physiological responses of workers were evaluated during performing different jobs. The parameters are discussed below.

4.13.1 Measurement of pulse rate:

The pulse rate was measured with the help of heart rate monitor (Polar S610i). Before joining the work the resting pulse rate of subject was measured. Before measurement of resting pulse rate subjects were asked to take rest for 15 min under sitting condition.

The working pulse rate of the female workers was recorded throughout the working period. The working pulse rate was recorded for different jobs in different working postures. The data were transferred to a computer and analyzed by the Polar Precision Performance software (Version 4.01.029).

4.13.2 Cardiovascular Stress Index:

The cardiovascular stress index **(**CSI) is a good parameter for measuring the level of stress imposes on the human body due to work. From measured values of both resting and working heart rate of the female workers, the cardiovascular stress index (CSI) was determined by the following formula (Trites et al., 1993):

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

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

The CSI was determined for performing different jobs.

4.14 Redesigning of workstation for golden thread work: optimization of work surface height:

4.14.1 Evaluations of existing golden threadworkstation

The golden thread workers had a definite workstation on which they had to perform their work. There was a working platform made up of a wooden / metal frame for their work.Different physical dimensions, e.g., breadth, length and height of the existing golden thread workstation were measured. The drawbacks of the design of the existing golden thread workstation was assessed by interviewing the users, measuring the body joint angles and evaluating the posture adopted during using the workstation.

After identifying the drawbacks of existing golden thread workstation, efforts were made to redesign it on the basis of user's preference score as well as body dimensions of the workers. Final selection of different design criteria was made by a psychophysical analysis, the results of which indicated the preference of the users.

4.14.2Preparation of Prototype Models:

Two prototypes were made by altering the height of the work surface of golden thread work from that of existing one. The developed prototypes were tested.

4.14.3Study of compatibility of the work station

The prototypes were evaluated by some simulation studies. The prototypes were given to the workers and asked to perform the tasks and to judge the suitability of use of the modified workstation. The compatibility of prototypes to the body of the users was evaluated by paired comparison test, biomechanical study as well as productivity study.

4.14.4.1 Psychophysical Analysis by paired comparison test:

The behavioral pattern of the workers during using the prototype models of the workstation were studied by paired comparison tests (Hunns, 1982).

The pair comparison was performed using a 11 point subjective scale ranging from -5 (at left hand) to +5 (at right hand) with zero mark in the middle (Ebe and Griffin, 2001)(Fig 4.7).

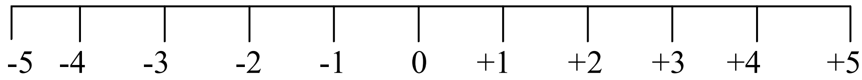


Fig. 4.7: Subjective scale asked for pair comparison test

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

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

The subjects were allowed to answer by words. The answers were tabulated with respective signs. From each of the mean scores, individual scores for each model 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 computed 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 user population.

4.14.4.2 Subjective study:

Subjective study was done by comparison of BPD rating of the user between existing and modified model of workstation. The workers were asked to work with the modified models and to express views regarding the comfort, discomfort and easiness of work.

4.14.4.3 EMG Study:

EMG studies were conducted on female worker during working with existing and modifiedworkstations ofgolden threadwork. The EMG was recorded from shoulder (Trapezius) and back (Latissimusdorsi) muscles by the method discussed earlier in this chapter.

4.14.4.4 Measurement of Joint Angles:

To evaluate which prototype modified heights of golden thread platform was more comfortable, different joint angles were measured and compared withexisting working platform.Different body joint angles, viz., neck, wrist joint, elbow joint, shoulder joint and hipangles of the body were measured during working with differentmodified heights of golden thread platform. The deviations of different joint angles were computed by subtracting the values joint angles in degrees in working condition fromthat of the normal erect posture. The other joint angles are already discussed earlier in this section.

4.14.4.5 Productivity study

The area knitted (sq.cm) with the golden thread on the cloth by the workers were measured and it was taken as the productivity. The productivity study was made while the worker working in existing and different modified model of workstation.

4.15 Statistical Analysis of Data:

The data analysis had been done with the help of respective formulae. Descriptive characteristics of the participants were presented as means and standard deviation and percentages. 't'-test of parameters between different groups had also been made. Chi square (χ^2)test was performed to compare groups for categorical variables. Multiple means were compared with the one-wayANOVA. The ANOVA study, Chi square test and Post-hoc analysis were made using the standard statistical software (ORIGIN 6.1).RMS Value of EMG had been done by using BIOPAC software.

Chapter-V

Result & Discussion

A. Craft work

5.1.1 Demography of the subject:

The physical characteristics i.e., the height, weight and BMI of the craft workers have been presented in Table 5.1. The average age of the subjects were 38.77±11.31 years having the age range of 18 to 60 years. Body weight and height are normally used as an indicator of an individual's health. Whereas, the body mass index (BMI) is an estimate of body composition that correlates an individual's weight and height to lean body mass. The BMI is also sensitive to socio-economic status and to seasonal fluctuations in food consumption relative to the level of physical activity (Venkatramana et al, 2005).

Table 5.1: Physical characteristics of female craft workers (n=124)

Parameter	Mean± SD
Age(years)	38.77±11.31
Height(cm)	150.80±4.08
Weight(Kg)	48.16±8.89
BMI(Kg/m^2)	21.18±3.85

It may be noted that the average BMI of the subjects was 21.18 Kg/m^2 which was within the normal range according to the cutoff value of WHO (2000) (Table 5.1). The prevalence of under-nutrition was analyzed and it was observed that a notable percentage (25.81%) of the female workers were undernourished (Table 5.2).According to WHO (2010) that percentage (20%-39% of prevalence cut-off values) indicates the female workers suffered from 'High prevalence' or 'serious situation' of malnutrition. Body mass index is an accepted measure of chronic energy deficiency malnutrition. Under nutrition remains the nutrition problem of greatest concern in developing countries (Martorell et al. 1998 and Tabak et al. 2000). While malnutrition is prevalent among all segments of the population, poor nutrition among women begins infancy and continues throughout their lifetime. (Chatterjee 1990;Desai 1994). Investigations carried out by different group of researchers revealed that adult Indian rural population suffered from some grade of chronic energy deficiency (Naidu and Rao 1994, Bose et al. 2006 and Chakraborty et al. 2007). In another study by Rao et.al (2010) the percentage of chronic energy deficiency in rural women was 36%.

Table 5.2: Distribution of Craft workers according to WHO re-defined BMI classification

BMI Classification		Craft workers (n=124)	
		Frequency (f)	Percentage (%)
Under Weight (<18.50 kg/m^2)		32	25.81
Normal weight (18.50-22.99 kg/m^2)		61	49.19
Overweight/Obese (>23 kg/m^2)	At risk (23-24.9 kg/m^2)	8	6.45
	Obese class I (25-29.9 kg/m^2)	19	15.32
	Obese class II (>30 kg/m^2)	4	3.23

A similar finding was observed by Joseph et.al, (2005) on women workers in a garment factory. They revealed that more than 25 per cent of women were undernourished. It was also noticed that about 49.19% and 25% of the respondents were within the normal range and overweight respectively according to the BMI cut-off values.

5.1.2 Socio-economic status:

The socioeconomic status of a person or a population is determined by several factors. In the present study the socioeconomic status of the female craft workers has been expressed in terms of the scores of modified Kuppuswami scale (Gururaj and

Maheshwaran, 2014). According to this scale female subjects were divided into different socioeconomic category. The results have been shown in Table 5.3. It was observed that the most of the female subjects were belonging to the ‘upper lower’ category (95.97%). Only 4.03% of the respondents were belonging to lower middle class. Thus the craft workers were categorized to lower socioeconomic status.

Table 5.3: Socio-economic status of the craft workers according to the modified Kuppuswami Scale

Total Score	Socioeconomic Status scale	craft workers (n=124)	
		Frequency	Percentage
26-29	Class I (upper)	-	-
16-25	Class II (upper middle)	-	-
11-15	Class III (lower middle)	5	4.03
5-10	Class IV (upper lower)	119	95.97
<5	Class V (lower)	-	-
Range of computed scores		6-13	

5.1.3 General Health Status:

- **Blood Pressure**

The blood pressure values of the subjects have been shown in Table 5.4. The mean systolic and diastolic pressure of female craft workers was within the normal range. In the studied population, the subjects were categorized into normotensive, hypotensive and hypertensive according to the blood pressure cut-off values (Chobanian et al 2003) and it was found that the most of the subjects were within the normotensive range (78.23%) (Table 5.5).

Table 5.4: Resting systolic and diastolic blood pressure of the female craft workers (n=124)

Resting blood pressure	Mean ±SD	Range
Systolic blood pressure (mm Hg)	106.48± 11.76	80-160
Diastolic blood pressure (mm Hg)	70.42± 8.34	50-100

Table 5.5: Prevalence (frequency and percentage) of different categories of blood pressure among the Craft workers according to cutoff value of Chobanian et al (2003)

Category	Frequency	Percentage
Hypertensive (SBP ≥140 mmHg; DBP ≥90 mmHg)	4	3.23
Normotensive (SBP <120 mmHg; DBP <80 mm Hg)	97	78.23
Hypotensive (SBP ≤ 90 mmHg; DBP ≤ 60 mmHg)	23	18.55

However, a notable percentage of the subjects had hypotension (18.55%), although the prevalence of hypertension was very low (3.23%). Wu et al (2008) noted the prevalence of orthostatic hypotension (15.9%) in Taiwan population and inferred that age was one of the factors determining for it.

5.1.4 Occupational Health Hazards

5.1.4.1 Musculoskeletal Disorder:

The prevalence of MSD among the female craft workers has been presented in Table 5.6A. It was noted that the occurrence of MSD was remarkably high (more the 80% of the respondents) in neck, shoulder, lower back and knee. The workers were divided into three age groups (Gr. A=18-30 yrs., Gr. B=31-45 yrs. and Gr. C= >45 yrs) and the occurrence of MSD in different age groups has also been studied and presented in Table 5.6. From the results it has been revealed that the prevalence of MSD was gradually increased among the workers of lower age group to higher age group in most of the body segments, viz, neck shoulder, elbow, wrist, upper and lower back. Chi Square ($\chi 2$) test revealed that the occurrence of MSD was significantly different ($p<0.00$) among three age groups in different segments of the body (e.g., elbow, wrist, upper back and feet). The subjects of higher age group of the workers (Gr.-C) showed significantly higher percentage of MSD in upper back ($p<0.05$) than that of the middle age group of workers (Gr.-B).

Table 5.6A: Prevalence of MSD of female craft workers in different age groups (the values in parenthesis indicate the percentage of MSD)

Body segment	All craft workers (n= 93)	Age groups			Chi Square Value for three groups ($\chi 2$)
		Gr. A 18-30 yrs. (n= 22)	Gr. B 31-45 yrs. (n= 28)	Gr. C >45 yrs. (n= 43)	
Neck	75 (80.65)	16 (72.73)	22 (78.57)	37 (86.05)	1.76
Shoulder	78 (83.87)	17 (77.27)	23 (82.14)	38 (88.37)	1.85
Elbow	47 (50.54)	10 (45.45)	14 (50.00)	23 (53.49)	54.62***
Wrist	50 (53.76)	9 (40.91)	16 (57.14)	25 (58.14)	46.12***
Upper back	43 (46.24)	10 (45.45)	8 (28.57)	25# (58.14)	80.05***
Lower back	79 (84.95)	17 (77.27)	24 (85.71)	38 (88.37)	2.27
Thigh	72 (77.42)	18 (81.82)	22 (78.57)	32 (74.42)	1.17
Knee	81 (87.10)	20 (90.91)	23 (82.14)	38 (88.37)	3.17
Feet	62 (66.67)	12 (54.55)	19 (67.86)	31 (72.09)	14.55***

* three groups;***$p<0.001$ # w.r.t. Gr. B; # $p<0.05$

There was no significant difference in the occurrence of discomfort between the workers of lower age group and middle age group. 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. Aweto et.al (2015) studied Work-related musculoskeletal disorders in highway sanitary workers and found increasing age have a significant role that can contribute to the development of WMSDs among these workers.

Table 5.6B: Prevalence of (frequency (f) and percentage (%)) of musculoskeletal disorders (MSD) of craft workers during adopting different postures

Body segment	Posture						Chi Square Value ($\chi 2$)
	Squatting (n=20)		Sitting on the floor with Stretched legs (n=24)		Sitting on the floor with Folded legs (n=49)		
	f	%	f	%	f	%	
Neck	9	45	24	100	42	85.71	14.98 ***
Shoulder	17	85	20	83.33	41	83.67	2.647 NS
Elbow	11	55	12	50	24	48.98	26.673 ***
Wrist	11	55	16	66.67	23	46.94	27.810 ***
Upper back	10	50	12	50	21	42.86	39.145 ***
Lower back	17	85	24	100	38	77.55	2.848 NS
Thigh	14	70	20	83.33	38	77.55	0.636 NS
Knee	17	85	24	100	40	81.63	3.635 NS
Feet	16	80	16	66.67	30	61.22	6.327 *

*$p<0.05$, ***$p<0.001$

In the present study the female craft workers performed their work in three different postures, Viz., sitting on the floor with folded legs, sitting on the floor with stretched legs and squatting posture and reported pain in different body segments. The occurrence of MSD of female craft workers in different sitting postures has been studied on comparative basis and presented in Table-5.6B.

It was revealed that the prevalence of MSD in the case of squatting posture and sitting on the floor with stretched leg was comparatively higher in most of the body segments than that of sitting on the floor with folded legs excepting the neck region. It was noted that 100% of the respondent reported problems in their neck, lower back, and knee during sitting on the floor with stretched legs. Beside these higher prevalence of MSD was observed in the shoulder, thigh and feet in that posture.

The results of the Chi square test among three subgroups according to their posture, revealed that there was a significant difference (P<0.001) in the occurrence of MSD in neck, elbow, wrist and upper back region among three postures. Kuorinka et al. (1990) also stated that there appeared to be an increased risk of problems in the neck, shoulders and arms in monotonous and tensed work tasks performed in a sitting position. 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 (Chaffin et al. 2006).

During performing craft work the workers have to move their upper limb frequently. They were compelled to twist their trunk and wrist frequently. The spinal rotation may cause chronic strain as when the workers twist their waist during work. Bending or twisting back in awkward way significantly increased prevalence of LBD symptoms (Gallagher et al, 2002). Craft workers used to work under squatting posture continuously. The frequent kneeling and squatting postures in the workplace are significant contributors to MSDs of the knee and lower back (Baker et al, 2003).

5.1.4.2 Body Part Discomfort (BPD) rating:

The quantitative assessment of the discomfort of the workers engaged in different tasks of craft work had also been done. The perceived rating of discomfort of the workers was studied by using a 10-point scale which was graded from no discomfort at all to maximum discomfort. 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 perceived rating of discomfort of the female craft workers in the three sitting postures, mentioned earlier, have been compared as shown in Table 5.7.

Table 5.7: The Body part discomfort (BPD) rating (Mean ±SD) in different segment of the body (in a 10 point scale) of female craft workers during adopting different sitting postures

Body Regions		Posture			F value
		Squatting (n=20)	Sitting on the floor with stretched legs(n=24)	Sitting on the floor with folded legs(n=49)	
Neck		2.25±2.61	4.83±0.92	3.71±1.81	5.37 **
Shoulder	R	4.4±2.04	4.08±2.10	3.47±1.82	1.75
	L	4.35±1.98	4.00±2.04	3.43±1.80	1.77
Upper arm	R	2.6±1.93	2.75±2.15	1.59±1.71	2.72
	L	2.6±1.93	2.75±2.15	1.59±1.71	2.72
Lower arm	R	1.35±1.53	1.50±1.53	1.27±1.56	0.07
	L	1.35±1.53	1.50±1.53	1.27±1.56	0.07
Upper back		2.3±2.43	2.33±2.04	1.73±2.13	0.46
Middle back		3.25±2.49	4.33±1.58	2.43±2.50	1.40
Lower Back		5.35±2.60	6.08±1.10	4.51±2.55	1.50
Buttock		2.35±2.16	1.50±1.53	0.90±1.66	4.62 *
Thigh	R	3.3±2.3	3.17±1.71	3.43±2.03	0.06
	L	3.3±2.3	3.17±1.71	3.37±2.03	0.06
Cuff	R	3.85±2.01	4.25±0.99	3.02±1.73	2.58
	L	3.85±2.01	4.25±0.99	3.02±1.73	2.58
Feet	R	2.7±1.56	2.33±1.83	1.90±1.46	2.01
	L	2.7±1.56	2.33±1.83	1.90±1.46	2.01
Over all discomfort rating of the body		3.05±1.26	3.25±0.78	2.50±0.84	3.02

* $p<0.05$ ** $p<0.01$

The results of ANOVA highlighted that there were significant differences in body part discomfort (BPD) rating in the buttock ($p<0.05$) and neck ($p<0.01$) region when compared among three postures. Although no significant difference was observed in

BPD rating in other body segments, the mean values of BPD were the lowest in most of the segments while sitting on the floor with folded legs in comparison to other sitting postures. The overall BPD rating was lower, although non-significantly, in case of sitting with folded legs, than in the other two sitting postures.

There were differences in degrees of discomfort among three posture adopted during performing craft work. While comparing three postures, it was revealed that moderate degree of discomfort (>4 to ≤7) was observed in shoulders and lower back in the case of the working with squatting posture and in neck, shoulder, middle back, lower back and calf in case of sitting on the floor with stretched legs. However, a moderate degree of discomfort was observed only in the lower back region while the subjects were sitting on the floor with folded legs (Figure-5.1).

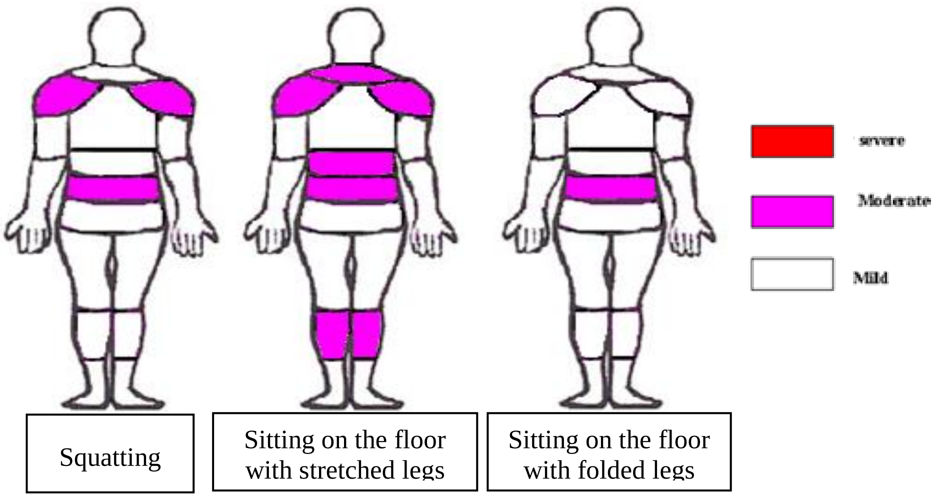


Fig. 5.1: Categories of body part discomfort of female Craft worker in three working postures

Severe degree of discomfort was not found in any of the sitting postures. The occurrence of mild discomfort in different body parts was more or less the same in all the sitting postures. Jain and Jain (2002) pointed out that continuous sitting for knotting in an awkward position leads to frequent backaches even at a young age.

Al-Rahamneh et al. (2010) also pointed out in their studies 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. 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 (Valachi and Valachi, 2003).

5.1.5 Work-Rest Cycle

Work rest cycle is composed by work and rest periods. The human body shows a rhythmic balance between energy consumption and energy replacement during work and rest period. This dual process is an integral part of the operation of muscles, of the heart and if we take all the biological function into account of the organism as a whole. Work - rest is, therefore, indispensable as 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).

Rest pauses during the day are needed for a number of reasons of which the most important are – static work, heavy physical work, standing work, work in hot climate, exposure to noise and vibration, repetitive and boring task, isolated work etc. studies have shown that it makes good economic sense to take well-planned rest pauses, as they have a positive effect on performance. The improved performance will compensate more than enough for the lost working time (FAO, 1992).

Table 5.8: Mean ± SD of work and rest time (min) in female craft workers

Work and rest time	Time (Mean ± SD)	Percentage of total time of work shift
Total Work time	194.48±35.96	65.24
Total Rest time	103.61±22.64	34.76
Total duration of Work shift	298.09±33.42	100%

The work-rest pattern of craft workers have been presented in Table 5.8. The female workers usually started their work by 11 a.m. because most of them were house wives. After house-hold work they would join in craft work. After joining they continued the work for about two hours. After this they used to take a food break (lunch) for about 40 to 50 minutes. They would recommence the work after this break and continued the work for about two hours. Then they used to take another food break (Tiffin or snacks) for a shorter duration than the former break. After this break they had to start work which would continue for one or two hours.

It was noted that the mean rest pause was about 35% of the total duration of work shift. The rest pause was further analyzed and the results have been presented in Table 5.9. The total rest period was divided into two categories, viz., the work related rest and the prescribed rest. The unprompted rest during performing the tasks was included within the work related rest. The prescribed rest was only the food breaks. It was recommended (FAO,1992) that if 50 percent of a person's maximal working capacity is required, the time needed for rest will be about 20 percent of the total working time. This means that a break of about ten minutes per hour should be provided. If the work is lighter the pauses will be shorter or less frequent. The craft work was light to moderate in nature (mean working heart rate was 94.6 beats /min). The mean value of age predicted maximal heart rate of the craft workers was 181 beats/ min. Therefore, it was noted that they would work at about 53% of their maximal heart rate. Total work time in a day was about 3 hours and 15 minutes. Therefore, as per above recommendation of rest (10 min / hour) they required 32.5 min of rest. The results showed that the craft workers took about 38 min of work related rest that was approximately 12 min per hour. So it can be stated that the craft workers had enjoyed required amount of rest.

Table 5.9: Mean ± SD of different rest pauses (min) of female craft workers

<table>
<tr><th colspan="2">Different rest pauses</th><th>Time (Mean ± SD)</th><th>Percentage of total rest time (%)</th></tr>
<tr><td colspan="2">Work related rest</td><td>37.73±10.36</td><td>36.42</td></tr>
<tr><td rowspan="2">Prescribed rest</td><td>Lunch break</td><td>44.38±8.63</td><td>42.83</td></tr>
<tr><td>Tiffin / snacks Break</td><td>21.50±9.68</td><td>20.75</td></tr>
<tr><td colspan="2">Total Rest time</td><td>103.61±22.64</td><td>100%</td></tr>
</table>

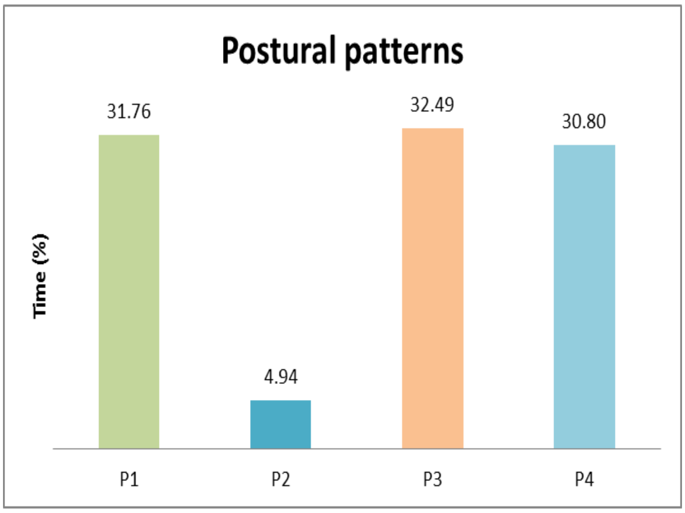
Balci and Aghazadeh_ (2003) studied work rest schedule of VDT workers and noted that 30-minute work /5-minute rest, and 15-minute work/micro breaks schedules resulted in the lowest eyestrain and blurred vision. Discomfort in the elbow and arm was the lowest with the 15/micro schedule. Yi and Chan (2013) proposed rest schedule construction rebar workers in hot and humid environment. From their study an optimized schedule of having a 15 min break after working 120 min continuously in the morning and having a 20 min break after working 115 min continuously in the afternoon was proposed.

The prescribed rest was continuous in nature and the work related rest was discontinuous. In the present study, it was observed that there was a long continuous rest period (food break) about 1½ hours; it might be more useful if the long food break was reduced and more number of short breaks was provided within the work-time. Proper designing of work-rest cycle for the craft workers is necessary. Even when the work is light and comfortable there will, however, always be a need for shorter breaks, as no work posture is so perfect that it is possible to remain the same during long periods of time without increasing discomfort (FAO,1992).

***5.1.6 Evaluation of postural stress*:**

5.1.6.1 Posture Analysis by direct observation method; Postural pattern:

The workers were used to adopt different postures for performing different tasks related to craft work. The change of posture was a common factor during performing dynamic work and in long term working condition. Female workers were compelled to adopt different awkward postures for a prolonged period while performing different crafting task.



P1: Sitting on the floor with two folded legs horizontally
P2: Sitting on the floor with one folded leg horizontally and one folded leg vertically
P3: Sitting on the floor with one leg Stretched
P4: Squatting

Fig 5.2: Percentage of Time for adopting different work postures in a work shift by female craft workers.

From the analysis of posture by direct observation method (Fig.5.2), it was noted that the workers engaged in craft work were found to adopt squatting posture, sitting on the floor with stretched legs and sitting on the floor with folded legs for most of the work time. Sometime bending was also associated with those postures. The percentage of time for adopting the said major postures was more or less the same (around 30%). However it was noteworthy that the female workers would prefer to sit on the floor either in folded legs or in stretched legs for a larger duration than that of squatting posture. The percentage of time covered by sitting on the floor was about 64% of total work time. Any sitting posture when wrongly done for long periods generates several alterations in the muscle-skeletal structures in many body regions including discomfort in lumber inter-vertebral disk (Raymundo, et al., 2004).

5.1.6.2 Posture analysis by the OWAS, REBA and RULA methods:

Different postures adopted by the female craft workers were assessed by three posture analysis methods, viz., OWAS, RULA and REBA and the results have been presented in Table 5.10. From the results of postural assessment by OWAS method it was found that all the postures adopted by the workers had ‘Action Level 2’ indicating the posture needed corrective measures in the near future.

The results obtained from REBA method represented that the workers who adopted squatting posture had ‘Action Level 12’ which indicated as very high risk posture. The Action Levels of other two postures, i.e., sitting on the floor with folded legs and stretched legs were lesser (7 and 8 respectively) than that of squatting posture. It can be mentioned that the workers who were sitting on the floor with stretched legs during work, were under the high risk. On the other hand, sitting on the floor with folded legs was categorized as medium risk posture.

Table 5.10: Results (action level and risk levels) of postural analysis of the craft workers working in Different work postures

Postures	Methods of Postural analysis					
	OWAS		REBA		RULA	
	Action Level	Risk level	Action Level	Risk level	Action Level	Risk level
Folded Legs	2	Corrective measures in the near future	7	Medium risk, further investigation, change soon	4	Investigation and change may be needed
Stretched Legs	2	Corrective measures in the near future	8	High risk, investigate and implement change	6	Investigation and change soon
Squatting	2	Corrective measures in the near future	12	Very high risk, implement Change	7	Investigate and implement change

The results of postural assessment by RULA method showed that the squatting posture had the highest Action level (7) and sitting on the floor with folded legs had the lowest action level (4) among three working postures. The risk levels of three postures were also different. From the results of posture analysis it appeared that the action level and risk category were lower when the workers sat on the floor with folded legs during work than that of other two postures. Singh et.al (2012) investigated the working posture in small scale forging industry by using RULA method and categorizes the workers engaged in this industry as having high to very high risk level of stress. Other investigators (Bandopadhyay and Sen , 2014; Das, 2015) also found that the female workers engaged in squatting posture for prolonged period of time had high scores of OWAS , RULA and REBA indicating high risk of postural stress.

Biomechanical Study

5.1.6.3 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. Due to change in posture CG is shifted and then it becomes difficult to maintain the equilibrium. The whole body center of gravity of the female workers was determined during adopting different working posture by the craft workers. The CG was taken in a reference posture (normal erect posture) from which deviation of CG in working postures was computed.

The result showed that the location of vertical CG of the workers during working conditions was lower than that of normal standing condition (Table 5.11). From the results it was noted that the location of CG in reference posture, i.e., normal erect posture, was 55% of the body length. Schfar (1997) also showed that the location of CG in a model subject was about 55% of the distance for women. In sitting posture total length of the body became lower than that of erect posture. Among three sitting postures the location of vertical CG was found to vary.

Comparative study among three posture revealed that the position of vertical CG was significantly lower ($p<0.001$) in sitting on the floor with folded legs posture than squatting and sitting on the floor with Stretched legs posture. It was observed that the position of vertical CG (42.91%) was higher during adopting squatting posture in comparison to other sitting postures, i.e., sitting on the floor with folded legs (37.51%) and it was slightly lower during sitting on the floor with stretched legs (41.35%) in comparison to squatting posture. Gallagher (2005) stated that the squatting posture appears to be the least stable of the restricted postures. The results revealed that there was a greater shift of the location of CG towards the base of the body during adopting latter two postures. Thus the body became more stable during work while the workers sat on the floor.

Table 5.11: Location (expressed as % of body length) of center of gravity (CG) of craft workers during adopting different postures (n=15)

Postures	Vertical CG		Horizontal CG	
	Location of CG (Mean ±SD)	Deviation from reference posture	Location of CG (Mean ±SD)	Deviation from reference posture
Normal standing (Reference)	55.69±2.83	-	43.40±9.38	-
Sitting on the floor with folded legs	37.51±1.22	18.18	44.80±1.55	-1.41
Squatting	42.91±1.69 *	12.78	52.60±1.67 *	-9.20
Sitting on the floor with Stretched legs	41.35±1.12 *	14.34	22.04±3.08 *#	21.36

*w.r.t Sitting on the floor with folded legs $p<0.001$; #w.r.t Squatting $p<0.001$

The position of horizontal CG was greater when the subjects sat on the floor with folded legs (52.60%) and squatting (52.60%) than that of reference posture. Thus the Horizontal CG shifted slightly toward left side of the body. On the other hand the horizontal CG has a lower value in case sitting on the floor with stretched legs (22.04%). Thus the horizontal CG shifted towards right side of the body sitting on the floor with stretched legs. The position of horizontal CG was significantly ($p<0.001$) greater in squatting posture than other two postures.

According to Page (1978), the shifting of CG towards upper side of body makes the body unstable and leads to impose postural load. On the other hand shifting of CG toward the base make the body more stable. A greater shift in vertical CG towards the base was found during sitting on the floor than that of squatting posture and a least deviation in horizontal CG was noted in case of sitting on the floor with folded legs. Thus considering both vertical and horizontal CG it may be inferred that the body was more stable in working condition whey used to work by sitting on the floor than that of squatting posture.

5.1.6.4 Study of base contact area:

The base contact areas between the body of the workers and the floor (base) are presented in Table 5.12. The results exhibited that there was a wide variation in body contact areas in different postures. The results of ANOVA showed that there was a significant variation ($p<0.001$) in base contact area among different postures.

It was noted from the results that base contact area was much lower in squatting posture than that of other sitting postures. The highest base contact area was noted in case of sitting on the floor with stretched legs followed by sitting on the floor with folded legs. It was noted that the mean base contact area of the female craft workers during sitting on the floor with folded legs was about 183% greater and in case of sitting on the floor with stretched legs it was 535% greater than that of squatting posture. Greater body contact area represents greater stability of the body in a particular posture. Hence sitting on the floor with stretched legs and with folded legs had greater stability of the body during performing craft work than that of squatting posture. Stability is provided if the gravity line falls approximately midway along the base of support. That is, the body is stable until the center of gravity falls perpendicularly outside the base of support. The larger the base of support, the greater displacement of the center of gravity from a midpoint before balance is lost (Schafer, 1987).

Table 5.12: Mean and SD value of Base Contact area of female Craft workers adopting different working posture

Postures	Base Contact area (in sq.cm)
Sitting on the floor with folded legs	794.13±183.34
Squatting	280.36±31.15
Sitting on the floor with stretched legs	1782.87±536.00
F-value	20.12 ###

p<0.001

Greater contact with the support surface plays an important role in maintaining a comfortable stance which may be applicable to sitting (Kavounoudias et al., 2001). Thus it may be suggested that the sitting on the floor with folded legs and stretched leg may an optimum sitting posture for the craft workers.

5.1.6.5 Joint Angles

The analysis of joint angles has a great role in biomechanical analysis in posture change. The craft workers were habituated to perform their job in three postures, as discussed earlier and they used to adopt free posture change during performing their jobs. There were no limitations for their posture changes. So, it was found that the joint angles of the workers deviated much in different postures from that of normal erect posture.

Different body joint angles (shoulder, elbow, wrist, hip and knee angle) of craft workers were measured in the course of their job engagements in different sitting postures and normal erect posture. The joint angles measured in normal erect posture were taken as reference. The deviations between the recorded measurements at each joint angle in different sitting postures from the standard measurement of the reference posture (standing erect) was calculated and presented in Table 5.13. It was inferred from the results that the deviation of joint angle from normal erect posture was greater in shoulder (left side 86.79%), elbow (left side 38.09%, right side 39.16%), hip (left side 62.18%, right side 61.20%) and knee (left side 76.13%, right side 77.94%) during squatting posture than in the other two working postures.

Table 5.13: Different body joint angles (Mean ±SD) of craft workers (n=114) during adopting normal erect posture and different working postures and their deviation from normal erect posture

Body Joint angles		Postures							
		normal erect posture	Squatting (n=20)		Sitting on the floor with Stretched legs(n=24)		Sitting on the floor with Folded legs (n=49)		F value
			working posture	% Deviation	working posture	% Deviation	working posture	% Deviation	
Shoulder	L	35.01 ± 3.23	65.4 ±18.64	86.79%	63.83 ±5.04	82.31%	60.43 ±12.81	72.59%	38.72 ***
	R	36.81 ± 3.07	62.75 ±19.20	70.49%	57.17 ±9.37	55.32%	65.29 ±15.11	77.38%	23.03 ***
Elbow	L	159.99 ± 2.57	99.05 ±25.28	38.09%	142.50 ±15.17	10.93%	118.27 ±22.56	26.08%	7.30 **
	R	160.18 ±4.65	97.45 ±30.45	39.16%	132.58 ±19.35	17.23%	113.02 ±31.94	29.44%	1.84
Wrist	L	173.36 ± 1.86	165.26 ±10.64	4.67%	156.00 ±22.55	10.01%	141.63 ±22.63	18.30%	3.74 **
	R	174.97 ±1.34	156.45 ±27.67	10.58%	156.17 ±22.60	10.75%	150.71 ±17.23	13.86%	0.56
Hip	L	174.23 ±1.48	65.9 ±30.98	62.18%	103.92 ±6.72	40.36%	85.57 ±20.96	50.89%	6.53 **
	R	174.50 ±1.45	67.7 ±30.38	61.20%	96.50 ±5.88	44.70%	75.22 ±11.49	56.89%	3.17 *
Knee	L	178.27 ±7.33	42.55 ±14.69	76.13%	174.50 ±2.55	2.11%	11.49 ±24.07	65.13%	8.71 ***
	R	174.52 ±0.44	38.5 ±11.63	77.94%	169.96± 7.23	2.61%	42.89 ±12.80	65.53%	8.4 ***

L=Left side, R=Right side

The high degree of flexion of the knees and the external pressure on the knees in squatting, are known contributors to knee complaints (Thun et.al 1987 and Kivimaki et.al 1992).There were also significant differences in different body joint angles, viz., shoulder, knee ($p<0.001$) and left side of elbow, wrist, hip ($p<0.01$) and right hip ($p<0.05$) vis-à-vis three postures. The greater deviation of body joint angle indicated greater postural stress imposed on the workers. The hip angle, which was an estimate of forward bending, showed greater values while sitting on the floor than that of squatting posture indicating lesser forward bending of the body. The results of shoulder joint angle also indicated that there was a lesser abduction of upper arm while sitting on the floor with folded legs during working. Thus the joint angle study showed that working in sitting on floor in folded legs or in stretched legs was less stressful than the squatting postures. On the other hand, squatting posture had greatest degree of deviations in most of the joint angles, particularly in the joints of lower extremities.

5.1.6.6 Study of EMG voltage:

The EMG study of the shoulder (Trapezius) and back (Lattisimus dorsi) muscles of the female craft workers was performed in three sitting postures on a comparative basis. EMG records which were taken in normal sitting posture (resting) was taken as reference posture and the deviations of the EMG voltages in working postures from that of the reference posture were computed. For EMG studies 10 subjects were randomly chosen from the previously selected female craft workers. The surface EMG reflects the algebraic sum of electric muscle action potentials that pass within the recording areas of the EMG electrodes (Arendt-Nielsen L. and Mills KR, 1985). In the present study the magnitude of raw EMG as well as RMS value of raw EMG were analyzed for shoulder and back muscles of female workers during rest and work. Root Mean Square EMG (RMS EMG) is defined as the time windowed RMS value of the raw EMG. RMS is one of a number of methods used to produce waveforms that are more easily analyzable than the noisy raw EMG (Arabadzhiev et al, 2010). The surface electromyography (EMG) is a technique to capture and measure electrical activity and muscle action potential. The Root Mean Square (RMS) value has been used to quantify the electric signal because it reflects the physiological activity in the motor unit during contraction (Fukuda et al, 2010).

5.1.6.6.1 Shoulder muscle (Trapezius)

The EMG voltage and RMS values of EMG signal of the shoulder (Trapezius) muscle of female craft workers have been presented in Table 5.14. From the results of ANOVA, it was revealed that there was a significant difference ($p<0.01$) in EMG values and RMS values of right shoulder muscle ($p<0.05$) among different sitting postures. In the case of left shoulder the EMG voltage and RMS values did not show significant difference in the different postures.

Table 5.14: Mean and standard deviation of EMG and RMS values (mV) of shoulder muscle of craft workers adopting normal sitting and three different working postures (n=10) [R : Right side ; L: Left side]

Postures	EMG-R		EMG-L		RMS-R		RMS-L	
	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal sitting (resting)	0.027 ±0.014	-	0.031 ±0.008	-	0.031 ±0.009	-	0.036 ±0.009	-
Sitting on the floor with Folded legs	0.045 ±0.021	66.67%	0.040 ±0.018	29.03%	0.052 ±0.016	67.74%	0.044 ±0.019	22.22%
Sitting on the floor with Stretched legs	0.046 ±0.008	70.37%	0.044 ±0.013	41.95%	0.059 ±0.024	90.32%	0.050 ±0.018	38.89%
Squatting	0.054 ±0.014	100%	0.042 ±0.014	35.48%	0.065 ±0.003	109.67%	0.050 ±0.017	38.89%
F-value	4.84**	-	1.37 NS	-	3.05*	-	1.12 NS	-

*p<.05 **p <0.01

Table 5.15A: Post-hoc analysis of EMG value of shoulder muscle of Craft workers adopting normal sitting and three different working postures (n=10)

Category of posture	MD & SL	Normal sitting (resting)		Sitting on the floor with Folded legs		Sitting on the floor with Stretched legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.027	0.031	0.045	0.040	0.046	0.044	0.054	0.042
Normal sitting (resting)	MD			-0.018	-0.009	-0.019	-0.013	-0.027	-0.011
	SL			NS	NS	p<0.05	p<0.05	p<0.001	NS
Sitting on the floor with Folded legs	MD					-0.001	-0.004	-0.009	-0.002
	SL					NS	NS	NS	NS
Sitting on the floor with Stretched legs	MD							-0.008	0.002
	SL							NS	NS

MD=Mean difference, SL=Significant level

Table 5.15B: Post-hoc analysis of RMS value of shoulder muscle of Craft workers adopting normal sitting and three different working postures (n=10)

Category of posture	MD & SL	Normal sitting (resting)		Sitting on the floor with folded legs		Sitting on the floor with stretched legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.031	0.036	0.052	0.044	0.059	0.050	0.065	0.050
Normal sitting (resting)	MD			-0.021	-0.008	-0.028	-0.014	-0.034	-0.014
	SL			p<0.05	NS	p<0.05	NS	p<0.05	NS
Sitting on the floor with Folded legs	MD					-0.007	-0.006	-0.013	-0.006
	SL					NS	NS	NS	NS
Sitting on the floor with Stretched legs	MD							-0.006	0
	SL							NS	NS

MD=Mean difference, SL=Significant level

While studying the relative percentage difference with respect to normal erect posture, it was found that the percentage deviation was the minimum in case of sitting on the floor with folded legs. Thus the results represented that the shoulder had lesser myoelectric activities during working in case of sitting on the floor with folded legs (Fig.5.3); so it may be stated that there might be lesser stress imposed on the shoulder muscle in that posture. It can be mentioned here that there was a lesser abduction of upper arm, appeared from joint angle study, during sitting on the floor with folded legs in comparison to other two postures.

A post hoc analysis of EMG voltage of shoulder muscle in different working postures has been presented in Table 5.15A and that of RMS value has been shown in 5.15B. The analysis indicated the facts that the EMG value was significantly higher while sitting on the floor with stretched legs ($p<0.05$) and squatting ($p<0.001$) when compared to normal sitting (reference) posture. However, no significant difference in EMG voltage was observed between reference sitting posture and sitting on the floor with folded legs. RMS values of EMG in right side also showed a significant difference ($p<0.05$) between normal sitting posture (reference posture) and the three working postures referred to earlier. The percentage difference of RMS values was notably lesser during sitting with folded legs than that in other postures. Salvendy (1997) had shown that the degree of forward shoulder flexion, or reach, significantly influences muscular fatigue, noting that as the horizontal distance was increased, the onset of fatigue was more rapid.

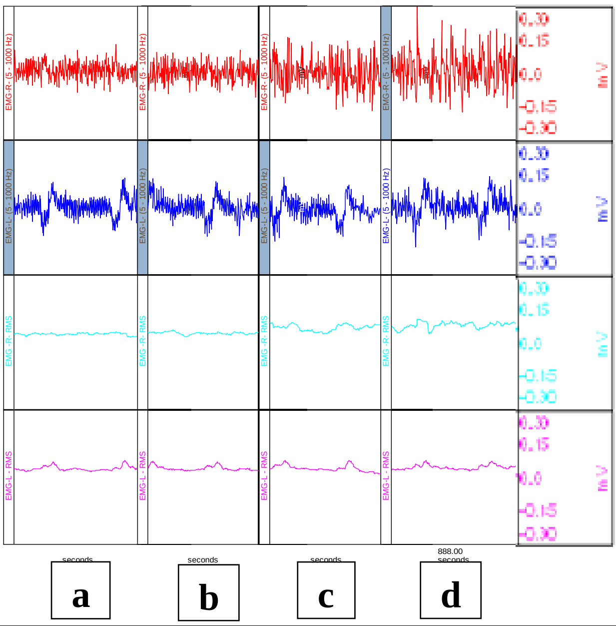


Fig.5.3: EMG and RMS of right and left side of the shoulder muscle during adopting normal (refference) [a] and different working postures: sitting on the floor with folded legs [b] Sitting on the floor with stretchered legs[c] and squatting[d]

5.1.6.6 .2 Back Muscle (Lattisimus dorsi)

The EMG voltage and RMS values of EMG signal of back muscle (lattisimus dorsi) of the craft workers have been presented in Table 5.16. The results of ANOVA represented that the EMG voltage and RMS values of the left and right back muscle showed a significant difference (p<0.05) amongst the postures under study. When only the working postures were compared it was observed that the magnitude of EMG signal (both absolute and RMS value) was the lowest while the workers were sitting on the floor with folded legs during performing work and it was the highest while adopting squatting postures (Fig5.4).

Table 5.16: Mean and standard deviation of EMG and RMS values (mV) of back muscle of Craft workers adopting normal and three different working postures

Postures	EMG-R		EMG-L		RMS-R		RMS-L	
	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal sitting (resting)	0.025 ±0.007	-	0.026 ±0.004	-	0.028 ±0.006	-	0.032 ±0.004	-
Sitting on the floor with Folded legs	0.028 ±0.006	12.00%	0.028 ±0.007	7.69%	0.033 ±0.009	17.86%	0.033 ±0.006	3.13%
Sitting on the floor with Stretched legs	0.030 ±0.009	20.00%	0.031 ±0.008	19.23%	0.034 ±0.013	21.43%	0.036 ±0.008	12.5%
Squatting	0.037 ±0.006	48.00%	0.036 ±0.006	38.46%	0.040 ±0.006	42.86%	0.040 ±0.004	25.00%
F-value	4.33 *	-	3.78 *	-	2.89 *	-	4.32*	-

* p<0.05

A post hoc analysis of EMG voltage and RMS value of back muscle has been done. The results of the post hoc analysis of the EMG voltage and RMS value of back muscle in different working posture have been presented in Table 5.17A, and 5.17B respectively. It was noted that the EMG voltage was significantly higher in squatting posture (Right side p<0.01 and Left side p<0.001) when compared to that of normal sitting posture.

Table 5.17A: Post-hoc analysis of EMG value of back muscle of Craft workers adopting normal sitting and three different working postures (n=10)

Category of posture	MD & SL	Normal sitting (resting)		Sitting on the floor with Folded legs		Sitting on the floor with Stretched legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.025	0.026	0.028	0.028	0.030	0.031	0.037	0.036
Normal sitting (resting)	MD			-0.003	-0.002	-0.005	-0.005	-0.012	-0.010
	SL			NS	NS	NS	NS	P<0.01	p<0.001
Sitting on the floor with Folded legs	MD					-0.002	-0.003	-0.009	-0.008
	SL					NS	NS	P<0.01	P<0.05
Sitting on the floor with Stretched legs	MD							-0.007	-0.005
	SL							NS	NS

MD=Mean difference, SL=Significant level

Table 5.17B: Post-hoc analysis of RMS value of back muscle of Craft workers adopting normal sitting and three different working postures (n=10)

Category of posture	MD & SL	Normal sitting (resting)		Sitting on the floor with Folded legs		Sitting on the floor with Stretched legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.028	0.032	0.033	0.033	0.034	0.036	0.040	0.040
Normal sitting (resting)	MD			-0.005	-0.001	-0.006	-0.004	-0.002	-0.008
	SL			NS	NS	NS	NS	NS	p<0.001
Sitting on the floor with Folded legs	MD					-0.001	-0.003	-0.007	-0.007
	SL					NS	NS	P<0.01	P<0.01
Sitting on the floor with Stretched legs	MD							-0.006	-0.006
	SL							NS	NS

MD=Mean difference, SL=Significant level

On comparing working postures it was revealed that there was a significant difference (Right side p<0.01 and Left side p<0.05) in EMG voltage between sitting on the floor with folded legs and squatting posture. RMS values of EMG also showed the same trends in the results. The percentage deviation in EMG values from that of reference posture (normal sitting) was lesser in case of sitting with folded legs than that of other two postures, that is, squatting and sitting with stretched legs. RMS values of EMG also showed the same trends of results. The deviation was found to be the maximum while working in a squatting posture.

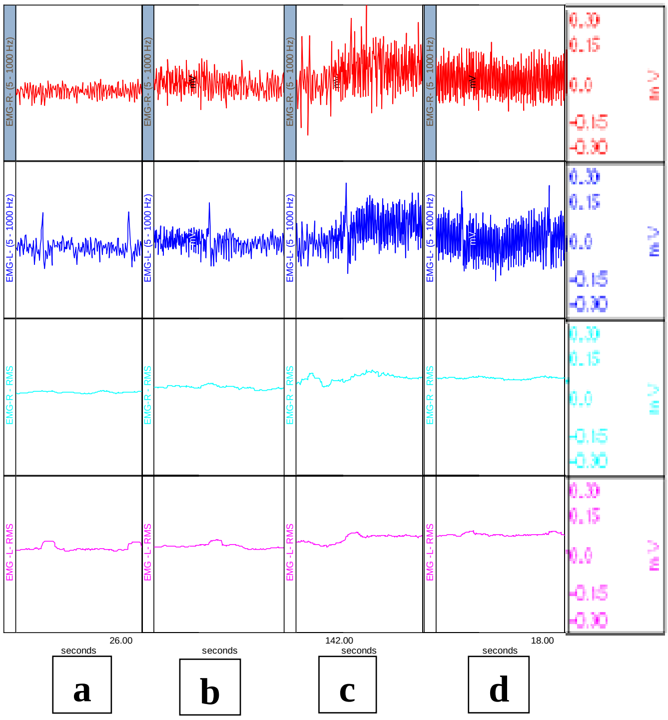


Fig.5.4: EMG and RMS of right and left side of the back muscle during adopting normal (refference) [a] and different working postures: sitting on the floor with folded legs [b] Sitting on the floor with stretchered legs[c] and squatting[d]

The result of EMG study of the shoulder (Trapezius) muscle of female craft workers indicated that there was lesser stress on shoulder muscle while sitting on floor with folded legs. This might be due to the fact that while sitting on the floor with folded legs, the workers had lesser shoulder abduction during work, as shown in Table 5.13, in comparison to other two postures. Another study was done by Kleine et. Al.,(1999) investigated the EMG changes of shoulder and back muscles for posture analysis in workers at visual display units and found that an increase in trapezius muscle activity was partly related to a lifting of the shoulders to compensate a slight slumping of the back. In our study trapezius muscle showed increased RMS values of EMG while working, especially, in squatting posture and in sitting with stretched legs. The shoulder abduction was comparatively greater than that in sitting with folded legs, as appeared from the joint angle study.

On the other hand the results of EMG study of back muscle (lattisimus dorsi) indicated that back muscle had lesser myoelectric activities due to lesser stress imposed on it while working in a sitting on the floor with folded legs posture in comparison to other two postures. It might be one of the reasons for the lesser BPD rating (Table 5.7) and lower prevalence of MSD (Table 5.6-A) at the lower back region while sitting on the floor with folded legs than in that of the other two postures. Hu et al (2007) made an elctromyographic assessment of back muscles. Miljkovic, (2011) applied a technique on independent components of low back surface electromyography (sEMG) signals, in order to differ sitting and standing postures. Preliminary results from small group of healthy subjects, suggested that presented method might be used to distinguish between two postures in different conditions.

5.1.7 Physiological Stress

The physiological stress of the craft workers was evaluated in terms of pulse rate and Cardio-vascular stress index measurement.

Evaluation of Cardiovascular Status:

The resting and working heart rate and Cardiovascular Stress Index (CSI) of female craft workers were determined during performing craft work in three different working postures. It was established that the heart rate in terms of relative cardiac cost is a reliable measure to rationalize the physiological workload (Dey et al. 2006). There was a significant difference ($p<0.01$) in working HR and resting HR of the workers (Table 5.18).There was no significant difference in working According to classification of CSI (Brant, 2009) the female craft workers were not suffering from any cardiovascular stress, which might be due to the fact that the worker performed their work in sitting posture and thus no involvement of large muscles of body during work.

Table 5.18: Resting pulse rate, working pulse rate, work pulse and Cardiovascular Stress Index (CSI) of Craft workers in different posture

Parameters	Craft workers (n=93)		
	Squatting (n=20)	Sitting on the floor with Stretched legs (n=24)	Sitting on the floor with Folded legs (n=49)
Resting HR	77.82±7.87	78.96±7.83	80.30±6.40
Working HR	94.56±7.86**	94.90±5.83**	94.22±6.27**
Work Pulse	16.74±10.66	15.94±8.48	13.925.02
CSI	15.76±9.82	15.69±7.48	14.06±4.98

**p<0.01

There was an effect of working posture although not significantly. The craft workers show lowest value of work pulse and CSI in Sitting on the floor with folded leg posture than other two postures.

B. Mat weaving

5.2.1 Demography of the subject:

Mat weaving is done professionally by the women in different districts of West Bengal. Some areas of West Midnapore distract deserve special mention because mat weaving has become an art. Along with the common mat some workers weave special mats with artistic flavor. The present study was carried out on 113 randomly selected adult female workers, who have been working for not less than 4 years in the profession of mat weaving.

Table 5.19: Physical parameter of mat weavers (n=113)

Parameter	Mat weavers
Age(years)	37.82±12.19
Height(cm)	150.79±4.05
Weight(Kg)	42.17±7.11
BMI(Kg/m^2)	18.61±3.41

The general physical characteristics i.e., the height and weight of the mat weavers have been presented in Table 5.19. The average age of the subjects were 37.82±12.19 years having the age range of 18 to 55 years. Anthropometric index like body mass index (BMI) is the simple, safe, inexpensive method (Gelber et al 1999) and useful indicator for the nutritional assessment (Lee and Nieman 2003). The mean BMI of female mat weavers was approximately within the normal range (18.61Kg/m^2) (Table 5.19). The mat weavers were classified according to their nutritional status. According to the BMI cut-off values (WHO, 2000) it was observed that about 51.33% of the female workers were undernourished (Table 5.20). It was also noticed that about 37.17% and 11.44% of the respondents were within the normal range and overweight respectively. The occurrence of undernutrition might be due to their low socio-economic status as discussed latter subsection. Shukla et al (2002) stated that the age and lowest level of education were significantly associated with low BMI. There was a positive relation between BMI and socioeconomic status (Subramanian et al 2011).

Table 5.20: Distribution of mat weavers according to WHO re-defined BMI classification

BMI Classification		Mat weavers (n=113)	
		Frequency (f)	Percentage (%)
Under Weight(<18.50 kg/m^2)		58	51.33
Normal weight(18.50-22.99 kg/m^2)		42	37.17
Overweight/Obese (>23 kg/m^2)	At risk(23-24.9 kg/m^2)	6	5.31
	Obese class I(25-29.9kg/m^2)	7	6.19
	Obese class II(>30 kg/m^2)	0	-

5.2.2 Socio-economic status:

The socioeconomic status of the female mat weavers was evaluated in terms of Kuppuswami scale (Gururaj and Maheshwaran, 2014) considering chiefly the literacy level, economic condition, and their professional level.

Table 5.21**:** Socio economic status of the female mat weavers according to the modified Kuppuswami Scale

Total Score	Socioeconomic Status	Mat weavers (n=113)	
		Frequency	Percentage
26-29	Class I (upper)	-	-
16-25	Class II (upper middle)	-	-
11-15	Class III (lower middle)	102	9.73
5-10	Class IV (upper lower)	11	90.27
<5	Class V (lower)	-	-
Range of computed scores		7-12	

The female subjects were divided into different socioeconomic category (Table 5.21).

It was observed that the most of the female subjects were belonging to the ‘upper lower’ category (90.27%). Only 9.73% of the respondents were belonging to lower middle class. The range of computed score of the subjects was 7 to 12. Thus the mat weavers were belonged to lower socioeconomic status.

5.2.3 General Health Status:

- **Blood Pressure:**

The mean values of blood pressure of the subjects were shown in Table 5.22. The mean systolic and diastolic pressure of female mat weavers was within the normal range.

Table 5.22: Resting systolic and diastolic blood pressure of the female Mat weavers (n=113)

Resting blood pressure	Mean ±SD	Range
Systolic blood pressure (mm Hg)	113.65± 12.24	90-160
Diastolic blood pressure (mm Hg)	75.40±8.13	58-100

Table 5.23: Frequency and percentage distribution of different levels blood pressure according to Chobanian et al (2003) among the Mat weavers

Category	Frequency	Percentage (%)
Hypertensive (SBP ≥140 mmHg; DBP ≥90 mmHg)	10	8.85
Normotensive (SBP <120 mm Hg ; DBP <80 mm Hg)	96	84.96
Hypotensive (SBP ≤ 90 mmHg ; DBP ≤ 60 mmHg)	7	6.19

However, the percentage of the subjects having hypotension (6.19%) and hypertension was very low (8.85%). Different factors in the workplace might be related to the occurrence of hypertension. Ismaila (2014) noted increase in systolic blood pressure among the sack manufacturing workers due to exposure of noise in work place.

5.2.4 Occupational Health Hazards

5.2.4.1 Musculoskeletal Disorder:

The prevalence of MSD among female mat weavers has been presented in Table 5.24A. It was noted that the prevalence of MSD in lower back was reported by 100% of the workers. Very high prevalence (>70%) of MSD was observed in neck, shoulder and knee.

Table 5.24 A: Prevalence of MSD of female mat weavers in different age groups (the values in parenthesis indicate the percentage of subjects reported MSD)

Body segments	All mat workers (n=108)	Age groups			Chi Square Value for three groups ($\chi2$)
		Gr. A (18-30 yrs.) (n=46)	Gr. B (31-45 yrs.) (n=34)	Gr. C (>45 yrs.) (n=28)	
Neck	79 (73.15)	27 (58.70)	27 (79.41)	25 ## (89.29)	9.28**
Shoulder	106 (98.15)	44 (95.65)	34 (100)	28 (100.00)	34.63***
Elbow	27 (25.00)	9 (19.57)	8 (23.53)	10 (35.71)	129.84***
Wrist	30 (27.78)	13 (28.26)	10 (29.41)	7 (25)	113.35***
Upper back	75 (69.44)	30 (65.22)	21 (61.76)	24 (85.71)	5.93
Lower back	108 (100.00)	46 (100)	34 (100)	28 (100)	39.65***
Thigh	68 (62.96)	25 (54.35)	27 (79.41)	16 (57.14)	12.61**
Knee	92 (85.19)	34 (73.91)	31 (91.18)	27 # (96.43)	13.36**
Feet	29 (26.85)	10 (21.74)	10 (29.41)	9 (32.14)	118.98***

**p<0.01 ***p<0.001 # w.r.t. Gr. A; # p<0.05

The subjects were divided into three different age groups (Gr. A=18-30 yrs., Gr. B=31-45 yrs. and Gr. C= >45 yrs.) To study age related variations of MSD among the mat weavers (Table 5.24 A).

The results revealed that there was a general tendency of increase in the prevalence of MSD with the increase of age. The occurrence of MSD was significantly different among three age groups in different segments of the body ($p<0.01$ or less), as appeared from Chi square test. The subjects of higher age group of the workers (Gr.-C) showed significantly higher percentage of MSD in neck ($p<0.01$) and knee ($p<0.05$) segments than that of the workers of lower age group of (Gr.-A). There was no significant difference in the occurrence of discomfort between the workers of lower age group and middle age group. Other groups of investigators also observed age related variation of the occurrence of MSD. Guo (2002) reported that the prevalence of MSDs increases as people enter their working years and, by the age of 35, most people have had their first episode of back pain. An increasing trend with age for MSD incidence was noted in the study of Shiue rt al (2008), as observed in the present study also.

Work posture may affect the occurrence MSD. Mat weavers perform their work in two sitting postures, viz., squatting and sitting on the floor with folded legs. Here attempts have been made to compare MSD of female workers between two working postures. The prevalence of musculoskeletal disorders (MSD) of the female mat weavers in different sitting postures has been presented in Table 5.24 B. The results revealed that the prevalence of MSD in case of adopting squatting posture was comparatively higher in most of the body segments than that of sitting on the floor with folded legs excepting the wrist. Those workers while adopted squatting posture during work, had significantly higher prevalence of pain / discomfort in neck ($p<0.05$), elbow, upper back, feet ($p<0.001$), wrist and thigh ($p<0.01$) compare to that of sitting on the floor with folded legs. The squatting posture was a strenuous posture in which majority of the body forced was imposed on the thighs and legs. Moreover, there were acute flexion of body at knee and hip joints. These were the probable reasons for higher occurrence of pain during adopting squatting posture.

Table 5.24 B: frequency (f) and percentage (%) of musculoskeletal disorders (MSD) of mat weavers during adopting different postures

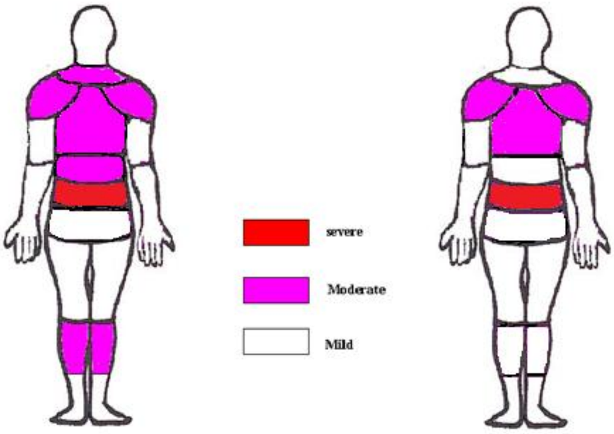
Body segment	Working Posture (n=108)				Chi Square Value (χ2)
	Squatting (n=60)		Sitting on the floor with Folded legs(n=48)		
	f	%	f	%	
Neck	51	85.00	28	58.33	9.65*
Shoulder	59	98.33	47	97.92	0.025 NS
Elbow	25	41.67	2	4.17	20.000***
Wrist	12	20.00	18	37.5	4.071*
Upper back	50	83.33	25	52.08	12.273***
Lower back	60	100.0	48	100.00	-
Thigh	45	75.00	23	47.92	8.388*
Knee	53	88.33	39	81.25	1.060 NS
Feet	26	43.33	3	6.25	18.670***

*p<0.05,***p<0.001

According to the report of NIOSH (1997), the kneeling, squatting, stooping, non-neutral trunk postures and lifting are the awkward posture, which are responsible for lower back disorder (LBD). 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) and there is a clear relationship between back disorders and physical load.

5.2.4.2 Body Part Discomfort (BPD) rating:

Body part discomfort rating (BPD) was assessed using a 10-point scale while mat weavers were performing their tasks. The BPD rating was categorized as mild, moderate and severe, as discussed earlier.



Squatting | Sitting on the floor with folded legs

Fig. 5.5: Distribution of different levels of body part discomfort of female mat weaver in two working postures

Table 5.25: The Body part discomfort (BPD) rating (Mean ±SD) in different segments of the body (in a 10 point scale) of female mat weavers during adopting different sitting postures

Body Regions		Posture	
		Squatting (n=60)	Sitting on the floor with Folded legs(n=48)
Neck		4.65±2.03	2.71±2.39 ***
Shoulder	R	5.90±1.15	5.31±1.34 *
	L	5.63±0.96	5.29±1.20
Upper arm	R	1.03±1.50	1.29±1.64
	L	1.03±1.50	1.29±1.64
Lower arm	R	0.05±0.39	0.38±0.49
	L	0.05±0.39	0.29±0.46
Upper back		4.52±2.79	4.04±2.20
Middle back		4.35±2.56	3.75±2.35
Lower Back		8.00±1.01	7.35±0.89 ***
Buttock		0.67±1.23	0.50±1.25
Thigh		3.55±2.59	1.71±1.92 ***
	L	3.55±2.59	1.71±1.92 ***
Cuff	R	4.18±2.31	3.60±1.93
	L	4.18±2.31	3.60±1.93
Feet	R	1.45±1.95	0.15±0.77 ***
	L	1.45±1.95	0.15±0.77 ***
Over all discomfort rating of the body		3.19±1.20	2.54±0.68 **

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 5.25 showed that the workers who adopted two postures during work, reported different degrees of perceived exertion in different body segments. In case of adopting squatting posture, the female workers perceived moderate degrees of discomfort (>4 to ≤7) in neck, shoulder, lower back, upper back and calf and severe degree of discomfort (>7) in lower back. On the other hand, in case of sitting on the floor with folded legs, the workers had perceived discomfort in a few body segments; For example, moderate degrees of discomfort (>4 to ≤7) was reported only in shoulder and upper back and severe degree of discomfort (>7) was reported in lower back (Fig.5.5). The occurrence of pain or discomfort in squatting posture was significantly higher in neck, lower back, thigh and feet ($p<0.001$) in comparison to that of sitting on the floor with folded legs.

Several associated factors like prolonged tasks (Al- ahamneh et al. 2010, Princivero et al. 2001), holding time (Reneman et al. 2001; Laura et al. 2010), complex postures (Bonney et al. 1990) have been positively associated with discomfort rating. Severe Lower back pain was observed in the study. 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.

5.2.5 Work-Rest Cycle

The work-rest pattern of mat weavers have been presented in Table 5.26. The workers usually started their work by 7 a.m. After joining they continued the work for about three hours. After this they used to take a break for taking food (breakfast) for about 40 to 50 minutes. They would resume the work after this break and continued the work for about three hours.

Table 5.26: Mean ± SD of work and rest time (min) female Mat weavers

Work and rest	Time (min)	Percentage (%)
Total Work time	282.22±42.94	57.21
Total Rest time	211.12±13.07	42.79
Total duration of Work shift	493.33±51.64	100%

Then they used to take another food break (lunch) for a longer duration than the former break. It would continue for about 2 hours or more. During this break they used to take a bath and rest for some time. The workers would also perform their household work, like, wiping, washing cloth and dishes and cooking during this period. After this break they had to start work from 3.30/4.00 pm, which would continue for three hours.

Table 5.27: Mean ± SD of different rest pauses (min) of female mat weavers

Different rest pauses		Time (min)	Percentage of total rest time (%)
Work related rest		39.45±3.01	18.69
Prescribed rest	Break for breakfast	44.17±4.92	20.92
	Break for Lunch	127.50±8.80	60.39
Total Rest time		211.12±13.07	100%

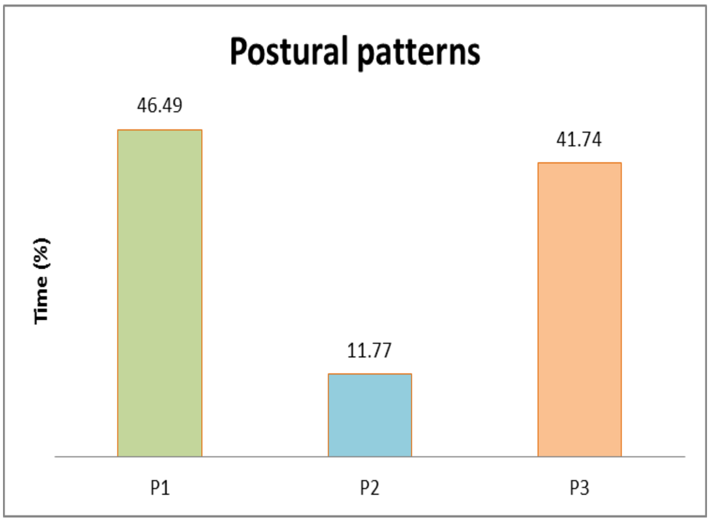
The rest pause was further analyzed and the results have been presented in Table 5.27. The total rest period was divided into two subdivisions, viz., the work related rest and the prescribed rest. The unprompted rest during performing the tasks was included within the work related rest. The prescribed rest was only the food breaks. The prescribed rest was continuous in nature and the work related rest was discontinuous. In the present study, it was observed that there was a long continuous rest period (food break) about 2½ hours. However, this rest pause appeared to longer than it was required. It has been recommended that a meal break of about three quarters of an hour or an hour should also be provided. It is necessary to allow for about 15 minutes elapsing after eating a more substantial meal for the digestive processes (FAO, 1992). It might be more useful if the long food break was reduced and more number of short breaks was provided within the work-time. Proper designing of work-rest cycle for the mat weavers is necessary. Even when the work is light and comfortable there will, however, always be a need for shorter breaks, as no work posture is so perfect that it is possible to remain the same during long periods of time without increasing discomfort (FAO,1992).

If 50 percent of a person's maximal working capacity is required, the time needed for rest will be about 20 percent of the total working time. This means that a break of about ten minutes per hour should be provided. If the work is lighter the pauses will be shorter or less frequent (FAO, 1992). It has been noted that the female mat weavers were used to work at about 53% of their maximal heart rate (age predicted). Thus according to the above recommendation, the workers required rest for 20% of the duration work shift. Here the workers took rest more than the said duration. However, it may be noted that the workers enjoyed about 19% of the work related rest (Table 5.27).

5.2.6 Evaluation of postural stress:

5.2.6.1 Posture Analysis by direct observation method:

The workers were used to adopt different types of postures for performing the tasks related to mat weaving. The Postural pattern of the mat weavers in their work shift was analyzed. The workers were found to change posture in a certain interval in the work shift. The change of posture was a common factor during dynamic work and in long term working condition. Female workers were compelled to adopt different awkward postures for prolonged period of time while performing different jobs. Although awkward postures were the most numerous in the job requiring high-energy consumption, it was also noted that there were a lot of awkward postures of certain parts of the body which might be the possible causes of pain / discomfort at different segments of body. Thus assessment of work postures is one of the starting points to address the problem of work related body pain.



P1: Sitting on the floor with two folded legs horizontally

P2: Sitting on the floor with one folded leg horizontally and one folded leg vertically

P3: Squatting

Fig. 5.6: Percentage of Time for adopting different work postures in a work shift by female mat weavers

From the postural pattern, presented in Fig. 5.6 , it was noted that the workers engaged in mat weaving task were found to adopt different postures like, squatting, sitting on the floor with one leg folded horizontally and other leg folded vertically and sitting on the floor with two legs folded horizontally (Fig. 5.6).

Choobineh et al. (2004) also found that carpet weavers are suffering from musculoskeletal problems mainly attributed to poor working postures. Long seated posture tends to reduce circulation in the lower limbs leading to promotes discomfort in neck and upper limbs (Rodgher et al, 1996).

5.2.6.2 Posture analysis by the OWAS, REBA and RULA methods:

The postural stress of the female mat weavers during adopting different postures were analyzed by three methods, viz., OWAS, RULA and REBA and the results have been presented in Table 5.28. From the results of postural assessment of mat weavers by OWAS method it was found that the squatting posture had an action level of 4 and it needed corrective measures immediately whereas in case of sitting on the floor with folded legs the action level was 2 and it required corrective measures in the near future. From the results of postural assessment by REBA methods it was found that the action level of squatting posture was 12 which were higher than that of sitting on the floor with folded legs (action level 10). The squatting posture was categorized as 'very high risk' posture the workers who sat on the floor with folded legs were categorized as 'high risk posture'.

Table 5.28: Results (action level and risk levels) of postural analysis of the mat weavers working in different work postures

Posture	Postural analysis of mat weavers					
	OWAS		REBA		RULA	
	Action Level	Risk level	Action Level	Risk level	Action Level	Risk level
Sitting on the floor with Folded Legs	2	Corrective measures in the near future	10	High risk, investigate and implement change	6	Investigation and change soon
Squatting	4	Corrective measures immediately	12	Very high risk, implement Change	7	Investigate and implement change

The assessment by RULA method also represented higher action level and risk level in case of squatting posture than that of sitting on the floor. Sahu and Set (2010) categorized the postures adopted by the female brick moulders, who were working in squatting posture, as having 'high' to 'very high' risk levels according to the OWAS and REBA methods which was similar to the findings with the present study.

So, from the postural analysis of mat weaver it was inferred that the workers sitting on the floor with folded legs had lesser postural stress and risk that that of other two postures.

- ***Biomechanical Study***

***5.2.6.3* Center of Gravity:**

Due to change in posture CG is shifted from its normal location and then it becomes difficult to maintain the equilibrium. In the present study the CG was determined in a reference posture (normal erect posture) from which deviation of CG in working postures was computed. The location of vertical and horizontal CG was determined in two different working postures adopted by the female mat weavers. The results showed that the location of vertical CG of the workers during working conditions was lower than that of normal standing condition (Table 5.29). This was might be due to adopting sitting posture during performing work. In sitting posture total length of the body became lower than that of erect posture. Among two sitting postures the location of vertical CG was found to vary. It was observed that the position of vertical CG (41.92%) was significantly ($p<0.05$) lower during adopting squatting posture in comparison to sitting on the floor with folded knees (52.86%). The results revealed that there was a greater shift of the location of CG towards the base of the body during adopting sitting on the floor postures. Thus the body became more stable during work while the workers sat on the floor.

The position of horizontal CG (84.79%) was when the subjects were working in squatting posture and sitting on the floor with folded legs than that of reference posture.

Thus the Horizontal CG shifted toward left side of the body. The position of horizontal CG was significantly ($p<0.001$) greater in squatting posture than sitting on the floor with folded legs posture. Fekete et al (2013) stated that the horizontal excursion of the COG line changes its position during squatting in contrary with steady-state assumption and it can be derived as a single empirical function of flexion angle. When the horizontal CG was compared between two working postures it was observed that the location horizontal CG was of lower value in case of sitting on the floor than that of squatting posture. Thus it may be stated that the shift of CG in horizontal plane was lesser during sitting on the floor with folded legs in comparison to squatting posture. Therefore, there will be less instability of the body while adopting former posture.

Table 5.29: Location (expressed as % of body length) of center of gravity (CG) of mat weavers during adopting different postures (n=15)

Postures	Vertical CG		Horizontal CG	
	Location of CG (Mean ±SD)	Deviation from reference posture	Location of CG (Mean ±SD)	Deviation from reference posture
Normal standing (Reference)	56.34±2.47	-	36.61±4.29	-
Sitting on the floor with folded legs	52.86±8.90	3.48	48.50±8.55	-11.90
Squatting	41.92±1.18*	14.42	84.79±6.70**	-48.18

w.r.t. Sitting on the floor with folded legs *$p<0.05$;**$p<0.001$

The shifting of CG towards upper side of body makes the body unstable and leads to impose postural load. Thus due to the deviation of CG indicated that the workers were compelled to work under unstable posture which might be a reason for having musculoskeletal problems among the workers. However, in the present case the CG was shifted to the base; more the shift to the base more will be the body stability.

Hence, during sitting on the floor the body might have more stability than that of squatting posture.

5.2.6.4 Study of base contact area:

The Base contact area of human body with the ground or sitting surface is related to the stability of the body. The high stability (low mobility) is characterized by a large base of support, a low center of gravity, a centralized center of gravity projection within the base of support, a large body mass, and high friction at the ground interface. Low stability (high mobility), in contrast, occurs with a small base of support, a high center of gravity, a center of gravity projection near the edge of the base of support, a small body mass, and low friction (Schafer 1987). The base contact areas between the body of the workers and the floor (base) are presented in Table 5.30.

Table 5.30: Mean and SD value of Base Contact area of female mat weavers adopting different working posture

Mat weavers (n=10)	
Postures	Base Contact area (in sq.cm)
Sitting on the floor with folded legs	1136.03±698.91
Squatting	281.76±30.54 ###

p<0.001

The results exhibited that there was a wide variation in body contact areas in different postures. It was noted from the results that the base contact area was significantly ($p<0.001$) lower in squatting posture than that of sitting on the floor with folded leg postures. Greater body contact area represents greater stability of the body in a particular posture. Hence sitting on the floor with folded legs had greater stability of the body during performing mat weaving work. Thus it may be suggested that the sitting on the floor with folded legs may an optimum sitting posture for the mat weavers.

***5.2.6.5* Joint Angles:**

Different body joint angles (shoulder, elbow, wrist, hip and knee angle) of mat weavers were measured in the course of their job engagements in different sitting postures. The joint angles measured in normal erect posture were taken as reference. The deviations between the recorded measurements at each joint angle in different sitting postures from the measurement of the reference posture (standing erect) was calculated and presented in Table 5.31.

Table 5.31: Deviation of Different body joint angle (Mean ±SD) of mat weavers (n=98) adopting different posture from normal erect posture

Body Joint angles		normal erect posture	Postures			
			Squatting (n=50)		Sitting on the floor with Folded legs(n=48)	
			working posture	% Deviation	working posture	% Deviation
Shoulder	L	35.92±5.23	58.72±15.89	63.48	63.23±6.52	76.04
	R	37.49±5.39	62.68±18.60	67.19	57.54±9.37	53.49
Elbow	L	164.98±8.17	147.04±11.66	10.87	144.46±20.72	12.44
	R	163.48±7.12	143.78±12.49	12.05	135.21±23.80	17.29
Wrist	L	175.57±5.33	150.5±24.25	14.28	156.83±18.51	10.67
	R	174.94±4.89	156.46±21.76	10.56	163.60±11.93	6.48
Hip	L	172.94±6.26	53.78±10.55 **	68.90	90.94±5.26 ***	47.42
	R	174.02±4.67	52.48±9.52 **	69.84	84.69±9.26 ***	51.33
Knee	L	174.90±3.62	34.68±6.70	80.17	48.46±5.69	72.29
	R	174.94±4.14	30.8±5.39	82.39	48.94±8.17	72.03

w.r.t. normal erect posture**p<0.01,***p<0.001; L=left side, R= right side

It was observed from the results that the deviation of joint angle from normal erect posture was higher in shoulder angle (right side 67.19%), wrist (left side 14.28 % and right side 10.56 %) ,hip (left side 68.90% and right side 69.84%) and knee (left side 80.17 % and right side 82.39 %) during squatting posture than that of sitting on the floor. There were also significant differences in hip joint angles ($p<0.001$) between two postures. From the results of the hip angle it appeared that there was a lesser extent of forward bending during sitting on the floor with folded legs than that of squatting posture.

Some researchers concluded that the long term bend posture (Marras and Karwowski 2006), lumbo-spinal strain and intense physical work (Bio et al 2007) as the risk factors for the occurrence of back pain. The shoulder angle represented lesser shoulder abduction in case of sitting on the floor with folded legs in comparison to squatting posture. From the joint angle study it was observed that sitting on floor with folded leg posture was less stressful rather than that of squatting postures.

5.2.6.6 Study of EMG voltage:

The EMG study of the shoulder (Trapezius) and back (Lattisimus dorsi) muscles of the female mat weavers was performed with the help of the BIOPAC system in two sitting postures on a comparative basis.

EMG records which were taken in normal sitting posture (resting) was taken as reference posture and the deviations of the EMG voltages in working postures from that of the reference posture were computed. For EMG studies 10 subjects were randomly chosen from the selected female mat weavers.

5.2.6.6.1 Shoulder muscle (Trapezius)

The magnitude of EMG voltages and RMS of EMG signal of the shoulder (Trapezius) muscle of female mat weavers have been presented in Table 5.32. From the results of ANOVA, it was revealed that there was a significant difference ($p<0.001$) in the EMG voltage and in the RMS values of shoulder muscle in different sitting postures. While studying the relative percentage difference of working postures with respect to normal erect posture, it was found that the percentage deviation was the minimum in case of sitting with folded legs than that of squatting posture (Fig-5.7).

Table 5.32: Mean and standard deviation of EMG and RMS values (mV) of shoulder muscle of mat weavers adopting normal sitting and three different working postures (n=10)

Postures	EMG-R		EMG-L		RMS-R		RMS-L	
	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal sitting (resting)	0.0265 ±0.013	–	0.0304 ±0.008	–	0.0306 ±0.008	–	0.0368 ±0.008	–
Squatting	0.3104 ±0.236	1071.6%	0.2075 ±0.124	583.2%	0.3806 ±0.08	1145.6%	0.213± 0.039	478.8%
Sitting on the floor with Folded legs	0.1720 ±0.105	549.14%	0.1599 ±0.075	426.47%	0.1929 ±0.055	531.35%	0.1660 ±0.03	351.20%
F-value	8.27 **	–	10.8 ***	–	90.32 ***	–	91.07 ***	–

**p <0.01, ***p<0.001

A post hoc analysis of EMG and RMS value of shoulder muscle in different working postures has been presented in Table 5.33 A and 5.33 B. The analysis revealed that the EMG value was significantly higher while sitting on the floor with folded legs ($p<0.001$) and squatting (right side $p<0.01$, left side $p<0.001$) when compared to normal sitting (reference) posture. RMS values of EMG also showed a significant difference between normal sitting posture (reference posture) and the two working postures referred to earlier. These changes might be due to increase of muscular activity during work. The female workers had to move their arms continuously during mat weaving.

Table 5.33 A: Post-hoc analysis of EMG value of shoulder muscle of mat weavers adopting normal sitting and three different working postures (n=10)

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Squatting	
Body side		R	L	R	L	R	L
Mean		0.0265	0.0304	0.1720	0.1599	0.3104	0.2075
Normal sitting (resting)	MD			-0.1455	-0.1295	-0.2839	-0.1771
	SL			p<0.001	p<0.001	p<0.01	p<0.001
Sitting on the floor with Folded legs	MD					-0.1384	-0.0476
	SL					NS	NS

MD=Mean difference, SL=Significant level

Table 5.33 B: Post-hoc analysis of RMS value of shoulder muscle of mat weavers adopting normal sitting and three different working postures (n=10)

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Squatting	
Body side		R	L	R	L	R	L
Mean		0.0306	0.0368	0.1929	0.1660	0.3806	0.2130
Normal sitting (resting)	MD			-0.1623	-0.1292	-0.35	-0.1762
	SL			P<0.001	P<0.001	P<0.001	P<0.001
Sitting on the floor with Folded legs	MD					-0.1877	-0.053
	SL					P<0.001	P<0.01

MD=Mean difference, SL=Significant level

The percentage differences of RMS values were notably lesser during sitting with folded legs than that in squatting posture. There was a significant difference in (right side p<0.001, left side p<0.01) RMS value of EMG between sitting on the floor with folded legs and squatting posture. The fact might be explained by the extent of movement of upper arm during performing mat weaving. It was observed from the joint angle study that the shoulder abduction was greater in case of adopting squatting posture, which might require greater extent of contraction of Trapezius muscle in comparison to that of sitting with folded legs.

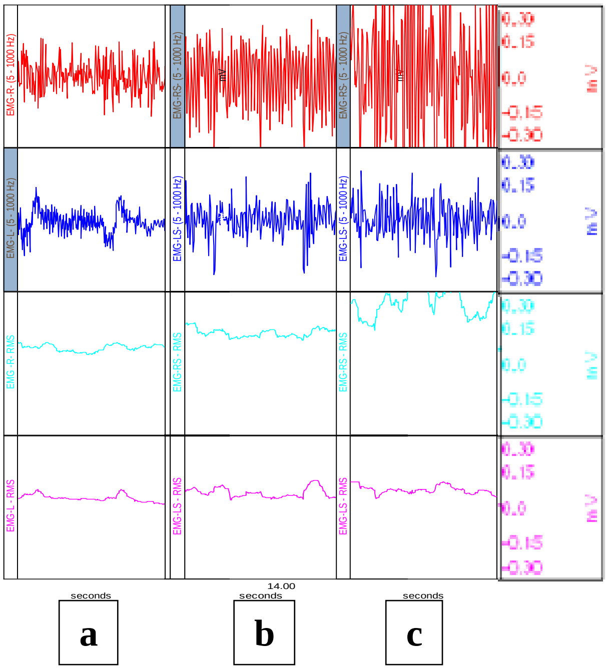


Fig-5.7: EMG and RMS of right and left side of the shoulder muscle during adopting normal (refference) [a] and two different working postures: Sitting on the floor with folded legs [b] and Squatting [c]

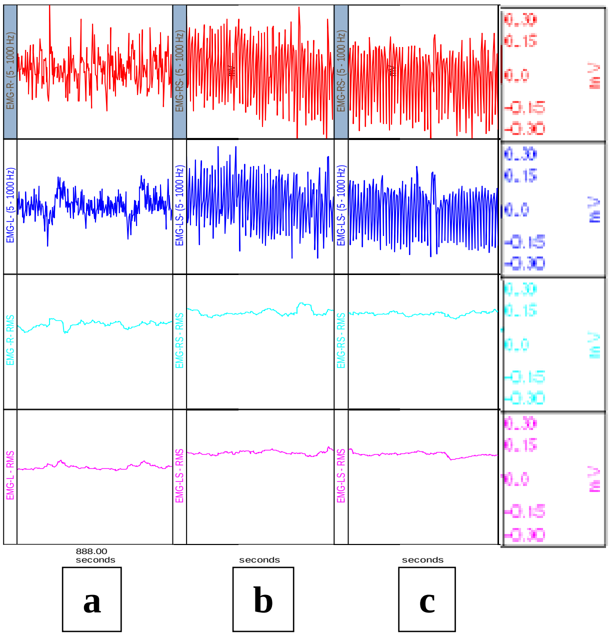


Fig-5.8: EMG and RMS of right and left side of the back muscle during adopting normal (refference) [a] and different working postures: Sitting on the floor with folded legs [b]and Squatting [c]

5.2.6.6.2 Back Muscle (Lattisimus dorsi)

The EMG voltage and RMS values of back muscle (lattisimus dorsi) of the mat weavers have been presented in Table 5.34. The EMG and RMS values of back muscle showed a significant difference ($p<0.01$ or less) amongst the postures under study. Both raw EMG and RMS values were greater in working postures than that of resting posture (reference posture) (Fig-5.8). It might be due to forward bend of the body during work, as appeared form the joint angle study.

Table 5.34: Mean and standard deviation of EMG and RMS values (mV) of back muscle of mat weavers (n=10) adopting normal and three different working postures

Postures	EMG-R		EMG-L		RMS-R		RMS-L	
	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal sitting (resting)	0.0253 ±0.008	–	0.0262 ±0.005	–	0.0279 ±0.007	–	0.0315 ±0.005	–
Squatting	0.1316 ±0.063	419.59%	0.0886 ±0.050	238.44%	0.1183 ±0.025	324.26%	0.0970 ±0.026	207.85%
Sitting on the floor with Folded legs	0.1012 ±0.050	299.67%	0.0448 ±0.032	70.97%	0.1005 ±0.011	260.69%	0.0821 ±0.01	160.68%
F-value	12.44 ***	–	7.95 **	–	80.45 ***	–	40.81 ***	–

* p<0.05 ***p<0.001

The results of the post hoc analysis of the EMG voltage and RMS value of back muscle in different working postures have been presented in Table-5.35 A, and 5.35 B. It was noted that the EMG voltage of right side of the body ($p<0.001$) was significantly higher in squatting posture and in sitting with folded legs when compared to the values in normal sitting posture in resting condition. In left side EMG value was significantly higher ($p<0.01$) only in squatting posture. A significant difference ($p<0.001$) in RMS voltage was noted between sitting on the floor with folded legs and squatting posture when compared to the values in normal sitting posture.

Table 5.35 A: Post-hoc analysis of EMG voltage of back muscle of mat weavers adopting normal sitting and three different working postures (n=10)

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Squatting	
Body side		R	L	R	L	R	L
Mean		0.0253	0.0262	0.1012	0.0448	0.1316	0.0886
Normal sitting (resting)	MD			-0.0759	-0.0186	-0.1063	-0.0624
	SL			P<0.001	NS	P<0.001	P<0.01
Sitting on the floor with Folded legs	MD					-0.0304	-0.0438
	SL					NS	P<0.05

MD=Mean difference, SL=Significant level

Table 5.35 B: Post-hoc analysis of RMS value of back muscle of mat weavers adopting normal sitting and three different working postures (n=10)

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Squatting	
Body side		R	L	R	L	R	L
Mean		0.0279	0.0315	0.1005	0.0821	0.1183	0.0970
Normal sitting (resting)	MD			-0.0726	-0.0506	-0.0904	-0.0655
	SL			P<0.001	P<0.001	P<0.001	P<0.001
Sitting on the floor with Folded legs	MD					-0.0178	-0.0149
	SL					NS	NS

MD=Mean difference, SL=Significant level

When comparing two working postures, it was noted that the EMG voltage and RMS value of back muscle was significantly lesser ($p<0.05$) in case of sitting with folded legs than that of squatting posture. The RMS value of left side was also lesser in sitting with folded legs than that of squatting, although it had no significant difference between two postures. The percentage deviation in EMG and RMS values from that of reference posture (normal sitting) was also lesser in case sitting on the floor with folded leg than that of squatting posture.

5.2.7 Physiological Stress

The physiological stress of the mat weavers was evaluated in terms of pulse rate and Cardio-vascular stress index measurement.

- **Evaluation of Cardiovascular Status:**

The resting and working heart rate and Cardiovascular Stress Index (CSI) of female mat weavers were determined during performing mat weaving tasks in two different working postures. There was a significant difference ($p<0.01$) in working heart rate and resting heart rate of the workers (Table 5.36). According to classification of CSI (Brant, 2009) the female mat weavers were not suffering from any cardiovascular stress, which might be due to the fact that the worker performed their work in sitting posture and thus no involvement of large muscles of body during work.

Table 5.36: Cardiovascular Stress Index (CSI) of mat weavers in different working postures

Parameters	Mat weavers (n=108)	
	Squatting (n=60)	Sitting on the floor with Folded legs (n=48)
Resting HR	71.58±6.91	67.53±5.68 *
Working HR	96.81±5.64#	90.16±5.20 #***
Work Pulse	25.24±7.29	22.64±6.43
CSI	23.54±6.51	19.84±5.77 *

# $p<0.01$; w.r.t squatting posture *$p<0.05$ ***$p<0.001$

The workers who adopted squatting posture, had significantly higher working heart rate ($p<0.001$) as well as CSI ($p<0.05$) than that of the workers who adopt sitting on the floor posture. So it indicated greater cardiovascular stress in squatting posture than in sitting on the floor. Therefore, the squatting posture had been considered as a remarkable lower extremity posture with a high postural load (Keyserling 1990, Genaidy et al. 1993, Buchholz et al. 1996, Hignett and McAtamney 2000).

It was inferred from this part that the female workers showed lesser prevalence of MSD and lesser extent of BPD, lesser postural risk, lower extent of myoelectric activities, greater stability of body, lesser degree of body flexion and shoulder abduction as well as lesser degree of cardiovascular stress during sitting on the floor with folded legs while working in comparison to that of squatting posture. Hence in may be stated that sitting on the floor with folded legs would be suitable posture for female mat weavers.

C. Golden thread work (Jori)

5.3.1 Demography of the subject:

The present study was carried out on 123 randomly selected adult female workers, who have been in the profession for not less than 4 years in golden thread (Jori) work. The general physical characteristics of the golden thread workers have been presented in Table 5.37. It may be noted that the average values of BMI of the subjects were within the normal range (20.48Kg/m^2). The prevalence of under-nutrition was analyzed and it was observed that about 21.95% of the female workers were undernourished (Table 5.38). It was also noticed that about 62.60 % and 15.45% of the respondents were within the normal range and overweight respectively according to the BMI cut-off values (WHO, 2000).

Table 5.37: Physical characteristics of female golden thread (Jori) workers (n=123)

Parameter	Golden thread workers
Age(years)	24.50± 7.45
Height(cm)	150.59±4.23
Weight(Kg)	46.52± 6.48
BMI(Kg/m^2)	20.48± 2.45

The occurrence of under nutrition might be due to their low socio-economic status as discussed later. From the study of the Bose et al., (2006) 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. About 15% of the workers were belonging to overweight category.

Table 5.38: Categorization of golden thread workers according to WHO re-defined BMI classification

BMI Classification		Frequency (f)	Percentage (%)
Under Weight(<18.50 kg/m^2)		27	21.95
Normal weight(18.50-22.99 kg/m^2)		77	62.60
Overweight/Obese (>23 kg/m^2)	At risk(23-24.9 kg/m^2)	15	12.20
	Obese class I(25-29.9 kg/m^2)	4	3.25
	Obese class II(>30 kg/m^2)	0	-

5.3.2 Socio-economic status:

In the present study the socioeconomic status of the female golden thread workers has been evaluated according to modified Kuppuswami scale (Gururaj and Maheshwaran, 2014). The results have been shown in Table 5.39. It was observed that the most of the female workers were belonging to the 'upper lower' category (98.37%). Only 1.63% of the respondents were belonging to lower middle class. Thus the golden thread workers were categorized to lower socioeconomic status.

Table 5.39: Socioeconomic status of the golden thread workers according to the modified Kuppuswami Scale

Total Score	Socioeconomic Status scale	golden thread workers (n=123)	
		Frequency	Percentage
26-29	Class I (upper)	-	-
16-25	Class II (upper middle)	-	-
11-15	Class III (lower middle)	2	1.63%
5-10	Class IV (upper lower)	121	98.37%
<5	Class V (lower)	-	-
Range of computed scores		7-13	

5.3.3 General Health Status:

- **Blood Pressure**

Blood pressure is important indicator of health. The high blood pressure is associated with higher risk of health problems in the future. If blood pressure is high, it is putting extra strain on arteries and on heart. The mean systolic and diastolic pressure of female golden thread workers was within the normal range (Table 5.40).

Table 5.40: Resting systolic and diastolic blood pressure of the female golden thread worker (n=108)

Resting blood pressure	Mean ±SD	Range
Systolic blood pressure (mm Hg)	115.46± 14.03	90-158
Diastolic blood pressure (mm Hg)	73.26± 10.15	50-90

Table 5.41: Classification of golden thread workers (frequency and percentage) according to different levels of blood pressure (Chobanian et al., 2003) (n=108)

Category	Frequency	Percentage
Hypertensive (SBP ≥140 mmHg DBP ≥90 mmHg)	8	7.41
Normotensive (SBP <120 mm Hg DBP <80 mm Hg)	82	75.93
Hypotensive (SBP <120 mm Hg DBP <80 mm Hg)	18	16.67

The golden thread workers were categorized into normotensive, hypotensive and hypertensive according to the cut-off values of blood pressure (Chobanian et al., 2003), as shown in Table 5.41. It was found that the most of the subjects were in the normotensive range (75.93%). However, a notable percentage of the subjects had hypotension (16.67%). However, the prevalence of hypertension was very low

(7.41%). Kabe et al., (2007) showed postural variation of hypotension in female workers. They noted that hypotension rates in the female standing workers' group were 75% for systolic blood pressure and were 92% for diastolic blood pressure. There were significantly higher than those in the female desk workers' group.

5.3.4 Occupational Health Hazards

5.3.4.1 Musculoskeletal Disorder:

Work-related musculoskeletal disorders (WMSDs) are a group of painful disorders of muscles, tendons, and nerves. Almost all work requires the use of the arms and hands. Therefore, most WMSD affect the hands, wrists, elbows, neck, and shoulders. Work using the legs can lead to WMSD of the legs, hips, ankles, and feet. Some back problems also result from repetitive activities. Among the golden thread workers a high prevalence of work related MSD was evident in lower back region.

The prevalence of work related MSD among golden thread workers were analyzed in three different age groups (Gr. A=18-30 yrs., Gr. B=31-45 yrs. and Gr. C >45 yrs.). The results of Chi square test (Table 5.42 A) revealed that in case of golden thread workers the occurrence of MSD was significantly different among three age groups in different parts of the body ($p<0.05$ or less). The subjects of higher age group of the workers (Gr.-C) showed significantly higher percentage of MSD in wrist, upper back and thigh ($p<0.05$) segments than that of the worker of lower age group (Gr.-A). On the other hand, the workers of middle age group (Gr.-B) showed significantly higher percentage of MSD in only upper back ($p<0.01$) than that of the workers lower age group (Gr.-A). Holmström and Engholm (2003) and Guo et al., (2004) noted that MSD was significantly increased with age. Age is the obvious cause of MSD. The incidence of many major musculoskeletal diseases, such as osteoarthritis and osteoporosis, was age-related, and in older people bone and joint diseases were the major cause of the very high prevalence of chronic pain and physical disability (Woolf and Akesson, 2001).

Table 5.42 A: Prevalence of MSD of female golden thread workers in different age groups (the values in parenthesis indicate the percentage of MSD)

Body segments	Golden thread workers of all age groups (n=114)	Age groups			Chi Square Value (χ2)
		Gr. A 18-30 yrs. (n=78)	Gr. B 31-45 yrs. (n=24)	Gr. C >45 yrs. (n=12)	
Neck	32 (28.07)	17 (21.79)	11 (45.83)	4 (33.33)	5.44
Shoulder	99 (86.84)	65 (83.33)	22 (91.67)	12 (100.00)	196.81***
Elbow	32 (28.07)	15 (19.23)	10 (41.67)	7 (58.33)	33.31***
Wrist	11 (9.65)	5 (6.41)	2 (8.33)	4 # (33.33)	22.92***
Upper back	58 (50.88)	30 (38.46)	18## (75.00)	10 # (83.33)	48.50***
Lower back	105 (92.11)	70 (89.74)	23 (95.83)	12 (100.00)	232.27***
Thigh	25 (21.93)	13 (16.67)	6 (25.00)	6 # (50.00)	7.99*
Knee	32 (28.07)	19 (24.36)	7 (29.17)	6 (50.00)	3.41
Feet	2 (1.75)	2 (2.56)	0 (0.00)	0 (0.00)	39.18

*p<0.05 ***p<0.001 # w.r.t. Gr. A; # p<0.05, ## p<0.05

The work related MSD may vary with the postural change. The golden thread workers were found to adopt different sitting postures during performing their work. The prevalence of MSD was studied in those postures on a comparative basis.

The prevalence of musculoskeletal disorders (MSD) of the female golden thread workers in different sitting postures has been presented in Table 5.42 B. Chi square test revealed that significant differences in the occurrence of MSD were observed among different postures (p<0.001) in most of the body segments.

Table 5.42 B: Frequency (f) and percentage (%) of musculoskeletal disorders (MSD) of golden thread workers during adopting different postures

Body segment	Working Posture (n=114)						Chi Square Value (χ2)
	Sitting on the floor with folded legs (n=68)		Squatting (n=28)		Sitting on the floor with stretched legs (n=18)		
	f	%	f	%	f	%	
Neck	19	27.94	7	25	6	33.33	0.38 NS
Shoulder	56	82.35	25	89.29	18	100.00	197.33*
Elbow	13	19.12	7	25	12	66.67	16.11 *
Wrist	5	7.35	3	10.71	3	16.67	19.79*
Upper back	31	45.59	9	32.14	18	100.00	56.69*
Lower back	61	89.71	26	92.16	18	100.00	223.27*
Thigh	14	20.59	8	28.57	3	16.67	3.05 NS
Knee	17	25.00	9	32.14	6	33.33	0.79 NS
Feet	1	1.47	1	3.57	0	0.00	39.18*

*p<0.001

The results also showed that the prevalence of MSD in case of adopting squatting posture and sitting on the floor with stretched leg was comparatively higher in most of the body segments than that of sitting on the floor with folded legs excepting the neck, upper back and thigh segments. Those workers who adopted squatting posture had higher prevalence of pain in shoulder, elbow, wrist, upper back, lower back, and feet compared to other two working postures. Studies made by other investigators (Ray and Desai, 1995) revealed that in small scale industries the major locations of the body pains were back (76%), leg (53%), head and neck (35%), hand (35%). However, in the present study major locations of body pains in golden thread workers were noted in shoulder and back region. In a study on handloom weavers (Naz et al., 2015) it was reported that the occurrence of MSD was high in lower back (75%), upper back (73.4), shoulder (68%) , elbow (65%), wrist (70.3%), and neck (57.8%). It may be noticed that the prevalence of MSD was very high in back, elbow, shoulder, and neck where workers were performing weaving type of task. It may be pointed out that the occurrence of pain in different segments of the body in the present study was higher than that of other studies.

Some other studies (Nordander et al., 2010; Walker-Bone and Palmer 2002) suggested that experimental task of repetitive arm elevation caused shoulder complaints and tenderness in the region of the descending part of the trapezius muscles among patients with shoulder pain. Baschera and Grandjean (1979) in their study have stated that uniform and repetitive tasks requiring great skill must be considered as high mental loads which impair the performance and the well-being of the workers. Repetitive fabrication jobs have been found to be classified as monotonous, boring and demotivating, and can result in decreased worker productivity (Shikdar and Das, 1995).

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 (Chaffin et al., 2006). Further, the occurrence of pain might be related to the posture adopted by the workers. Nag et al., (2010) in their study reported that female workers involved in handloom sectors were found to suffer from back and knee pain which might result from minimal hip support with constrained posture. Borah et al., (2014) studied on women workers engaged in cashew nut processing industry and observed that the workers had high prevalence of MSDs due to adoption of unnatural squatting posture on the ground for a long time. Workers reported complaints about musculoskeletal problems after adopting the squatting posture since they were supported with non-suitable facilities (Manuaba 1997, Tirtayasa et al., 2003).

5.3.4.2 Body Part Discomfort (BPD) rating:

The quantitative assessment of the perceived rating of discomfort of the workers was studied by using a 10-point scale. The body part discomfort (BPD rating of the female workers was compared among different sitting postures during performing golden thread work. The results showed that the golden thread workers, who adopted different postures, reported to suffer from different degrees of perceived exertion (Table 5.43).

According to the degree of severity, the scores of the 10-point scale were divided into three subgroups (Dutta and Dhara, 2012), i.e., mild (1–4), moderate (>4–7) and severe (>7), as done earlier cases also. It was revealed that in case of sitting on the floor with stretched legs, a moderate degree of discomfort (>4 to ≤7) was observed in upper back, middle back and in shoulder and severe degree of discomfort (>7) was noted in lower back (Fig-5.9) whereas in squatting posture moderate degree of discomfort (>4 to ≤7) was found in both shoulder and lower back. In case of sitting on the floor with folded legs moderate degree of discomfort (>4 to ≤7) was observed only in right shoulder and lower back. There were significant differences in BPD rating in upper back ($p<0.001$), middle back ($p<0.001$) and buttock ($p<0.05$) among three postures.

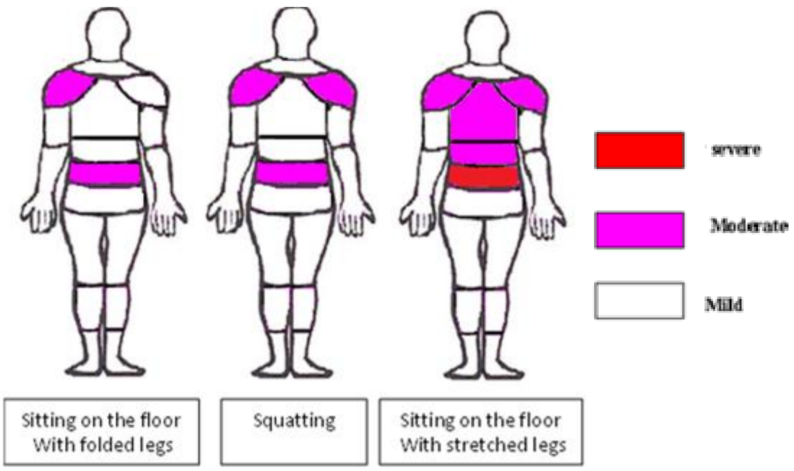


Fig. 5.9: Body part discomfort rating of female Golden thread worker in three working postures

Table 5.43: The Body part discomfort (BPD) rating (Mean ±SD) in different segments of the body (in a 10 point scale) of female golden thread workers during adopting different sitting postures

Body Segments		Posture			F value
		Sitting on the floor with folded legs (n=68)	Squatting (n=28)	Sitting on the floor with stretched legs (n=18)	
Neck		0.96±1.64	0.93±1.74	1.33±2.03	0.37
Shoulder	R	4.24±2.46	4.96±2.38	5.17±1.25	1.74
	L	3.31±2.59	4.54±2.10	4.00±2.38	2.64
Upper arm	R	1.04±2.08	1.11±2.17	1.67±2.28	0.62
	L	0.79±1.85	0.96±1.95	1.67±2.28	1.43
Lower arm	R	0.46±1.56	0.50±1.53	0.83±1.92	0.40
	L	0.43±1.45	0.46±1.40	0.83±2.04	0.52
Upper back		2.47±2.43	1.33±2.04 #	5.00±1.19 ### $$$	15.46 ***
Middle back		1.94±2.64	2.46±2.78	5.00±2.97 ### $$	8.98 ***
Lower Back		6.46±2.54	6.64±2.83	7.83±1.25	2.24
Buttock		0.07±0.61	0.32±1.70	1.00±2.30##	3.54*
Thigh	R	0.85±1.94	0.93±1.90	0.83±1.92	0.02
	L	0.85±1.94	0.93±1.90	0.83±1.92	0.02
Cuff	R	1.34±2.28	1.46±2.22	2.67±2.77	2.32
	L	1.34±2.28	1.46±2.22	2.67±2.77	2.32
Feet	R	0.07±0.61	0.21±1.13	0.00±0.00	0.55
	L	0.07±0.61	0.21±1.13	0.00±0.00	0.55
Over all discomfort rating of the body		1.57±0.74	1.73±0.73	2.43±1.25 ### $	7.18 **

* p<0.05 ** p<0.01 ***p<0.001
w.r.t. folded legs #p<0.05,##p<0.01,###p<0.001,
w.r.t Squatting $p<0.05,$$p<0.01,$$$p<0.001

Bandopadhyay and Sen (2014) also reported severe (Garde 3) pain in different body segments of women workers due to adopting awkward sitting posture for a long time during work. Other investigators (Das, 2015; Sahu and Sett, 2010) also reported high degree of low back pain among a large percentage (70%) of female brick workers due to awkward working posture for prolonged period of time. Dewangan et al., (2007) observed maximum work related BPD at lower back among the female agricultural workers.

While comparing three sitting postures, the extent of pain was the lowest in most of the body segments in case of sitting on the floor with folded legs. The overall discomfort / pain, considering all body segments studied, was also significantly lower during sitting on the floor with folded legs. Thus the findings of the comparison indicated that the female workers had lesser extent of pain / discomfort while sitting on the floor with folded legs.

5.3.5 Work-Rest Cycle:

The work-rest pattern of golden thread workers was more or less the same as craft workers and mat weavers. The workers would start their work usually in the early morning (7.00 a.m.). They would continue the work for about three hours after which they were used to take a break for taking food (breakfast) for about 40 to 50 minutes. They would resume the work after this break and continue the work for about three hours. After this they would take pause for lunch. It would continue for about 2 hours. During this break they used to take a bath and food during this time the female workers had to perform some household work, like, wiping, washing cloth and dishes and cooking etc. After this break they would start work from 3.30/4.00 pm, which would continue for about three hours. The duration of work-rest pattern of golden thread workers has been presented in Table 5.44.

The rest pause was further analyzed and the results have been presented in Table 5.45. The total rest period was divided in to two categories, viz., the work related rest and the prescribed rest. The unprompted rest during performing the tasks was included within the work related rest. The prescribed rest was only the food breaks. The prescribed rest was continuous in nature and the work related rest was discontinuous.

Table 5.44: Mean ± SD of work and rest time (min) female golden thread workers

Time	Time (min.)	Percentage
Total Work time	255.04±45.64	51.10
Total Rest time	244.10±23.43	48.90
Total duration of Work shift	499.15±58.34	100%

It was found that the golden thread workers enjoyed about rest pause of about 49% of the total work shift including two long food breaks. It was recommended that the rest pause should be about 20% of the total work time when the workers perform the work at 50% of their maximal work capacity (FAO, 1992). It was noted that the female golden thread workers had mean working heart rate was about 97 beats / min (discussed later) and the age predicted mean maximal heart rate was 195 beats /min. Therefore, it was depicted that the workers performed their task at about 50% of the maximal heart rate. If we consider the work related rest, which was taken during work period only, it was revealed that the workers had taken rest for about 27% of their total work time. It may be stated that the rest pause was more than it was required (20%), as mentioned above.

Pascal (2007) studied on MSD in computer operators and reported that static posture increased the risk of work related MSD and rest periods may lower risk of MSDs. Chandra and Dubey (2014) concluded from their study that rest periods provided in between the working hours help the workers to relieve them from fatigue and monotonous routine work. Otherwise it may cause frustration and stress at workplace.

Table 5.45: Mean ± SD of different rest pauses (min) of female golden thread workers

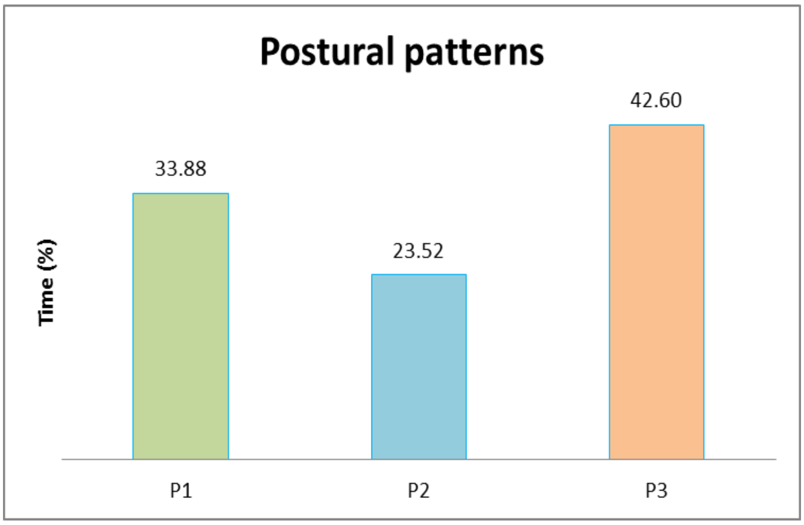
Different rest pauses time		Time (min.)	Percentage of total rest time (%)
Work related rest		69.10±9.67	28.31
Prescribed rest	Break for breakfast	44.29±6.07	18.14
	Break for Lunch	130.71±12.05	53.55
Total Rest time		244.10±23.43	100%

In the present study, it was observed that there was a long continuous rest period (food break) about 2½ hours; it might be more useful if the long food break was reduced and more number of short breaks was provided within the work-time. Proper designing of work-rest cycle for the golden thread workers is necessary.

5.3.6 Evaluation of Postural stress:

5.3.6.1 Posture Analysis by direct observation method:

The Postural pattern of the golden thread workers in the total work shift was analyzed by direct observation. The workers were used to adopt different postures for performing different tasks related to golden thread work. The change of posture was a common factor during performing dynamic work and in long term working condition. The duration of adopting different postures has been presented in Fig.5.10. The workers engaged in golden thread work were observed to adopt different postures, e.g., squatting, sitting on the floor with stretched legs and sitting on the floor with folded legs posture for most of the work time (Fig.5.10). It was observed that the workers were used to work for a longer duration in sitting with stretched legs than that of other two postures.



P1: Sitting on the floor with folded legs

P2: Squatting

P3: Sitting on the floor with Stretched legs

Fig. 5.10: Percentage of Time for adopting different work postures in a work shift by female golden thread workers

5.3.6.2 Posture analysis by the OWAS, REBA and RULA methods:

From the results of OWAS method (Table 5.46) it was found that the female golden thread workers had greater action level (3) in case of squatting posture than those other two postures (action level 2) indicating that the former posture needed 'corrective measures as soon as possible and 'Corrective measures in the near future' in other two postures.

From the analysis of REBA method it was found that the action level of in case of sitting on the floor with folded legs had lesser action level (10) than that of other two postures (action level 12). It was further noted that sitting on the floor with stretched legs and the squatting posture were categorized as 'very high risk' whereas sitting on the floor with folded legs was categorized as 'high risk'. However, postural assessment by RULA method (Table 5.48) indicated that there was no difference in action level among three postures. So, from the results of postural analysis by tree methods it was revealed that the workers who sat on the floor with folded legs showed the lowest action level than that of other two postures. Such findings might be related to postural stress owing to long term adoption of squatting during performing the tasks. Other investigations suggested that working in squatting and squat bending posture were both significantly associated with prevalence of lower back problems and both were judged by workers to be the most problematic job factors contributing to pain and injury (Maity et al.,2013, Roffey et al., 2010, Merlino et al.,2003).

Table 5.46: Results (action level and risk levels) of postural analysis of the golden thread workers working in different work postures

Posture	Methods of Postural analysis					
	OWAS		REBA		RULA	
	Action Level	Risk level	Action Level	Risk level	Action Level	Risk level
Sitting on the floor with folded legs	2	Corrective measures in the near future	10	High risk, investigate and implement change	7	Investigate and implement change
Sitting on the floor with stretched legs	2	Corrective measures in the near future	12	Very high risk, implement Change	7	Investigate and implement change
Squatting	3	Corrective measures as soon as possible	12	Very high risk, implement Change	7	Investigate and Implement change

- **Biomechanical Study**

***5.3.6.3* Center of Gravity:**

The location of the center of gravity represents the stability and equilibrium of the body. The location of CG of female golden thread workers was determined in three different working postures adopted by the golden thread workers and in normal standing posture which was taken as reference posture.

The result showed that the location of vertical CG of the workers during working conditions was lower than that of normal standing condition (Table 5.47). The location of vertical CG was lower in three different sitting postures from the reference posture. This might be due to adopting sitting posture during performing work. In sitting posture total length of the body became lower than that of erect posture. The center of gravity shifts with each change in body alignment, and the amount of weight borne by the joints and the pull of the muscles vary within reasonable limits with each body movement. The body's stability is the greatest when its center of gravity is low and its base of support is wide. Knee and hip joints are fully extended during weight bearing (Schafer, 1997).

Among three sitting postures the location of vertical CG was found to vary. It was observed that the position of vertical CG (50.28%) was significantly higher ($p<0.001$) during adopting squatting posture in comparison to other sitting postures, i.e., sitting on the floor with folded legs (42.15%) and sitting on the floor with stretched legs (42.13%). Such variation in the location of CG might be due difference in posture in relation to working demands and relative positions of different body segments. Any change in position of a partial center of gravity produced a corresponding change in the common center of gravity. When the arms were raised overhead and lowered, the center of gravity was respectively raised and lowered within the body. When the arms are stretched forward or backward, the center of gravity is respectively moved anteriorly or posteriorly within the body. When the trunk is flexed severely forward or laterally, the center of gravity shifts outside the body (Schafer, 1997).

Table-5.47: Location (expressed as % of body length) of center of gravity (CG) of golden thread workers during adopting different postures (n=15)

Postures	Vertical CG		Horizontal CG	
	Location of CG (Mean ±SD)	Deviation from reference posture	Location of CG (Mean ±SD)	Deviation from reference posture
Normal standing (Reference)	55.32±3.06	-	44.71±2.17	-
Sitting on the floor with folded legs	42.15±2.35	13.17	47.14±3.15	-2.43
Squatting	50.28±2.80**	5.04	36.37±7.9*	8.56
Sitting on the floor with Stretched legs	42.13±2.44#	13.19	39.54±6.03*	5.17

w.r.t Sitting on the floor with folded legs *p<0.05; **p<0.001; w.r.t Squatting #p<0.001

The results revealed that there was a greater shift of the location of CG towards the base of the body during sitting on the floor than that of squatting posture. Thus the body became more stable during work while the workers sat on the floor.

The position of horizontal CG (47.14%) was greater when the subjects sat on the floor with folded legs than that of reference posture. Thus the Horizontal CG shifted slightly toward left side of the body. However, the shift of CG was significantly lesser (p<0.001) in case of sitting on the floor with folded legs in comparison to squatting posture and sitting on the floor with stretched leg position. On the other hand the horizontal CG shifted towards right side of the body in squatting posture and sitting on the floor with stretched legs position. Among three postures the location of horizontal CG showed least shift in case sitting with folded legs. Thus it indicated that the CG had lesser shift from the line of CG. Greater shift of CG from the line of CG induced instability (Schafer, 1997). Fekete et al., (2013) suggested that the general relationship between the squatting and the excursion of COG can be described with linear, dimensionless functions.

The shifting of CG towards upper side of body makes the body unstable and leads to impose postural load. Thus due to the deviation of CG indicated that the workers were compelled to work under unstable posture which might be a reason for having musculoskeletal problems among the workers. A greater shift in vertical CG towards the base was found during sitting on the floor than that of squatting posture and a least deviation in horizontal CG was noted in case of sitting on the floor with folded legs.

5.3.6.4 Study of base contact area:

Since the body is a segmented system, the stability of the body depends upon the stability of its individual segments. The force of gravity acting upon each segment must be individually neutralized if the body as a whole is to be in complete gravitational balance. Both the size and position of the base of support are important in maintaining equilibrium (Schafer, 1987).

Table 5.48: Mean and SD value of Base Contact area of golden thread workers adopting different working posture

Postures	Base Contact area (in sq.cm)
Sitting on the floor with folded legs	1065.13±752.25
Squatting	279.76 ±31.04
Sitting on the floor with stretched legs	1792.87±535.71
F-value	20.12 ###

p<0.001

The base contact areas between the body of the workers and the floor (base) have been presented in Table 5.48. The results exhibited that there was a wide variation in body contact areas in different postures. The results of ANOVA showed that there was a significant variation ($p<0.001$) in base contact area among different postures. It was noted from the results that base contact area was much lower in squatting posture than that of other sitting postures. It was calculated that the mean base contact area of subjects was about 2.8 times and 5.4 times greater in sitting on the floor with folded legs and sitting with stretched legs respectively in comparison to that of squatting posture. Greater body contact area represents greater stability of the body in a particular posture. Hence sitting on the floor with stretched legs and with folded legs had greater stability of the body during performing golden thread work. Thus it may be suggested that the sitting on the floor with folded legs and stretched leg may an optimum sitting posture for the golden thread workers.

***5.3.6.5* Joint Angles:**

The golden thread workers were used to perform their task in three postures discussed earlier and they used to adopt free posture change during performing their jobs. The deviations between the recorded measurements at each joint angle in different sitting postures from the reference posture (standing erect) was calculated and presented in Table 5.49.

It was revealed from the results that the deviation of joint angle from normal erect posture was higher in shoulder (right side 185.52%), elbow (right side 40.58%) and hip (right side 48.52%) angles during working in squatting posture than in the other two working postures. There were also significant differences in knee ($p<0.001$) joint angles among three postures and the knee flexion was the highest in squatting posture among those angles. The high degree of flexion of the knees and the external pressure on the knees, especially in kneeling and squatting, are known contributors to knee complaints (Bejjani et al., 1984).

Table-5.49: Different body joint angles (Mean ±SD) of golden thread workers (n=114) during adopting normal erect posture and different working postures and their deviation from normal erect posture

Body Joint angles		Postures							
		Normal erect posture	Squatting (n=28)		Sitting on the floor with stretched legs(n=18)		Sitting on the floor with folded legs (n=68)		F value
			working posture	% Deviation	working posture	% Deviation	working posture	% Deviation	
Shoulder	L	33.30± 0.43	54.57± 18.3	63.90%	60.67± 23.09	82.21	50.97± 17.04	53.09%	1.1
	R	33.66± 0.46	96.11± 18.3	185.52%	91.00± 20.12	170.35%	91.66± 22.79	172.31%	0.40
Elbow	L	166.54± 2.65	98.96± 25.8	40.58%	100.67± 24.31	39.55%	96.18± 21.38	42.25%	0.04
	R	165.35± 1.34	88.86± 16.3	46.26%	86.83± 11.53	47.49%	90.32± 22.72	45.38%	0.17
Wrist	L	176.37± 1.70	166.71± 13.8	5.47%	164.50± 25.30	6.73%	166.31± 20.43	5.70%	0.04
	R	175.20± 0.77	174.50± 5.0	0.40%	167.00± 8.46	4.68%	169.51± 13.92	3.24%	1.29
Hip	L	172.06± 3.35	92.75± 11.9	46.09%	92.33± 8.35	46.34%	90.41± 11.90	47.45%	1.99
	R	172.73± 0.45	88.93± 15.1	48.52%	89.67± 5.87	48.09%	91.63± 11.51	46.95%	0.24
Knee	L	175.24± 0.08	45.36 ± 13.5	74.12%	158.50± 25.01	9.55%	55.89± 13.28	68.10%	158.2 ***
	R	175.86± 0.33	49.18± 15.4	72.04%	165.00± 11.44	6.17%	55.79± 17.08	68.27%	119.3 ***

L=Left side, R=Right side ***p<0.001

5.3.6.6 Study of EMG voltage:

Electromyographic (EMG) analysis can provide information as to the relative amount of muscular activity an exercise requires, as well as the optimal positioning for the exercise (Richard et al., 2007).The EMG study of the shoulder (Trapezius) and back (Lattisimus dorsi) muscles of the female golden thread workers was performed in three sitting postures on a comparative basis. EMG records which were taken in normal sitting posture was taken as reference posture and the deviations of the EMG voltages in working postures from that of the reference posture were computed. For EMG studies 10 subjects were randomly chosen from the previously selected female golden thread workers.

5.3.6.6.1 Shoulder Muscle (Trapezius)

The EMG voltages and RMS values of EMG signal of the shoulder (Trapezius) muscle of female golden thread workers have been presented in Table 5.50. ANOVA was performed for the EMG voltage and RMS values among three postures. From the results of ANOVA, it was revealed that there was a significant differences ($p<0.01$ or lesser) in the EMG values and RMS values of shoulder muscle , in both left and right side, among different sitting postures. While studying the relative percentage difference with respect to normal sitting posture, which was taken as reference posture, it was found that the deviation was the minimum in case of sitting with folded legs, except the left shoulder muscle, than that of other two postures (Fig.5.11).

As F-values of ANOVA were significant EMG voltage and RMS value of back muscle a post hoc analysis was performed. The result of post hoc study of EMG and RMS value of EMG of shoulder muscle in different working postures has been presented in Table 5.51 A and 5.51 B respectively. The EMG values (right side) and RMS values (both side) was significantly lower ($p<0.01$) in case of sitting on the floor with folded legs than that of squatting posture. Also a significantly lower EMG values in the left side ($p< 0.05$) was observed while sitting on the floor with stretched legs than that of squatting posture. The RMS value showed significantly lower value ($p<0.05$ or lesser) while sitting on the floor with folded legs than that of other two postures.

The result of EMG study of the shoulder (Trapezius) muscle of female golden thread workers revealed that there was lesser stress on shoulder muscle while sitting on floor with folded legs. This might be due to the fact that while sitting on the floor with folded legs, the workers had lesser shoulder abduction, as shown in Table 5.49 during work in comparison to other two postures.

Table 5.50: Mean and standard deviation of EMG and RMS values (mV) of shoulder muscle of golden thread workers adopting normal sitting and three different working postures (n=10)

Postures	EMG-R		EMG-L		RMS-R		RMS-L	
	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal sitting (resting)	0.0264 ± 0.012	-	0.0298 ± 0.008	-	0.0307 ± 0.007	-	0.0368 ± 0.008	-
Sitting on the floor with Folded legs	0.0512 ±0.024	94.13	0.0407 ± 0.044	36.60	0.0473 ± 0.007	54.28	0.0458 ± 0.008	24.59
Stretched legs	0.0608 ±0.067	130.63	0.0303 ± 0.037	1.43	0.0913 ± 0.019	197.72	0.0951 ± 0.014	158.49
Squatting	0.1061 ±0.044	302.44	0.0901 ± 0.054	201.98	0.0836 ± 0.048	172.58	0.0749 ± 0.032	103.54
F-value	5.75 **	-	4.65 **	-	18.67 ***	-	19.20 ***	-

**p <0.01, ***p<0.001

The EMG voltage of shoulder muscle was the minimum in case of the workers sitting on the floor with folded legs among three working postures and in this posture minimum deviation of the EMG voltage from that of the reference posture was also noted in the dominant hand, i.e., right hand. In case of left hand the minimum EMG voltage or deviation of EMG voltage from the reference position, was noted during sitting with stretched leg. This might be due to the fact that the left hand remained in the lower side of the work surface under working condition and it had a supporting role for weaving golden thread. The EMG voltage of the right side was greater than that of left side, which might be due to greater activity of right hand as a result of raising the arm during work. A greater relative amplitude of an EMG signal of a muscle is associated with greater relative contractile force (Neumann, 2010).

Table 5.51 A: Post-hoc analysis of EMG value of shoulder muscle of golden thread workers adopting normal sitting and three different working postures (n=10)

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Stretched legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.0264	0.0298	0.0512	0.0407	0.0608	0.0303	0.1061	0.0901
Normal sitting (resting)	MD	-	-	-0.02	-0.01	-0.03	-0.0004	-0.08	-0.06
	SL			P<0.05	NS	NS	NS	P<0.001	P<0.01
Sitting on the floor with Folded legs	MD	-	-	-	-	-0.0096	0.0105	-0.0549	-0.0493
	SL					NS	NS	P<0.01	NS
Stretched legs	MD	-	-	-	-	-	-	-0.0453	-0.0598
	SL							NS	P<0.05

MD=Mean difference, SL=Significant level

Table 5.51 B: Post-hoc analysis of RMS value of shoulder muscle of golden thread workers adopting normal sitting and three different working postures (n=10)

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Stretched legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.0307	0.0368	0.0473	0.0458	0.0913	0.0951	0.0836	0.0749
Normal sitting (resting)	MD	-	-	-0.02	-0.01	-0.06	-0.06	-0.05	-0.04
	SL			P<0.001	P<0.05	P<0.001	P<0.001	P<0.01	P<0.01
Sitting on the floor with Folded legs	MD	-	-	-	-	-0.0440	-0.0493	-0.0363	-0.0290
	SL					P<0.001	P<0.001	P<0.01	P<0.05
Stretched legs	MD	-	-	-	-	-	-	0.0077	0.0202
	SL							NS	NS

MD=Mean difference, SL=Significant level

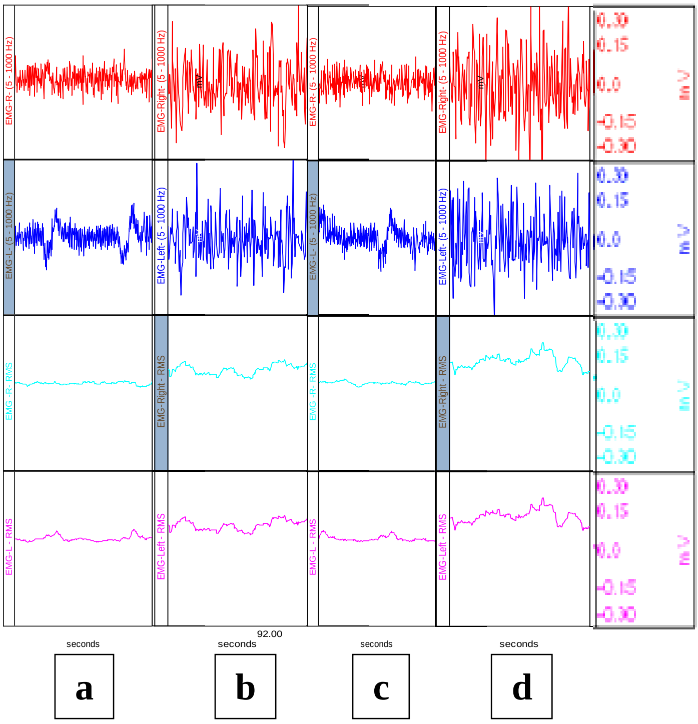


Fig.5.11: EMG and RMS of right and left side of the shoulder muscle during adopting normal (refference) [a] and different working postures: Stretched leg[b] Sitting on the floor with folded legs[c] and Squatting[d]

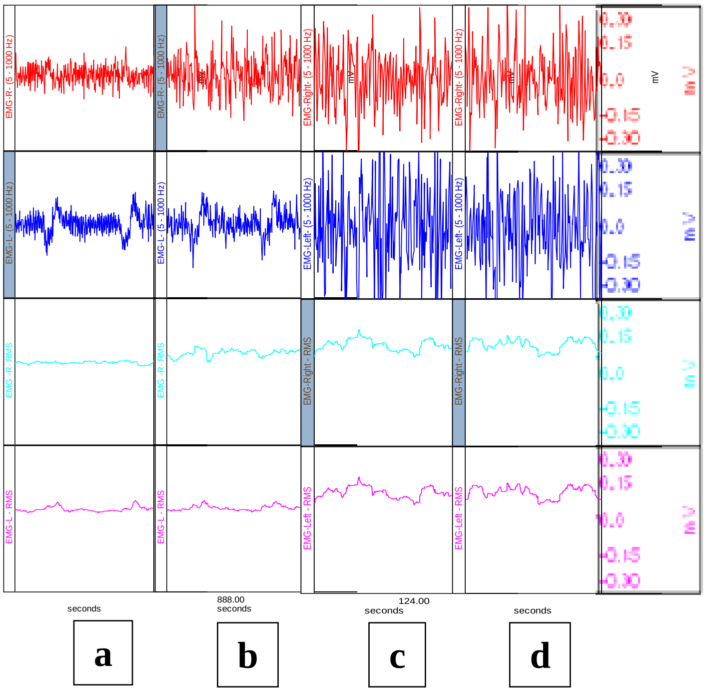


Fig.5.12: EMG and RMS of right and left side of the back muscle during adopting normal (refference) [a] and different working postures: Sitting on the floor with folded legs[b] Squatting[c] and Stretched leg[d]

5.3.6.6.2 Back Muscle (lattisimus dorsi)

The EMG voltage and RMS values of back muscle (lattisimus dorsi) of the golden thread workers have been presented in Table 5.52. The EMG voltage in the right side and RMS values of EMG signal, of both left and right side, of back muscle showed a significant difference (p<0.05 or lesser) amongst the postures under study. The percentage difference of EMG and RMS values from that of reference posture (normal sitting) was greater in case of squatting posture than that of other two postures. However, the lowest EMG and RMS values were noted in case sitting on the floor with stretched legs (Fig.5.12).

Table-5.52: Mean and standard deviation of EMG and RMS values (mV) of back muscle of golden thread workers adopting normal and three different working postures

Postures	EMG-R		EMG-L		RMS-R		RMS-L	
	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal sitting (resting)	0.0234 ± 0.0060		0.0258 ± 0.0049		0.0265 ± 0.0055		0.0315 ± 0.0049	
Sitting on the floor with Folded legs	0.0361 ± 0.015	53.94	0.0287 ± 0.017	11.15	0.0857 ± 0.027	223.56	0.0800 ± 0.021	153.56
Stretched legs	0.0428 ± 0.035	82.41	0.0383 ± 0.030	48.22	0.0279 ± 0.010	5.34	0.0262 ± 0.011	16.83
Squatting	0.0758 ± 0.049	223.40	0.0642 ± 0.064	148.42	0.1016 ± 0.024	283.51	0.0999 ± 0.022	216.72
F-value	3.825*		1.69 NS		28.95***		34.86***	

* p<0.05 ***p<0.001

The results of the post hoc analysis of the EMG voltage and RMS value of back muscle in different working postures have been presented in Table 5.53 A, and 5.53 B respectively.

Table-5.53 A: Post-hoc analysis of EMG value of back muscle of golden thread workers adopting normal sitting and three different working postures (n=10)

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Stretched legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.0234	0.0258	0.0361	0.0287	0.0428	0.0383	0.0758	0.0642
Normal sitting (resting)	MD	-	-	-0.0126	-0.0029	-0.0193	-0.0125	-0.0524	-0.0383
	SL			P<0.05	NS	NS	NS	P<0.05	NS
Sitting on the floor with Folded legs	MD	-	-	-	-	-0.0067	-0.0096	-0.0397	-0.0355
	SL					NS	NS	NS	NS
Stretched legs	MD	-	-	-	-	-	-	-0.0331	-0.0259
	SL							NS	NS

MD=Mean difference, SL=Significant level

Table-5.53 B: Post-hoc analysis of RMS value of back muscle of golden thread workers adopting normal sitting and three different working postures (n=10)

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Stretched legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.0265	0.0315	0.0857	0.0800	0.0279	0.0262	0.1016	0.0999
Normal sitting (resting)	MD	-	-	-0.0592	-0.0484	-0.0014	-0.0053	-0.0751	-0.0684
	SL			P<0.001	P<0.001	NS	NS	P<0.001	P<0.001
Sitting on the floor with Folded legs	MD	-	-	-	-	0.0578	0.0537	-0.0159	-0.0199
	SL					P<0.001	P<0.001	NS	NS
Stretched legs	MD	-	-	-	-	-	-	-0.0737	-0.0737
	SL							P<0.01	P<0.01

MD=Mean difference, SL=Significant level

It was noted that the EMG voltage of right side was significantly higher in squatting posture and during sitting on the floor with folded legs ($p<0.05$) when compared to values in normal sitting posture. There was no significant difference in EMG voltage between sitting on the floor with folded lags and stretched legs as well as between sitting with stretched legs and squatting posture. In case of RMS values significant differences ($p<0.01$ or lesser) were noted between sitting on the floor with folded lags and stretched legs as well as between sitting with stretched legs and squatting posture. This might be due to lesser stress imposed on the back muscle during performing the task. The stress on the back muscle depends on the degree of forward bending, twisting and instability of the body. As there was a wider base contact area of the body with the ground the worker was more stable during sitting on the floor with folded legs than that in squatting posture (Dutta and Dhara, 2012).

Further, there was lesser degree of bending of the trunk during sitting on the floor with folded leg in comparison to work under squatting posture. Those might be the probable reasons for imposing lesser stress on back muscle during sitting on the floor with folded legs. Bidard et al., (2000) also revealed that the stabilization effort was greater for unsupported sitting than for standing because of not optimal alignment of the centers of mass. Thus in squatting posture, more stabilizing efforts might be adopted by the body than that of sitting on floor, which possessed large contact area with the ground. Therefore, it might be one of the reasons for the lesser BPD rating (Table 5.43) and lower prevalence of MSD (Table 5.42 B) at the lower back region while sitting on the floor with folded legs than in that of the squatting postures.

5.3.7 Physiological Stress

The physiological stress of the golden thread workers was evaluated in terms of pulse rate and Cardio-vascular stress index measurement.

- **Evaluation of Cardiovascular Status:**

The resting and working heart rates and Cardiovascular Stress Index (CSI) of female workers were determined during performing golden thread work in three different working postures. There was a significant difference ($p<0.01$) in working HR and resting HR of the workers (Table 5.54). According to classification of CSI (Brant, 2009) the female golden thread workers low cardiovascular stress, probably due to work in sitting posture.

Table-5.54: Cardiovascular Stress Index (CSI) of golden thread workers (n=114)

Parameters	Golden thread workers (n=114)		
	Squatting (n=28)	Sitting on the floor with Stretched legs (n=18)	Sitting on the floor with Folded legs (n=68)
Resting HR	71.74±4.79	69.41± 6.62	69.30±2.69
Working HR	96.89±6.97	92.33±3.15*	91.38±9.13
Work Pulse	25.16±9.43	22.92±6.67	22.08±10.06
CSI	20.56±7.18	18.41±5.04	17.29±7.65

w.r.t. squatting $p<0.05$

The working heart rate as well as CSI was lower, although non-significantly, in sitting on the floor with folded legs posture than other two postures. The working heart rate and work pulse were greater in squatting posture than that of sitting on the floor. The increase of heart rate might be due to impose of work related stresses. Several evidences revealed that heart rate increased during work as a result of cardiovascular responses might be due to physical, psychosocial stressors (Belkaie et al., 2004, Kivimaki et al., 2006) and also due to work related stress (Savonen et al., 2006). When comparative study was done according to posture it was observed that the workers who adopted squatting posture having significantly higher working heart rate ($p<0.05$) than that of the workers who adopt sitting on the floor with stretched legs posture, which indicates squatting posture impose greater cardiovascular stress than sitting on the floor.

D. Comparative study of different work related stresses among three groups of female workers engaged in craft work, mat weaving and golden thread work

5.4.1 Occupational Health Hazards

5.4.1.1 Musculoskeletal Disorder: The prevalence of musculoskeletal disorders (MSD) in the female workers of three occupational groups was compared and the results have been presented in Table 5.55, 5.56 and 5.57 for three different postures. The comparative study revealed that the prevalence of musculoskeletal disorders of the female workers had significant ($p<0.001$) differences in all segments of body among three jobs, except a few segments. The thigh, in case of squatting, upper back in case of sitting on the floor with folded legs and shoulder and elbow in sitting on the floor with stretched legs had no significant difference among the women of three occupations.

Table 5.55: Prevalence (%) of musculoskeletal disorders (MSD) in female workers of three occupations during adopting squatting posture

Body segment	Squatting Posture			Chi Square Value ($\chi2$)
	Craft workers (n=20)	Mat workers (n=60)	Golden thread workers (n=28)	
Neck	45.00	85.00	25.00	12.80**
Shoulder	85.00	98.33	89.29	80.20***
Elbow	55.00	41.67	25.00	39.82***
Wrist	55.00	20.00	10.71	104.11***
Upper back	50.00	83.33	32.14	9.65**
Lower back	85.00	100.0	92.16	89.83***
Thigh	70.00	75.00	28.57	0.45 NS
Knee	85.00	88.33	32.14	7.52*
Feet	80.00	43.33	3.57	39.21***

**p<0.01 ***p<0.001

In case of adopting squatting posture Chi square test showed that there were significant differences ($p<0.01$ or less) in the occurrence of MSD in all the body segments, excepting thigh, among the female workers of three jobs (Table 5.55). In the said posture the prevalence of MSD was the lowest in the female workers engaged in golden thread workers, except for shoulder and lower back, among three jobs. When compared between craft and mat workers it appeared that the Mat weavers had greater prevalence of MSD in most of body segments, except elbow, wrist and feet.

Table 5.56: Prevalence (%) of musculoskeletal disorders (MSD) in female workers of three occupations during adopting Sitting on the floor with folded legs

Body segment	Sitting on the floor with Folded legs			Chi Square Value ($\chi2$)
	Craft workers (n=49)	Mat workers (n=48)	Golden thread workers (n=68)	
Neck	85.71	58.33	27.94	38.79***
Shoulder	83.67	97.92	82.35	76.89***
Elbow	48.98	4.17	19.12	81.53***
Wrist	46.94	37.5	7.35	65.59***
Upper back	42.86	52.08	45.59	4.40 NS
Lower back	77.55	100.00	89.71	86.10***
Thigh	77.55	47.92	20.59	42.14***
Knee	81.63	81.25	25.00	52.46***
Feet	61.22	6.25	1.47	120.34***

***$p<0.001$

The prevalence of MSD, in case sitting on the floor with folded legs, was significantly different ($p<0.001$) in all the body segments, excepting upper back, among the women of three occupational groups (Table 5.56). The occurrence of MSD was lower in golden thread workers in most of the body segments than that of other two groups of workers. A lower prevalence of MSD was noted among mat weavers in neck, elbow, wrist, thigh, and feet when compared with that of craft workers.

Table 5.57: Prevalence (%) of musculoskeletal disorders (MSD) in female workers of three occupations during sitting on the floor with stretched legs.

Body segment	Sitting on the floor with Stretched legs		Chi Square Value ($\chi 2$)
	Craft workers (n=24)	Golden thread workers (n=18)	
Neck	100.00	33.33	22.40 ***
Shoulder	83.33	100.00	3.32 NS
Elbow	50.00	66.67	1.17 NS
Wrist	66.67	16.67	10.38 ***
Upper back	50.00	100.00	12.60 ***
Lower back	100.00	100.00	0.00
Thigh	83.33	16.67	18.45 ***
Knee	100.00	33.33	22.40 ***
Feet	66.67	0.00	19.39 ***

***$p<0.001$

The mat weavers were not used to stretch their legs, due to work demand, while sitting on the floor during performing the task. Therefore, other two jobs, craft and golden thread workers, were compared for the sitting with stretched legs. When the workers were performing their task in sitting with stretched legs, 100 percent of the golden thread workers reported MSD in shoulder, and lower and upper back (Table 5.57). On the other hand, 100 percent of the craft workers showed musculoskeletal problems in neck, lower back and knee. From the results of the Chi square test it was noticed that there were significant differences ($p<0.001$) in the occurrence of MSD in different body segments, except for shoulder, elbow and lower back. The prevalence of MSD was comparatively lower among the golden thread workers than that of craft workers in most of the body segments.

It appeared from the above discussion that the prevalence of MSD was the highest in lower back segments in all the jobs and it was also very high in shoulder segment in all the jobs. The prevalence of MSD was lower among the female golden thread worker. A comparatively lower mean age of the golden thread workers might be one of the reasons for the lower rate of occurrence of MSD in that occupational group.

5.4.1.2 Body Part Discomfort (BPD) rating:

Table 5.58: The Body part discomfort (BPD) rating (Mean ±SD) in different segments of the body (in a 10 point scale) of female workers during adopting squatting posture

Body segments		Squatting Posture			F value
		Craft workers (n=20)	Mat weavers (n=60)	Golden thread workers (n=28)	
Neck		2.25±2.61	4.65±2.03	0.93±1.74	33.27 ***
Shoulder	R	4.40±2.04	5.90±1.15	4.96±2.38	6.84 **
	L	4.35±1.98	5.63±0.96	4.54±2.10	7.90 ***
Upper arm	R	2.6±1.93	1.03±1.50	1.11±2.17	6.20 **
	L	2.6±1.93	1.03±1.50	0.96±1.95	7.07 **
Lower arm	R	1.35±1.53	0.05±0.39	0.50±1.53	11.58 ***
	L	1.35±1.53	0.05±0.39	0.46±1.40	12.59 ***
Upper back		2.3±2.43	4.52±2.79	1.33±2.04	16.88 ***
Middle back		3.25±2.49	4.35±2.56	2.46±2.78	5.30 **
Lower Back		5.35±2.60	8.00±1.01	6.64±2.83	14.95 ***
Buttock		2.35±2.16	0.67±1.23	0.32±1.70	11.21 ***
Thigh	R	3.3±2.3	3.55±2.59	0.93±1.90	12.11 ***
	L	3.3±2.3	3.55±2.59	0.93±1.90	12.11 ***
Cuff	R	3.85±2.01	4.18±2.31	1.46±2.22	14.21 ***
	L	3.85±2.01	4.18±2.31	1.46±2.22	14.21 ***
Feet	R	2.7±1.56	1.45±1.95	0.21±1.13	12.56 ***
	L	2.7±1.56	1.45±1.95	0.21±1.13	12.56 ***
Over all discomfort rating of the body		3.05±1.26	3.19±1.20	1.73±0.73	16.69 ***

*** $p<0.001$, ** $p<0.01$

A comparison of body part discomfort (BPD) rating of different jobs, while adopting squatting posture, has been presented in Table 5.58. The statistical analysis of data (ANOVA) represented that the mean values of BPD had significant differences ($p<0.01$ or less) in all the body segments among three groups of female workers. It was revealed that the mat weavers had greater degree of BPD in most of the body segments, e.g., neck, shoulder, back, thigh and cuff during working in squatting posture (Table 5.58) than that of other groups of workers. In upper extremities the craft workers had higher degree of discomfort / pain than other groups of workers. The results also revealed that the overall BPD rating, considering discomfort ratings of all body segments, had a significant difference ($p<0.001$) among the groups of workers. The golden thread workers had lowest degree of BPD rating among three groups of workers while adopting squatting posture. On the other hand, the mean overall BPD was of highest degree in female mat weavers.

Table 5.59: The Body part discomfort (BPD) rating (Mean ±SD) in different segments of the body (in a 10 point scale) of female workers during adopting Sitting on the floor with folded legs Posture

Body segments		Sitting on the floor with folded legs Posture			F value
		Craft workers (n=49)	Mat workers (n=48)	Golden thread workers (n=68)	
Neck		3.71±1.81	2.71±2.39	0.96±1.64	30.55 ***
Shoulder	R	3.47±1.82	5.31±1.34	4.24±2.46	30.39 ***
	L	3.43±1.80	5.29±1.20	3.31±2.59	15.36 ***
Upper arm	R	1.59±1.71	1.29±1.64	1.04±2.08	1.25 NS
	L	1.59±1.71	1.29±1.64	0.79±1.85	3.12 *
Lower arm	R	1.27±1.56	0.38±0.49	0.46±1.56	6.85 **
	L	1.27±1.56	0.29±0.46	0.43±1.45	8.48 ***
Upper back		1.73±2.13	4.04±2.20	2.47±2.43	20.57 ***
Middle back		2.43±2.50	3.75±2.35	1.94±2.64	7.46 ***
Lower Back		4.51±2.55	7.35±0.89	6.46±2.54	21.51 ***
Buttock		0.90±1.66	0.50±1.25	0.07±0.61	6.86 **
Thigh		3.43±2.03	1.71±1.92	0.85±1.94	24.73 ***
	L	3.37±2.03	1.71±1.92	0.85±1.94	23.55 ***
Cuff	R	3.02±1.73	3.60±1.93	1.34±2.28	19.84 ***
	L	3.02±1.73	3.60±1.93	1.34±2.28	19.84 ***
Feet	R	1.90±1.46	0.15±0.77	0.07±0.61	58.01 ***
	L	1.90±1.46	0.15±0.77	0.07±0.61	58.01 ***
Over all discomfort rating of the body		2.50±0.84	2.54±0.68	1.57±0.74	31.50 ***

*** $p<0.001$, ** $p<0.01$, * $p<0.05$

During performing the work, while sitting on the floor with folded legs, the mat weavers reported greater extent of discomfort / pain in neck, shoulder, back, and cuff regions in comparison to other two groups (Table 5.59). Further, the craft workers showed higher extent of discomfort / pain in segments of upper extremities than that of other two groups. Statistical analysis showed that there were significant differences ($p<0.05$ or less) in BPD in all body segments among three occupational groups. The overall BPD, considering discomfort ratings of all body segments, was significantly different ($p<0.001$) among three groups of female workers. In this working posture (sitting on the floor with folded legs) the golden thread workers had lower extent of BPD in comparison to other two groups of workers.

Table 5.60: The Body part discomfort (BPD) rating (Mean ±SD) in different segment of the body (in a 10 point scale) of female workers during adopting Sitting on the floor with Stretched legs Posture

Body segments		Sitting on the floor with Stretched legs Posture	
		craft workers	golden thread workers
Neck		4.83±0.92	1.33±2.03***
Shoulder	R	4.08±2.10	5.17±1.25
	L	4.00±2.04	4.00±2.38
Upper arm	R	2.75±2.15	1.67±2.28
	L	2.75±2.15	1.67±2.28
Lower arm	R	1.50±1.53	0.83±1.92
	L	1.50±1.53	0.83±2.04
Upper back		2.33±2.04	5.00±1.19
Middle back		4.33±1.58	5.00±2.97
Lower Back		6.08±1.10	7.83±1.25
Buttock		1.50±1.53	1.00±2.30
Thigh	R	3.17±1.71	0.83±1.92**
	L	3.17±1.71	0.83±1.92**
Cuff	R	4.25±0.99	2.67±2.77
	L	4.25±0.99	2.67±2.77
Feet	R	2.33±1.83	0.00
	L	2.33±1.83	0.00
Over all discomfort rating of the body		3.25±0.78	2.43±1.25***

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

A comparison of BPD rating was also made between two jobs for another working posture, i.e., sitting on the floor with stretched legs (Table 5.60).The results revealed that there was not much differences in BPD between two groups of workers. However, the craft workers had significantly higher degree of discomfort / pain in neck and in the segments of upper and lower extremities than golden thread workers. In shoulder and back segments, the golden thread workers had higher extent of pain / discomfort than that of craft workers. There was a significant difference ($p<0.001$ or less) in BPD rating in all body segments of the workers among three jobs in different working posture.

Table 5.61: Comparison of Overall BPD of different groups of workers in different working postures

Posture	Craft workers (n=93)	Mat weavers (n=108)	Golden thread workers (n=114)	F -values
Squatting	3.05±1.26	3.19±1.20	1.73±0.73	16.69 ***
Sitting on the floor with Folded legs Posture	2.50±0.84	2.54±0.68	1.57±0.74	31.50 ***
Sitting on the floor with Stretched legs Posture	3.25±0.78	-	2.43±1.25	6.66*

*$p<0.05$, ***$P<0.001$

However, the overall BPD had not much difference between two groups of workers. The overall BPD of three groups of workers has been compared among three working postures Table 5.61. From the results of BPD rating it may be stated that the golden thread workers had lower extent of BPD than that of the workers of other two groups. When the posture was considered it was noted that the lowest degree of BPD was noted in case of sitting on the floor with folded legs.

5.4.2.2 Work-Rest Cycle

Work rest cycle is accompanied by work and rest periods. The human body shows a rhythmic balance between energy consumption and energy replacement during work and rest period. According to Caicoyal and Delclos (2010), those performing highly repetitive tasks for longer duration reported pain at different segments of their body parts. So, the total duration of work shift is very much important for assessment of job related stress. From the comparative study it was observed that the total duration of work shift was lower in craft work than that of mat and golden thread jobs (Table 5.62). In latter two jobs the workers were used to work for 8 to 9 hours in a day. However, in craft work the percentage of work time was the highest and the rest pause was the lowest among three jobs. It may be noted that in case of golden thread work the rest period was the highest (about 49% of the work shift) among three jobs. It may be pointed out that the BPD rating and prevalence of MSD was the lowest (considering all three postures) in golden thread work among three postures. Sufficient rest pause might be helpful for reducing fatigue as well as work related MSD. Samani, et al (2009) pointed out that active pauses contributed to a more variable muscle activity pattern that might have functional implications with respect to work-related musculoskeletal disorders. It is an established fact that fatigue is one of the major job related stress factor. 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. Thus fatigue is usually short-lived and reversible: they disappear after 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 (Åkerstedt 2006; Härmä 2006; Sluiter et al. 2001; Van Hooff et al. 2005) and eventually may lead to ill-health (Meijman & Mulder, 1998).

Table 5.62: Comparative study of work time and rest time (Mean ± SD) of the workers engaged in different jobs.

Time	Craft work		Mat weaving		Golden thread work	
	Time *(min)*	Percentage of work shift	Time *(min)*	Percentage	Time *(min)*	Percentage of work shift
Total Work time	194.48± 35.96	65.24	282.22± 42.94	57.21	255.04± 45.64	51.10
Total Rest time	103.61± 22.64	34.76	211.12± 13.07	42.79	244.10± 23.43	48.90
Total duration of Work shift	298.08± 33.42	100%	493.33± 51.64	100%	499.15± 58.34	100%

The rest pause was further analyzed and the results have been presented in Table 5.63. The total rest period was divided in to two subdivisions, viz., the work related rest and the prescribed rest. It was revealed that the work related rest was the minimum in case of mat weaving. This might be related to the work related discomfort of the workers. It was noteworthy that the overall discomfort (BPD) of the mat weavers (considering all postures) was the highest among three jobs. Faucett et al. (2007) presented their findings of research on rest and recovery breaks as interventions for MSDs. They concluded that the introduction of frequent, brief rest breaks may improve symptoms for workers engaged in strenuous work tasks (Faucett et al., 2007). The implementation of regular rest pauses during repetitive work is considered to be a valuable strategy in the prevention of overuse disorders (Balci & Aghazadeh, 2003). Thus it may be concluded that work rest cycle of the total work shift requires proper modifications to improve the well-being of workers. Rest pauses are also necessary if performance and efficiency are to be maintained in these tasks.

Table 5.63: Comparative study of rest pause (Mean ± SD) of female workers engaged in different jobs

Different rest pauses time (min.)		Craft work		Mat weaving		Golden thread work	
		Time *(min)*	Percentage	Time *(min)*	Percentage	Time *(min)*	Percentage
Work related rest		37.73± 10.36	36.42	39.45± 3.01	18.69	69.10± 9.67	28.31
Prescribed rest	Tiffin Break	21.50± 9.68	20.75	44.17± 4.92	20.92	44.29± 6.07	18.14
	Lunch break	44.38± 8.63	42.83	127.50± 8.80	60.39	130.71± 12.05	53.55
Total Rest time		103.61± 22.64	100 %	211.12± 13.07	100 %	244.10± 23.43	100 %

5.4.3 Postural stress:

5.4.3.1 Posture analysis by the OWAS, REBA and RULA methods:

Postural analysis of the female workers which was made by OWAS, RULA and REBA methods were compared among three different jobs and the results have been presented in Table 5.64. From the comparative study of OWAS method it was observed that the mat weaving job was more stressful than other two jobs under study. From the results of postural assessment of REBA method it was found that the workers engaged in mat weaving and golden thread work showed higher degree of risk level than craft workers.

The results of REBA method showed differences in action level while the workers were sitting on the floor with folded legs. In this analysis craft workers had the lowest level of action level among the workers of three jobs. In case of other working postures there was not much difference in action levels among three jobs. It may be stated that the postural stress was the lowest in case of craft workers when all postures were considered.

Table 5.64: Results (action level and risk levels) of postural analysis of the female workers of different jobs working in different work postures

Posture	Job	Postural analysis of female workers in different job and posture					
		OWAS		REBA		RULA	
		Action Level	Risk level	Action Level	Risk level	Action Level	Risk level
Folded Legs	Craft	2	Corrective measures in the near future	7	Medium risk, further investigation, change soon	4	Investigation and change may be needed
	Mat	2	Corrective measures in the near future	10	High risk, investigate and implement change	6	Investigation and change soon
	Golden thread	2	Corrective measures in the near future	10	High risk, investigate and implement change	7	Investigate and implement change
Stretched Legs	Craft	2	Corrective measures in the near future	8	High risk, investigate and implement change	6	Investigation and change soon
	Golden thread	2	Corrective measures in the near future	12	Very high risk, implement Change	7	Investigate and implement change
Squatting	Craft	2	Corrective measures in the near future	12	Very high risk, implement Change	7	Investigate and implement change
	Mat	4	Corrective measures immediately	12	Very high risk, implement Change	7	Investigate and implement change
	Golden thread	3	Corrective measures as soon as possible	12	Very high risk, implement Change	7	Investigate and Implement change

Biomechanical Study

5.4.3.2 Center of Gravity

It appeared from the comparative study that the location of vertical CG of the workers during working in squatting posture was significantly higher ($p<0.001$) in golden thread workers than that of other two groups of workers. From the ANOVA study it was observed that there was a significant difference in the location of CG among three groups of workers were working their tasks in squatting posture and in sitting on the floor with folded legs posture. The location of vertical CG of the workers during working in sitting on the floor with folded legs was significantly higher ($p<0.001$ or higher) in mat weavers than that of golden thread workers and craft workers. The craft workers had significantly lower ($p<0.001$) position of CG than that of golden thread workers. In case of sitting on the floor with stretched legs during work, the golden thread workers had higher position of CG than that of craft worker, although non-significantly.

5.4.3.3 Joint Angles

Comparative analyses of different postures adopted by the female workers engaged in different jobs were made by joint angles study. In case of adopting squatting posture, it was observed that the percentage deviation of joint angle from normal erect posture was the highest in upper extremities of body in golden thread workers than craft workers and mat weavers. But in case of lower extremities mat weavers showed highest percentage of deviation than other two groups.

During performing the work, in case of adopting sitting on the floor with folded legs, the percentage deviation of joint angles from normal erect posture was also higher in right shoulder and both sides of elbow in golden thread workers than that of craft workers and mat weavers. The workers who would work in sitting on the floor with stretched legs, the deviation was higher in most of the body joint angle except wrist in golden thread workers than that of the craft workers.

5.4.3.4 Posture analysis by Study of EMG:

The comparative study of EMG voltages and RMS values of EMG signal of the shoulder (Trapezius) muscle of female workers adopting squatting posture have been presented in Table 5.65. From the results of ANOVA, it was revealed that there was a significant difference (p<0.01) in the EMG values and in the RMS values (p<0.001) of shoulder muscles of both sides among different jobs. Similarly during sitting on the floor with folded legs (Table 5.66) a significant difference (p<0.001) was observed in EMG and RMS value and in stretched leg posture (Table 5.67) only the RMS value showed significant differences among three postures.

Table 5.65: Mean and standard deviation of EMG (mV) and RMS values (mV) of shoulder muscle of female workers adopting squatting postures in different jobs (n=30)

Jobs	EMG-R		EMG-L		RMS-R		RMS-L	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Craft worker	0.054	0.014	0.042	0.014	0.065	0.003	0.050	0.017
Mat weavers	0.310	0.236	0.208	0.124	0.381	0.079	0.213	0.039
Golden thread workers	0.106	0.044	0.090	0.054	0.084	0.048	0.075	0.032
F-value	7.12 **	-	8.69 **	-	77.94 ***	-	66.29 ***	-

**p<0.01, ***p<0.001

Table 5.66: Mean and standard deviation of EMG (mV) and RMS values (mV) of shoulder muscle of female workers during sitting on the floor with folded legs in different jobs (n=30)

Jobs	EMG-R		EMG-L		RMS-R		RMS-L	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Craft worker	0.045	0.021	0.040	0.018	0.052	0.016	0.044	0.019
Mat weavers	0.172	0.105	0.160	0.075	0.193	0.055	0.166	0.03
Golden thread workers	0.051	0.024	0.041	0.044	0.047	0.007	0.046	0.008
F-value	9.62 ***	-	14.27 ***	-	47.23 ***	-	92.07 ***	-

***p<0.001

During working in squatting and sitting on the floor with folded legs, the mat weavers showed the highest value and in stretched leg posture golden thread workers showed significantly higher voltage in EMG and RMS value than that of other groups of female workers. In all three postures the EMG voltages and RMS values of shoulder muscle showed the minimum and the Maximum magnitudes by the craft workers and the mat weavers respectively. Therefore, it may be stated that the craft workers had lesser muscular stress in shoulder muscles during performing their work.

Table 5.67: Mean and standard deviation of EMG (mV) and RMS values (mV) of shoulder muscle of female workers while sitting on the floor with stretched legs in different jobs (n=30)

Jobs	EMG-R		EMG-L		RMS-R		RMS-L	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Craft worker	0.046	0.008	0.044	0.013	0.059	0.024	0.050	0.018
Golden thread workers	0.061	0.067	0.030	0.037	0.091	0.019	0.095	0.014
P-value	0.59	-	0.96	-	2.95 *	-	5.48 ***	-

*p<0.05, ***p<0.001

The EMG studies of back muscle have been conducted on the subjects of three occupational groups on a comparative basis. The comparative study of EMG voltages and RMS values of the back muscle (lattisimus dorsi) while adopting squatting posture by the female workers engaged in three jobs have been presented in Table 5.68. From the results of ANOVA, it was revealed that there was a significant difference ($p<0.001$) in EMG values of the right side and in the RMS values of back muscles of both side in different jobs. Similarly during sitting on the floor with folded legs (Table 5.69) a significant difference ($p<0.001$) was observed in EMG (right side) and RMS value (both side) of the workers of different jobs. On the other hand, in stretched leg posture (Table 5.70) the EMG (right side) and RMS value had no significant difference between two groups although the EMG parameters were higher in golden thread worker than that of the craft workers.

Table 5.68: Mean and standard deviation of EMG (mV) and RMS values (mV) of back muscle of female workers during adopting squatting postures in different jobs (n=30)

Jobs	EMG-R		EMG-L		RMS-R		RMS-L	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Craft worker	0.037	0.006	0.036	0.006	0.040	0.006	0.040	0.004
Mat weavers	0.132	0.063	0.089	0.050	0.118	0.025	0.097	0.026
Golden thread workers	0.076	0.049	0.064	0.064	0.102	0.024	0.010	0.022
F-value	10.96 ***	-	3.75 *	-	44.81 ***	-	27.81 ***	-

*p<0.51, ***p<0.001

Table 5.69: Mean and standard deviation of EMG and RMS values (mV) of back muscle of female workers while sitting on the floor with folded legs in different jobs (n=30)

Jobs	EMG-R		EMG-L		RMS-R		RMS-L	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Craft worker	0.028	0.006	0.028	0.007	0.033	0.009	0.033	0.006
Mat weavers	0.101	0.050	0.045	0.032	0.101	0.011	0.082	0.01
Golden thread workers	0.036	0.015	0.029	0.017	0.086	0.027	0.080	0.021
F-value	15.23 ***	-	1.74 NS	-	46.79 ***	-	48.93 ***	-

***p<0.001

Table 5.70: Mean and standard deviation of EMG and RMS values (mV) of back muscle of female workers while sitting on the floor with stretched legs in different jobs (n=30)

Jobs	EMG-R		EMG-L		RMS-R		RMS-L	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Craft worker	0.030	.009	0.031	0.008	0.034	0.013	0.036	0.008
Golden thread workers	0.043	0.035	0.038	0.030	0.028	0.010	0.026	0.011
P-value	-1.12 NS	-	-0.77 NS	-	0.98 NS	-	1.99 NS	-

During working with squatting and sitting on the floor with folded legs the mat weavers showed the highest value and while adopting stretched leg posture the golden thread workers showed the highest voltage in EMG (both side).

So from the EMG study it was inferred that the mat weavers had greater muscular stress than other groups of workers that is golden thread or craft workers.

5.4.4 Physiological Stress

A comparison of Cardiovascular Stress Index (CSI) of different jobs, while adopting different working posture, has been presented in Table 5.71 The comparative study revealed that the CSI of the female workers had significant difference in squatting postures ($p<0.01$) and sitting on the floor with folded legs ($p<0.05$) among three job groups. Mat weavers who were working in sitting on the floor with folded legs had significantly ($p<0.01$) greater cardiovascular stress than that of the craft workers.

Table 5.71: Cardiovascular Stress Index (CSI) of different groups of workers in different working postures

Posture	Craft workers (n=93)	Mat workers (n=108)	Golden thread workers (n=68)	F -values
Squatting	15.76±9.82	23.54±6.51	20.56±7.18	6.57 **
Sitting on the floor with Folded legs Posture	14.06±4.98	19.84±5.77#	17.29±7.65	4.85*
Sitting on the floor with Stretched legs Posture	15.69±7.48	-	18.41±5.04	-

#w.r.t to craft p<0.01,*p<0.05, **p<0.01

In case of sitting on the floor with stretched legs, the cardiovascular stress was higher in the female workers engaged in golden thread workers than that of the craft workers. The cardiovascular stress was the lowest in the female workers engaged in craft work than that of other two groups.

The prevalence of MSD and BPD rating was the lowest in golden thread workers among all three jobs. It might be attributed to the fact that the golden thread workers had lowest percentage of work time and highest percentage of rest time which ensured less fatigue during work. The lowest postural stress was noticed in craft workers. The CG indicated greater instability of the body during work in case of golden thread workers. This might be due to using a workstation the height of the same was not suitable for the workers. Due to this reason the joints angles of the golden thread workers might have greater extent abduction or flexion than other two postures. The mat workers had the higher degree of muscular stress, as appeared from EMG study, and greater extent of cardiovascular stress in comparison to other two groups of workers. It appeared from the comparative studies that mat workers were exposed to greater amount of work related stress.

E. Ergonomic intervention of workstation for Golden thread work:

In the present investigation three jobs in which female workers are engaged have been taken for ergonomics study. Among them craft workers and mat weavers had no definite work station. They were used to work by sitting on the floor in a specified space. On the other hand the golden thread workers had a definite workstation in which they had to perform their work. There was a working platform made up of a wooden / metal frame for their work. The workstations were designed with a conventional practice without due consideration of ergonomics principles. Ergonomics intervention may be helpful for improving the work condition.

There were some drawbacks in the existing design of workstation of golden thread workers from the view point of human factors. For example, the main problem of this workstation was that there was no standard working height for golden thread work. There was a wide variation in the physical dimension of work station. Therefore, the workers were sometimes required to bend forward or to raise their shoulder for long time, which caused biomechanical stress in different body joints and produced different segmental pain. For solving the problem, it is important to evaluate the workstation for the following purpose:

- To improve work posture
- To reduce musculoskeletal problems in different body parts
- To increase productivity of the workers

Therefore, an effort has been made to modify the workstation for golden thread work considering ergonomics principle. The workstation included different components, viz., length, breadth, height etc. Here, main emphasis has been given to optimize the work surface height of the workstation. The following steps were undertaken for modifying the golden thread workstation.

5.5.1 Evaluation of existing workstation

The existing workstation was evaluated by the subjective assessment as well as by some objective measurements. Five existing models of traditional golden thread workstation were selected and their physical dimensions were studied and shown in Table 5.72. The workstation used for golden thread work was found to vary in their physical dimensions. As no standard was followed, the local people made the workstation according to their own concept and requirements and also on availability of space in the working area.

Table 5.72: Physical Dimension of golden thread Workstation

Model No.	Length(cm)	Breadth(cm)	Height (cm)
1	182.5	72.9	42
2	173.45	93.5	55.5
3	190	75.3	50
4	183.5	85.5	53
5	178.6	68.6	50.5
Mean ±SD	181.61±6.13	79.16±10.14	50.2±5.08
Range	173.45-183.5	68.6-93.5	42-55.5

The physical dimension of the existing workstation played an important factor for in adopting posture during work. It was noted that female workers used to adopt awkward posture; they had to work with raised shoulder or bent forward. Results (Table 5.72) showed that the mean height of the existing workstation was 50.2 cm, which appeared high enough for the target group of subjects. This was the main reason for problem faced in shoulder and back pain among the workers. Mean length and breadth of the workstation was 181.61 cm and 79.16 cm respectively. The larger variation of length and breadth might be due to type of work and the availability of space. Sometimes the length depends on the number of workers working in the work station at a time.

5.5.2 Study of BPD and MSD

The problems of using existing workstation were evaluated by assessing the Body Part discomfort rating (BPD). This has been already discussed in the earlier section (Section **5.3.4.2**). From the discussion of the earlier sections it was depicted that the suitable working posture for female workers was sitting on the floor with folded legs. The body part discomfort (BPD) rating and prevalence of MSD have been mentioned here while sitting with folded legs. From the result of BPD rating (Table 5.43) it was found that the workers had higher extent of pain or discomfort in shoulder (right side: 4.24 & left side : 3.31) and lower back (6.46) than other segments of the body. The prevalence of MSD was also higher in those body segments than that of other body segments (Table 5.42 B). It was 82.35% in shoulder and 89.71% in case of lower back. So it may be stated that work related pain or discomfort was conspicuous in shoulder and lower back which might be due to incompatibility with the height of the workstation.

5.5.3 Joint angle study:

Here also the joint angles in sitting with folded legs were considered. From the results it was revealed that the deviation of shoulder joint angle (Table-5.49) was too large (172.31% in right side and 53.09% for left side). It was also noted that the right arm was abducted to a greater extent and it was raised to about 90^0. It was mentioned earlier that abduction of left shoulder was relatively lesser than that of right side because the left arm remained in much lower height during performing golden thread work. The above findings might be related to the unsuitable height of working surface.

It appeared from the above studies that the height of the work surface was greater than it was required. Thus it may be stated that there should be modification of workstation by optimization of the working height of the golden thread work.

5.5.4 Design Approach:

To modify the workstation a design concept was developed in which some modifications were suggested. The main emphasis was given to optimize the height of the work surface for performing golden thread work. To solve the problem the height of the existing workstation was reduced in three steps and evaluation was made. Two prototypes were made by altering the height of the work surface of golden thread work from that of existing one. The mean height of the existing work surface was about 50.0 cm. The height of the other two prototypes was 45 cm and 40 cm. Therefore, finally three prototypes, viz., H40, H45 and E (existing with a height of 50 cm) were used for further study.

5.5.4.1 **Evaluation of prototypes:**

The prototypes were evaluated by some simulation studies. The prototypes were given to the workers and asked to perform the tasks and to judge the suitability of use of the modified workstation. The compatibility of prototypes to the body of the users was evaluated by paired comparison test, different biomechanical study as well as productivity study.

5.5.4.2 **Paired comparison test:**

The paired comparison test was employed for identifying a suitable height of the workstation. The prototypes were named as E for existing model and H45 and H40 for modified prototypes having the height of 45 cm and 40 cm respectively. The test was performed on 30 subjects. The subjects were asked to work on each of the prototypes and to make relative rating for each pair of the prototype using an 11-point scale, as stated in methodology section. The raw score of the test have been presented in Table 5.73 A.

Table 5.73 A: Raw score for pair comparison test

Criteria: Height of workstation

E=existing model: 50 cm. height H40= 40 cm. height H45= 45 cm. height

No. of Subjects	Stimuli set		
	E:H40	E:H45	H40:H45
1	5	2	-3
2	4	-2	-2
3	3	1	0
4	5	3	-4
5	4	-1	-5
6	3	0	-2
7	2	2	-3
8	5	3	-1
9	2	2	0
10	3	0	-2
11	2	2	0
12	3	1	-1
13	1	3	-3
14	2	1	-2
15	3	-1	-1
16	4	-2	0
17	3	0	-2
18	4	1	-1
19	2	2	-2
20	1	1	-3
21	1	0	-2
22	3	-1	0
23	4	2	-4
24	5	3	-2
25	2	2	-1
26	2	1	-3
27	3	0	0
28	4	2	-1
29	3	-1	0
30	2	3	-2
mean	3.00	0.97	-1.73

Table 5.73 B: Resultant score for individual prototypes

Prototypes	E	H45	H40
Resultant scores	-1.98	-0.38	+2.37

The mean score of each pair of stimuli (response to each pair of prototype) were also shown in the table. From the mean raw score the resultant score for each stimulus (prototype) was computed and shown in Table 5.73 B.

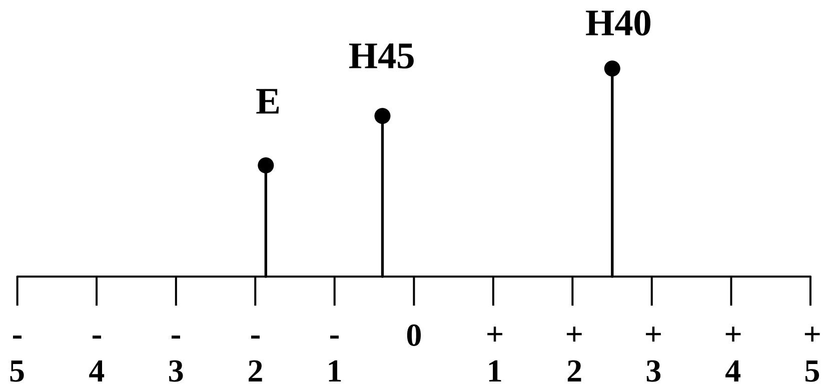


Fig.5.13: Stimuli space for height of workstation

The computed scores of the test for each prototype models have plotted in an 11-point scale as shown in Fig.5.13. It was noted from the results (Fig.5.13) that the prototype models E and H45 obtained negative rating and the prototype model H40 had positive ratings of the subjects. It was noted that the prototype H40, having the height of 40 cm, obtained the highest preference score of the subjects. The result indicated that the height of the prototype H40 would be suitable for the workers. Thus a workstation height of 40 cm was taken as optimum height for work surface height and it may be recommend for workstation height for golden thread work.

***5.5.4.3* Body Part Discomfort (BPD) rating:**

A comparative study of body part discomfort rating was performed between existing and modified model of workstation. The workers were asked to perform their work with different prototypes and to express their views regarding the extent of discomfort in different segments of the body in a 10-point scale. The results have been presented in

Table 5.74. Statistical analysis (ANOVA) showed that there was no significant difference in mean BPD among three workstations. However, a tendency of lowering of BPD rating was observed in case of modified workstations.

Table 5.74: The Body part discomfort (BPD) rating (Mean ±SD) in different segments of the body (in a 10 point scale) of female workers during sitting on the floor with folded legs during using existing and modified models of workstations

Body Segments		Different workstation height		
		Existing working (height : 50cm) [n=68]	Modified workstation [n=60]	
			45cm	40cm
Neck		0.96±1.64	0.33±0.92	0.57±1.14
Shoulder	R	4.24±2.46	3.97±2.01	3.60±1.83
	L	3.31±2.59	3.20±2.59	2.93±2.32
Upper arm	R	1.04±2.08	1.07±1.89	1.00±1.78
	L	0.79±1.85	0.67±1.60	0.67±1.60
Lower arm	R	0.46±1.56	0.43±1.36	0.47±1.25
	L	0.43±1.45	0.43±1.36	0.40±1.04
Upper back		2.47±2.43	1.83±2.49	2.20±2.57
Middle back		1.94±2.64	1.67±2.44	1.63±2.39
Lower Back		6.46±2.54	6.53±3.28	6.43±3.19
Buttock		0.07±0.61	0.20±0.76	0.30±0.92
Thigh		0.85±1.94	1.47±2.47	1.47±2.47
	L	0.85±1.94	1.47±2.47	1.47±2.47
Cuff	R	1.34±2.28	2.13±2.73	2.13±2.73
	L	1.34±2.28	2.13±2.73	2.13±2.73
Feet	R	0.07±0.61	0.17±0.91	0.17±0.91
	L	0.07±0.61	0.17±0.91	0.17±0.91
Over all discomfort rating of the body		1.57±0.74	1.64±0.82	1.63±0.78

From the results (Table 5.74) it was observed that the body part discomfort rating in different segments of the body was comparatively lower during using modified workstation compared to the existing one (although non-significantly). It was noted that the body part discomfort rating in shoulder, and lower back was the lowest in case of working with the workstation with a height of 40 cm among three workstations. The workstation with 40 cm height showed the lowest overall body part discomfort rating also. Therefore, from the result of the subjective assessment it may be stated that the modified workstation was relatively more comfortable than that of existing one.

5.5.4.4 Study of EMG voltage:

The EMG study of the shoulder (Trapezius) and back (Lattisimus dorsi) muscles of the female golden thread workers was performed in three workstations with different heights on a comparative basis. EMG records which were taken in normal sitting posture on the floor (without work) was treated as reference posture and the deviations of the EMG voltages in working postures from that of the reference posture were computed. From the results it was noted that that there was an increase in the EMG values of the shoulder muscle in different heights of workstation (Table 5.75).

Table 5.75: Mean and standard deviation of EMG voltage and RMS values (mV) of shoulder muscle of golden thread workers during resting and working with existing and modified workstations (n=10) [R= right side, L= left side]

Different workstations height	EMG-R		EMG-L		RMS-R		RMS-L	
	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal resting								
Sitting on the floor (relaxed)	0.0264 ±0.012	-	0.0298 ±0.008	-	0.0307 ±0.007	-	0.0368 ±0.008	-
Performing golden thread work in different heights								
50 cm (existing)	0.0512 ±0.024	94.13	0.0407 ±0.044	36.60	0.0473 ±0.007	54.28	0.0458 ±0.008	24.59
45cm	0.0447 ±0.017	69.65	0.0178 ±0.017	40.21	0.0436 ±0.026	42.25	0.0441 ±0.025	20.01
40 cm	0.0396 ±0.019	50.21	0.0150 ±0.010	49.76	0.0460 ±0.011	49.82	0.0425 ±0.009	15.51
F-value	0.72 NS	-	2.34 NS	-	0.11 NS	-	0.10 NS	-

Such increase was due to increase in muscular contraction during work. However, when the EMG voltages in working condition were considered, the raw EMG and RMS values were found to be decreased gradually, although non-significantly, with the lowering the work surface height (Table 5.75). Moreover, the percentage deviation of EMG voltage of right hand and the RMS value of the left hand from that of reference values (normal resting) were the lowest.

Table 5.76: Mean and standard deviation of EMG voltage and RMS values (mV) of back muscle of golden thread workers adopting sitting on the floor with folded legs in normal resting and working in three workstations with different height (n=10)

Different workstation height	EMG-R		EMG-L		RMS-R		RMS-L	
	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal resting								
Sitting on the floor (relaxed)	0.0234 ±0.006		0.0258 ±0.005		0.0265 ±0.006		0.0315 ±0.005	
Performing golden thread work in different heights								
50 cm (existing)	0.0361 ±0.015	53.94	0.0287 ±0.017	11.15	0.0857 ±0.027	223.56	0.0800 ±0.021	153.56
45cm	0.0334 ±0.016	42.50	0.0734 ±0.077	184.24	0.0667 ±0.017	151.78	0.0669 ±0.016	112.12
40 cm	0.0259 ±0.021	10.45	0.0697 ±0.044	169.79	0.0493 ±0.031	86.03	0.0548 ±0.029	73.71
F-value	0.63 NS	-	1.66 NS	-	3.32 NS	-	2.13 NS	-

From the analysis of EMG of back muscle (Table 5.76) it was observed that there was an increase in the EMG values of the back muscle during working from that of reference condition. As the worker had to bend forward, as appeared from joint angle study, during working, the myoelectric activities of the back muscles was increased from that of reference condition. While comparing EMG signals among three workstations during working, the EMG voltages (right side) and RMS values (both side) represented the lowest value in case of working with workstation with 40 cm height. While studying the relative percentage difference of EMG voltage from normal resting (reference) condition, it was found that the percentage deviation was the minimum in case of workstation having 40 cm height than other workstation with higher heights.

From the EMG studies it appeared that the lowest myoelectrical activities of was found in shoulder and back muscles during working with a workstation with lower work surface height (40 cm). So the results indicated that the muscle stress was lower in the said work station. Thus a workstation with a height of 40 cm might be suitable for the female golden thread workers.

***5.5.4.5* Evaluation by body joint angles**:

Different body joint angles were measured during using modified workstations and those were compared with that of using the existing one. The body joint angles, viz., shoulder, elbow, wrist and hip were also measured in reference condition, that is, in normal erect posture. The deviation of each angle, while using modified and existing workstations, from that of reference posture was computed. The results have been shown in Table 5.77.

It was observed that the shoulder angle became reduced with the lowering of workstation height and it was the lowest in case of working the workstation height of 40 cm in both left and right side. The deviation of shoulder angle was also the lowest, in both side of the body, during using the 40 cm-workstation. It may be inferred that the shoulder abduction was reduced while working with the workstation of the lowest height. The neck angle was slightly increased with lowering height of the workstation, which indicated lesser neck flexion during work. However, there was slight decrease in hip angle with the lowering of work surface height indicating slight increasing in forward bending.

Table 5.77: Deviation of Different body joint angle (Mean ±SD) of golden thread workers working in three different workstation height from normal erect posture

Body Joint angle		normal erect posture (resting)	Different workstation height					
			Existing working height		Modified workstation height			
			50cm		45cm		40cm	
			working angle	% Deviation	working angle	% Deviation	working angle	% Deviation
Neck		32.1± 1.85	55.4± 5.04	36.18	64.4± 3.20	47.50	68± 4.27	111.84
Shoulder	L	33.89± 2.52	76.72± 21.02	126.39	72.39± 11.38	113.61	62.11± 9.12	83.28
	R	32.17± 3.05	102.22± 12.84	217.79	90.67± 15.42	181.87	81.67± 15.06	153.89
Elbow	L	161.94± 16.58	124.44± 30.03	23.16	92.39± 10.52	42.95	109.33± 26.72	32.49
	R	163.78± 12.82	122.22± 31.38	25.37	93.28± 8.40	43.05	96.50± 23.38	41.08
Wrist	L	173.28± 7.47	169.22± 13.81	2.34	170.44± 6.58	1.64	173.78± 6.57	0.29
	R	174.28± 6.66	169.39± 21.33	2.81	177.00± 6.80	1.56	170.22± 16.30	2.33
Hip	L	164.78± 18.25	107.78± 20.17	34.59	103.61± 10.57	37.12	100.39± 6.98	39.08
	R	165.56± 17.35	108.94± 20.51	34.19	100.44± 10.40	39.33	96.17± 7.38	41.91

The greater deviation of body joint angle imposes postural stress among the workers. So, from the joint angle study it was inferred that the workstation height of 40 cm was less stressful than the other two models.

Therefore, it may be pointed out that the biomechanical problems of the users were reduced while they used modified workstation with a height of 40 cm.

***5.5.4.6* Productivity Study:**

The productivity study was made when the workers were performing the task in existing and different modified workstations. The area (sq.cm) knitted with the golden thread on the cloth by the workers were measured while working in three workstations of different heights in a given time and it was expressed in unit time. The area (sq.cm) knitted per unit time was taken as the productivity. From the results of the productivity study (Fig 5.14) it has been revealed that there was a notable increase in productivity in case of working in the modified workstations. Among the modified workstations, the workstation with the height of 40 cm showed significantly ($p<0.01$) higher productivity than that of existing workstation. The results indicated that there was an increase in productivity by about 4.31% in the workstation of 45 cm and by about 46.91% in the workstation of cm 40 respectively.

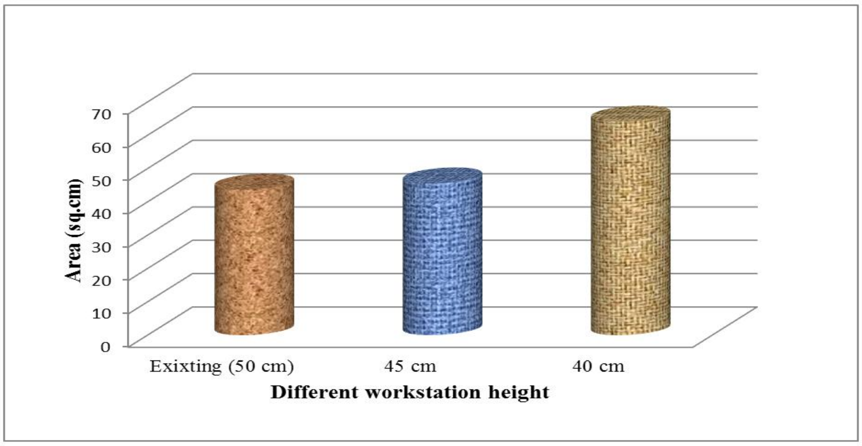


Fig.5.14: Mean productivity (sq.cm/hour) with existing and modified workstation

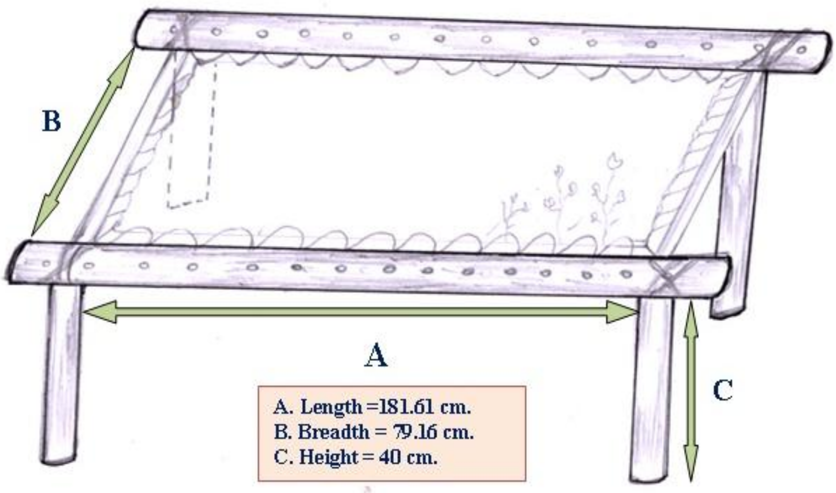


Fig.5.15: Recommended height for golden thread workstation

Thus, it can be concluded that the modified 40 cm workstation height was far better than that of existing workstation from the view point of productivity.

From the above discussion, it may be summarized that the modified workstation height of 40 cm was suitable for the users and was also comfortable for them. However the length and breadth of the platform remain same as the existing platform for jori work. The results of the EMG study, joint angle study and productivity study were in favour of the modified workstation with a height of 40 cm for golden thread work. Therefore, the workstation with a height of 40 cm was recommended as optimum height (Fig.5.15).

Chapter-VI

Conclusion

6.1 Conclusion and recommendation

The present study focused on the female workers engaged in small or home industries. Main emphasis has been given to find scope of ergonomic application in different jobs where sitting on floor and squatting postures are adopted by the female workers. Efforts have been made to evaluate the postural stress of the workers in different jobs and to find their relationship with physiological response. The followings are the summary of general conclusion of the present study:

According to the modified Kuppuswami's scale the majority of the workers were belonging to lower socioeconomic category. Their nutritional status was poor, a notable percentage were belonging to under nourished category according to BMI value. The general health status study was also support these findings. The reason behind undernourishment in female workers might be due to their low food intake in comparison to their male and child counterparts or their compulsion to perform both household and occupational activities leading to excess energy expenditure. Ignorance about the nutritious food might be another factor influencing it. An awareness program about nutrition may improve the situation.

The musculoskeletal disorder (MSD) among the workers was prevalent in neck, shoulder and back regions followed by thigh, leg and knee of the affected respondent. Such musculoskeletal problems might be involved with working conditions while performing work in different jobs under the study. The prevalence of MSDs was comparatively higher in mat weaving and golden thread work compared to craft work. However, neck, shoulder, upper back and lower back problem were extremely prevalent in all types of job. They showed moderate to severe degree of discomfort in those body parts. The causative factors of musculoskeletal problems were awkward working posture and long term static work. Performance of tasks in awkward postures for a prolonged duration might be the possible cause of pain at different segments of the body

The total duration of work shift is very much important for assessment of job related stress. The work-rest pattern showed that the total working hours was approximately 8 to 9 hours including rest pause. From the comparative study it was observed that the total duration of work shift was higher in mat weaving and golden thread work than craft work.. However, the total rest pause in three jobs was high. It varied from about 35% to 49% of the total work shift. It may be pointed out the rest pause during lunch was long (more than two hours in case of mat weaving and golden thread work). As all workers were female, they had to perform household work during this break. Although it was a long break for professional work, but there was practically no rest for them. Workers were compelled to do some physical activities at home during the rest pause. However, there are scopes for rescheduling the work-rest cycle for the female workers to reduce the work related MSDs.

The risk level of the postures adopted by the female workers was categorized as 'moderate' 'to 'very high' during performing different tasks in different jobs. The squatting, sitting on the floor with stretched legs, and sitting on the floor with folded legs were the dominating posture in these jobs. The squatting posture was one of the strenuous postures during performing the work. The high occurrence of MSD in lower limb might be caused by adopting squatting posture. Posture analysis showed that posture adopted during those tasks were of high risk and needed corrective measures as soon as possible. Different body parts like neck, shoulder, and back showed higher level of risk scores. The workers should be aware about those awkward postures in different body segments and should take precautions against getting musculoskeletal problems.

The joint angles study showed the postural pattern of the workers as well as relative position of the limbs in relation to the trunk. The study indicated that the workers had lesser shoulder abduction, elbow and wrist flexion while sitting on the floor with folded legs than that of other sitting postures. The hip angle showed lesser forward bend while sitting on the floor with folded legs.

The location of vertical CG became lowered during sitting on the floor with folded legs than squatting posture indicating higher stability of the body, which was evident from the results of base contact area. It was noted that base contact area was much lower in squatting posture than that of other sitting postures. Greater body contact area represents greater stability of the body in a particular posture. Hence sitting on the floor with stretched legs and with folded legs had greater stability of the body during performing the work.

The EMG study of shoulder and back muscles indicated the extent of contractility of the muscles. The myoelectric activity of shoulder and back muscle was of the lowest in sitting on the floor with folded legs among three postures. The results revealed that the back and shoulder had lesser stress in the said posture. It might be due to lesser shoulder abduction and lesser extent of forward bending during performing the tasks.

From the study of physiological stress of the workers it was inferred that the female workers were not suffering from much cardiovascular stress, which might be due to working in sitting posture and with a low work load. However, when cardiovascular stress was compared among different postures, a greater cardiovascular stress in squatting posture was noted than that in sitting on the floor. Therefore, the squatting posture had been considered as high stressed sitting posture.

6.2 Main Achievements of the study:

1. The work related health problems of the female workers of home based industries indentified. It was noted that the prevalence and extent of pain / discomfort were located in the neck, shoulder, upper and lower back as well as in the lower extremities.
2. From the results of the present study a suitable working posture for the female workers involved in home based industries has been identified. Indian traditional sitting posture that is, sitting on the floor with folded legs was the posture of choice for the female workers engaged in home based industries. The female workers engaged in craft work, golden thread work and mat weaving were used to perform their tasks under different sitting postures, viz., : squat sitting, sitting on the floor with folded legs and sitting on the floor with stretched legs. From different studies, viz., prevalence of MSD, BPD rating, cardiovascular stress, EMG studies, and biomechanical studies like, center of gravity (CG), body joint tangles, base contact area , it was inferred that the musculoskeletal problems, physiological and biomechanical stresses were the minimum during working while sitting on the floor with folded legs.
3. One of the main achievements of the present study was ergonomic modification of the work station for golden thread work. The workstation of the golden thread work had some incompatibility with the workers which lead to occurrence of pain or discomfort in some body segments like, shoulder, upper

arm, back etc. Such problems might be due to greater work surface height of the workstation than that of it was required. From the anthropometric dimensions of the users and psychophysical behavior of the workers towards the workstation, the height of the work surface was optimized. The height of the optimized work surface (40.0 cm) was supported by subjective and objective studies, viz., body part discomfort rating, EMG studies, and joint angle analysis. The followings were the advantages of modified workstation for golden thread work:

a) The postural stress of the female golden thread workers was lessened during using the modified workstation.

b) Biomechanical stress was lowered during using modified workstation.

c) Muscle stress of the female was reduced. Therefore, it may lengthen the initiation of fatigue.

d) The productivity rate of the workers was increased

The main achievements of the study for the three industries are outlined below separately:

- **Craft work:** Highest prevalence of MSD was noted in lower back, shoulder and neck segments of in craft workers. The lowest postural stress was noticed in craft workers in comparison to other two groups of workers. It was inferred from different studies that the musculoskeletal problems, physiological and biomechanical stress was the minimum during work while sitting on the floor with folded legs. This posture may be suggested for the worker to lessen the job related stress. The golden thread workers may adopt sitting posture with stretched legs occasionally as this posture had 2nd degree of postural stress from the lower side.

- **Mat weaving:** The most prevalent MSD was observed in lower back, shoulder, and knee segments of the female mat weavers**.**The mat weavers had the higher degree of muscular stress, as appeared from EMG study, and greater extent of cardiovascular stress in comparison to other two groups of workers. It appeared from the comparative studies that mat workers were exposed to greater amount of work related stress. Mat weavers used to work two sitting postures: squat sitting and sitting on the floor with folded legs. From different physiological and biomechanical studies it was inferred that the sitting on the floor with folded legs posture was less stressful than that of squatting posture. The mat weavers were used to adopt squatting posture for about 41% of the work time. They should reduce the duration of adopting squatting posture and to increase sitting posture on the floor as far as practicable

- **Golden thread work:** The lower back and the shoulder were the most affected segments of the golden thread workers due to musculoskeletal problems. Sitting on the floor with folded legs was less stressful than other two postures for the workers engaged in this job. Therefore, the optimum working posture for golden thread workers was the posture stated above. However, sitting on the floor with stretched legs may be taken as second choice of working posture because this posture had second lowest degree of postural and other stresses during work. Occasional change of posture is beneficial. Using modified workstation may lessen the postural stress of the female golden thread workers.

6.3 Recommendations:

The following recommendations may be helpful for the workers to reduce some of the work related health problems of the female workers:

i. To reduce the occurrence of musculoskeletal hazards the workers should adopt appropriate posture during performing the work. It was recommended to work in traditional sitting posture that is, sitting on the floor with folded legs as long as possible. However, they can change the posture for some duration of the work shift to avoid fatigue. The second choice of posture was sitting on the floor with stretched legs.

ii. The workers should avoid squatting posture as far as practicable because it is a strenuous posture.

iii. In case of mat weaving it was not possible to work in sitting with stretched legs condition. In this case is only option for changing posture is the squatting posture. When squatting is unavoidable the workers may be suggested to use a small wooden slab as a hip support during squatting. This will lessen some of adverse effects squatting posture.

iv. The problems of the postural stress can also be reduced by modifying the work rest cycle. Continuous sitting is also tiring. Therefore, it is recommended to limit unrestricted sitting time to a maximum of 2 hours and to stand up and move after 30 minutes of continuous sitting (as a break in sitting time) (Owen et.al, 2011).

v. It is necessary to make the female workers aware of proper work-rest schedule, and to modify the cycle. The female workers had long breaks. It will be helpful for reducing WRMSD and increasing the productivity by the introduction of frequent and brief rest breaks.

vi. Back pain is awfully prevalent in workers. The workers may perform some exercise or 'jogaasana' for reducing the pain. Relief from 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. The workers are advised to lean backward for a few times during the short rest. This may lessen harmful effects of bend posture for a long time.

vii. Training modules should be formulated for awareness regarding safety and to lessen the work related pain and discomfort in different body parts, especially low back.

viii. A notable percentage of the female workers were under nourished. It has been noted that the workers had lack of awareness about the nutritive values of common available foods. Some awareness programmes about the nutrition may be arranged for them. A low cost balanced diet may be helpful for reducing malnutrition of the workers.

6.4 Limitation of the Study

In the present study there were some limitations:

- Modification of workstation in other two home based industries i.e., Handicrafts and Mat weaving were not taken into consideration because there were no standard workstation for those tasks. They were used to perform their tasks on the floor. However, there is scope for developing new workstations for each task to reduce the postural stress and other job related problems. A detailed long term study is required for each of the cases separately.

- Environmental factors may influence the work related stresses of the workers. Different environmental factors, e.g., illumination, heat stress etc were not included in this study.

- To find a suitable posture, EMG studies were done in shoulder and back muscles only. To support the findings of the present study EMG voltages of other muscles like, muscles of upper arm and fore arm might be helpful. The EMG of those muscles was not included in the study.

- A notable percentage of the female workers were suffering from under nutrition. The nutritional status of the respondents was evaluated only but anthropometric method. It would better to evaluate detailed nutritional assessment of the subjects. A dietary survey on the workers would more informative to find the nutritional status of the workers.

- The workstation of the golden thread workers has been modified. However, the acceptability of the modified workstation can be confirmed after a long term study, which was lacking in this study.

6.5 Further scope of Study

- The height of the workstation for golden thread has been suggested. The suggest workstation was fixed in nature. Further study may be carried out to make the workstation adjustable so that the works can set the work surface height according to their need. Further work may be planned to design a user centered and low cost work station to make it adjustable.

- Research work can be formulated to find a novel design of workstation in a suitable height above the ground for the mat weavers.
- The possibility for developing an ergonomic workstation for craft workers may be investigated. As the task of craft workers varies from case to case, emphasis should be given for a versatile workstation.
- The jobs of the present study were essentially possessed some esthetic components. The workers had to perform some fine works as a part of their job. The illumination level in the work place may influence the quality and quantity of the production, especially where fine work is involved. Thus it is required to investigate the optimum level of illumination in the workplace of different jobs to increase the productivity. A study may be planned to find amount of natural light and artificial light, location of placement of light, and source of glare in the workstation.
- In the present study work rest cycle has been analyzed for all the jobs selected for the study. Further study is required to optimize the work and rest cycle for each job which may be useful for reducing MSD and enhancing productivity.

Chapter-VII

Summary

Home based industrial work is one of the most tedious professions, requiring long hours of static work. It is also a high risk occupation for developing MSDs as awkward posture, repetitive movements, long working hours and inadequate rest pauses are associated with those jobs. Mainly females are engaged in those jobs. In the present investigation three jobs, viz., craft work, mat weaving, and golden thread work ('jori') were selected for the study. The main goal of the present study was to find scope of ergonomic application in these three jobs where different sitting postures were adopted during performing the work. The major sitting posture of those jobs were a) sitting on the floor with folded legs, b) squatting posture, and c) sitting on the floor with stretched legs. Efforts have been made to evaluate the postural stress of the workers in different jobs and to find their relationship with physiological response. The musculoskeletal problems of the workers were also evaluated in relation to posture adopted by the female workers. An ergonomic intervention was also made in the workstation of Golden thread workers. The workstation for golden thread work is poorly designed. Conventional work method and poor design of workstation also imposed postural stress which in turn adds to physiological stress.

Thus the main objectives of the study were: i) Evaluation of work related health problems of female craft workers, mat weavers and golden thread workers. ii) finding the suitability of existing work posture adopted by the women workers engaged in different jobs mentioned above. iii) Optimization of work posture in relation to job and work. And iv) Ergonomic intervention by redesigning the workstation for golden thread work.

Suitable methodology was employed to implement the above objectives. The present study was conducted on 360 randomly selected female workers (age range 18 to 55 yrs.) engaged in three different home based industries in different districts of West Bengal,

The socio-economic and general health status of the female workers was assessed. The socio-economic status was evaluated by modified Kuppuswami scale (Gururaj and Maheshwaran, 2014). The educational level of the subjects was evaluated by questionnaire technique also. Anthropometric survey (height, weight, BMI) was conducted by standard measurement technique. The blood pressure was measured by auscultatory method. The female workers were classified into normotensive, hypotensive and hypertensive subjects.

Occupational health problems of the female workers were evaluated by modified Nordic Musculoskeletal Questionnaire (MSQ) method and perceived discomfort rating (PDR) in different segments of the body. Working postures were evaluated by standard posture analysis methods, viz., OWAS, REBA, and RULA.

The biomechanical studies were made by determining the center of gravity of the whole body, the joint angles study, the EMG study and base contact area of the female workers in different working posture.

Different Physiological responses of the workers were evaluated by the cardiovascular response by taking resting and working pulse rate and Cardiovascular Stress Index (CSI) during performing different jobs.

For redesigning the workstation used for golden thread work some systematic steps were executed. At first, the drawbacks of the design of the existing golden thread workstation was assessed by interviewing the users, evaluating PDR and measuring the body joint angles and evaluating the posture adopted during using the workstation by EMG study. Final selection of the design criteria was made by a psychophysical analysis, the results of which indicated the preference of the users and by productivity study.

The results of the present study reveal that according to the modified Kuppuswami scale the majority of the workers were belonging to lower socioeconomic category. Their nutritional status was poor, a notable percentage were belonging to under nourished (<18.50 kg/m2) category according to BMI value. The general health status study was also support these findings. About 78% of the female workers were within normotensive range and approximately 19% of the workers were belonging to hypotensive category.

The musculoskeletal disorder (MSD) among the workers was prevalent in neck, shoulder and back regions followed by thigh, leg and knee of the affected respondent. Such musculoskeletal problems might be involved with working conditions while performing work in different jobs under the study. The results represented that the prevalence of MSD was gradually increased among the workers of lower age group to higher age group in most of the body segments, viz, neck shoulder, elbow, wrist, upper and lower back. The occurrence of MSD was significantly different in different posture adopted during performing the tasks. Different awkward postures intensified the problems. The prevalence of MSDs was comparatively higher in mat weaving and golden thread work compared to craft work. However, neck, shoulder, upper back and lower back problem were extremely prevalent in all types of job. They showed moderate to severe degree of pain / discomfort in those body parts. The body part discomfort (BPD) had significance difference in some of the body segments among three posture adopted by the workers.

The total duration of work shift is very much important for assessment of job related stress. The work-rest pattern showed that the total working hours was approximately 8 to 9 hours including rest pause. From the comparative study it was observed that the total duration of work shift was higher in mat weaving and golden thread work than craft work. It was noted that the female workers engaged in different jobs had enjoyed rest pauses slightly excess of recommended value. The golden thread workers had higher percentage of rest pause than that of other two working groups. The prolonged tasks performed in awkward postures may be possible causes of pain at different segments of the body as well as postural stress among the workers.

According to the different posture analysis methods, the postures adopted by the female workers were categorized as 'moderate' 'to 'very high' risk levels in different jobs. The workers were suffering from job related health problems, perhaps because of prolonged working hours as well as adopting awkward postures. The squatting, sitting on the floor with stretched legs and sitting on the floor with folded legs posture was the dominating posture in these jobs. The squatting posture was one of the strenuous postures during performing the works. The occurrence of MSD in lower limb was pronounced during adopting squatting posture. Posture analysis showed that posture adopted during those tasks were of high risk and needed corrective measures as soon as possible. Different body parts like neck, shoulder, and back showed higher level of risk scores. The workers should be aware about those body segments and take precautions against getting musculoskeletal problems. According to OWAS, RULA and REBA methods the squatting posture was categorized as very high risk which has to investigate and implement change should be done.

From the study of the joint angles, the workers had lesser shoulder abduction, elbow and wrist flexion while sitting on the floor with folded legs than that of other sitting postures. The hip angle of the workers showed lesser flexion of the body when they were working in sitting on the floor with folded legs. The findings indicated less forward bending during work while adopting the said posture in all the jobs. From the results of the present study, it was revealed that location of vertical CG became lowered during sitting on the floor with folded legs than squatting posture indicating higher stability of the body, which was evident from the results of base contact area. The base contact area was significantly higher when the workers were sitting on the floor than that of working by adopting squatting posture. EMG study of shoulder and back muscles also represented that the myoelectric activities was comparatively lesser during sitting on the floor with folded legs than that of other two postures. . Thus the shoulder and back muscle had lesser degree of contraction during work while adopting the former posture. So, sitting on the floor with folded legs may reduce the discomfort of the worker.

From the study of physiological stress among the workers engaged in different jobs it was inferred that the workers were not suffering from much cardiovascular stress, probably due to work in sitting posture and a low work load. The comparative evaluation of cardiovascular stress among three working postures it was observed that squatting posture imposed greater cardiovascular stress than that of other two postures. It may be pointed out that the cardiovascular stress was the lowest in the female workers engaged in craft work than that of other two groups of female workers.

Hence, the workers may be suggested to work in traditional sitting posture, that is, sitting on the floor with folded legs to lessen work related health hazards as well as postural stress.

One of the main achievements of the present study was obtained through the ergonomic intervention in the workstation for golden thread work. Pain in the neck and shoulder segments with tenderness over the descending part of the trapezius and other adjoining muscles are more commonly seen among the golden thread workers. The most common cause of such problems was the awkward posture adopted by the workers due to poorly designed work station. This poorly designed work station forces the golden thread worker to perform the task for a prolonged period which promoted unnecessary physical effort. That might caused reduction in the efficacy and productivity. There were some drawbacks in the existing design of workstation from the view point human factors. The height of the workstation was optimized considering the human factors of the users. The existing height of the work surface of the golden thread workstation was about 50 cm. To find a suitable height of the workstation some prototype workstations with altered work surface height were made and those were evaluated. In the modified prototypes, the heights of the work surface were reduced to 45 cm and 40 cm. The psychophysical analysis of the workers towards the preference of the workstation was made by paired comparison test and it was noted that the workstation having a height of 40 cm had the best score. In the EMG studies on the prototypes it appeared that there was lowest myoelectrical activity in shoulder and back muscles during working with a workstation with lower work surface height (40 cm). The joint angle study also showed lesser biomechanical stress while working the work station with 40 cm height. The productivity was slightly increased when the workers used low work surface height. After evaluation of modified workstation, the work surface height of 40 cm was optimized. It was inferred that the new workstation height was suitable as well as comfortable for the workers.

It was concluded from the studies on different jobs performed by the female workers that there was prevalence of musculoskeletal problems in different body segments. Those problems might be associated with postural stress during performing the work. From the studies it appeared that the Indian traditional sitting posture that is, sitting on the floor with folded legs was better than the squatting posture and sitting on the floor with stretched legs. It may be recommended that the former posture would be suitable for the female workers where static work was essential rather that dynamic work. The suggested design the workstation for golden thread work will be able to reduce the drudgery of the female workers and it will be able to enhance the productivity.

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Appendix

Appendix-I

VIDYASAGAR UNIVERSITY

P.O. : Vidyasagar University, Midnapore - 721 102, Dist.: Paschim Medinipur.

D.O No.... VU/R/Ethical/IEC-07/2012 Dated : ....

TO WHOM IT MAY CONCERN

This is to certify that a meeting of the Institutional Ethical Committee (~~Animal~~/Human) was held on ...22.3.2012... at ...2.00......~~A.M.~~/~~Noon~~/ P.M. at the Chamber of the Registrar of Vidyasagar University to consider and issue the letter of ethical clearance in favour of the project proposal "Evaluation of Postural Stress of women workers engaged in different Jobs and ergonomic intervention for modifying the posture while working in squatting posture and sitting on floor", submitted by ....Payel Maity.........., Department of ....Human Physiology..........of Vidyasagar University. The Committee unanimously approved the above mentioned proposal and recommended it for submission ~~to~~ for ......Ph. D in Science..........

....

Relevant portion of the minutes of the meeting of Institutional Ethical Conmmittee is enclosed.

Ranajit Dhar

(Dr. Ranajit Dhar)

Registrar.

Registrar
VIDYASAGAR UNIVERSITY
Midnapore-721102

VIDYASAGAR UNIVERSITY MIDNAPORE

Encl.: as stated above.

Phone : (953222) 275297 / 276554-555-557, Fax : (953222) 275329, e-mail : registrar@vidyasagar.ac.in

Appendix-II

DEPARTMENT OF HUMAN PHYSIOLOGY WITH COMMUNITY HEALTH

VIDYASAGAR UNIVERSITY, MIDNAPORE 721102, WEST BENGAL, INDIA
Phone: (03222) 62297/63201/62441/60554 Extn. 350 Fax: (91)03222 – 62329,

e-mail:vidya295@sancharnet.in /vulib@dte.vsnl.net.in

Informed consent form with participant information sheet

Nature and purpose of the study: This is a very inexpensive study conducted on female workers engaged in home based industries to find the scope of ergonomic application in different jobs where sitting on floor and squatting postures are adopted by the women workers. Efforts have been made to evaluate the general health problems, work related health problems and postural stress of the workers.

Parameter to be studied: Height, weight, Blood pressure Pulse rate, Musculoskeletal disorders, Body part discomfort rating, and EMG

Risk factors: Nil

Benefits: The community involved will be benefitted in terms of heath and productivity.

Steps taken to ensure confidentiality: Name and identity or any photo of the participants will not be exposed during or after the completion of the project.

Withdrawal process: As theparticipation is voluntary, the participant is free to withdraw at any time during the project without giving any reason and without legal problems.

Contact details of PI:

ADDRESS: Department of Human Physiology with Community Health,
Vidyasagar University, Midnapore – 721 102, West Bengal
Phone: 09433226695 (mobile); 033-24483299 (Res)
Email: prakashdhara@rediffmail.com

Voluntary participation: Participation is totally voluntary; any kind of pressure will not be put on the participants.

Subject's or volunteer's Identification Number:

CONSENT FORM

Title of Research work: Evaluation and optimization of work posture of female worker engaged in home based industries and ergonomic intervention for modifying a workstation

Name of the Researcher: Payel Maity

Please tick [√] the boxes

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without legal problems. ☐

3. I understand that therelevant sectionof data collected during the study may be looked at by individuals from regulatory authorities or from the institute, where it is relevant to my taking part in this research. I give permission for these individuals regarding this. ☐

4. I agree to take part in the above study. ☐

____________________	____________________	____________________
Name of Participant	Date	Signature/thumb impression
____________________	____________________	____________________
Name of Person taking consent	Date	Signature

Appendix-III

Modified Kuppuswamy classification of socioeconomic status (Gururaj and Maheshwaran, 2014)

Table 1: Education

Sr. No.	Education of the Head	Score
1	Profession or Honours	7
2	Graduate or post graduate	6
3	Intermediate or post high school dip	5
4	High school certificate	4
5	Middle school certificate	3
6	Primary school certificate	2
7	Illiterate	1

Table 2: Occupation

Sr. No.	Occupation of the Head	Score
1	Profession	10
2	Semi-Profession	6
3	Clerical, Shop-owner	5
4	Skilled worker	4
5	Semi-skilled worker	3
6	Unskilled worker	2
7	Unemployed	1

Table 3: Income

Sr. No.	Family Income Per Months in Rs (1976)	Family Income Per Months in Rs (1982)	Family Income Per Months in Rs (2001)	Family Income Per Months in Rs (2014)	Family Income Per Months Score
1	≥2000	≥3319	≥15197	≥36017	12
2	1000–199	1659–3318	7595–15196	18000–36016	1
3	750–999	1244–1658	5694–7594	13495–17999	6
4	500–749	829–1243	3793–5693	8989–13494	4
5	300–499	497–828	2273–3792	5387–8988	3
6	101–299	167–496	761–2272	1803–5386	2
7	≤100	≤166	≤760	≤1802	1

Table 4: Total Score

Sr. No.	Score	Socioeconomic Class
1	26–29	Upper (I)
2	16–25	Upper Middle (II)
3	11–15	Lower Middle (III)
4	5–10	Upper Lower (IV)
5	< 5	Lower (V)

Appendix-IV

OWAS: Posture analysis work sheet

Back

1. Straight
2. Bent
3. Twisted
4. Bent and Twisted

Arms

1. Both arms below shoulder level
2. One arm at or above shoulder level
3. Both arm at or above shoulder level

Legs

1. Sitting
2. Standing with both legs straight
3. Standing with the weight on one straight leg
4. Standing with both legs bent at the knee
5. Standing with the weight on one bent leg
6. Kneeling
7. Walking

Load / Effort

1. No effort or effort less than 10 kg.
2. Load or effort of 10-20 kg.
3. Load or effort of 10 kg or more

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-V

REBA Employee Assessment Worksheet

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

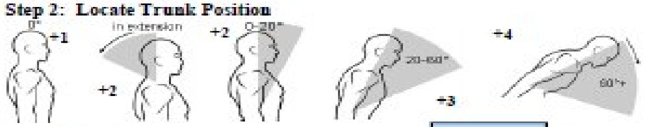
A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

Neck Score

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

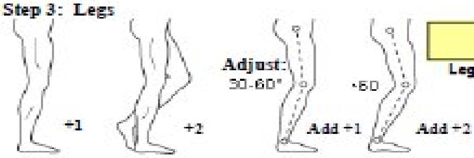
Step 2: Locate Trunk Position



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

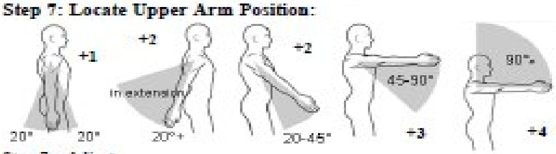
Score A (score from table A +load/force score)	Score B, (table B value +coupling score) 1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11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

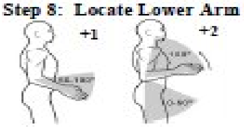
Step 7: Locate Upper Arm Position:



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
rbarker@ergosmart.com (816) 444-1667

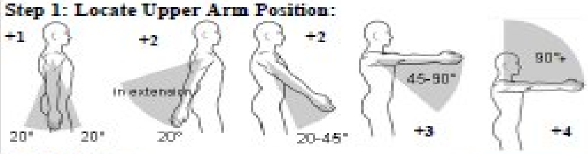
Appendix-VI

RULA Employee Assessment Worksheet

based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:



Step 1a: 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 2: Locate Lower Arm Position:

Lower Arm Score

Step 2a: Adjust…
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:

Step 3a: Adjust…
If wrist is bent from midline: Add +1

Wrist Score

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A

+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 7: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score

=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain
Wrist and Arm Score. Find row in Table C.

Wrist & Arm Score

SCORES

Table A: Wrist Posture Score

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	5	5	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: Neck, trunk and leg score

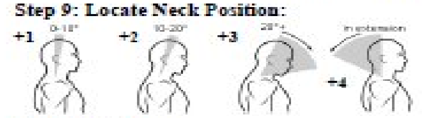
Wrist and Arm Score	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1 or 2 = acceptable posture
3 or 4 = further investigation, change may be needed
5 or 6 = further investigation, change soon
7 = investigate and implement change

Final Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:



Neck Score

Step 9a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:

Step 10a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Table B: Trunk Posture Score

Neck Posture Score	Trunk 1, Legs 1	Trunk 1, Legs 2	Trunk 2, Legs 1	Trunk 2, Legs 2	Trunk 3, Legs 1	Trunk 3, Legs 2	Trunk 4, Legs 1	Trunk 4, Legs 2	Trunk 5, Legs 1	Trunk 5, Legs 2	Trunk 6, Legs 1	Trunk 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:
Using values from steps 9-11 above,
locate score in Table B

Posture Score B

+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 14: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score

=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain
Neck, Trunk and Leg Score. Find Column in Table C.

Neck, Trunk & Leg Score

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 RULA.

rbarker@ergosmart.com (816) 444-1667

List of Publication

Full Paper:

1. **Maity P.**, De S., Pal A., and Dhara P. C. (2016): An Experimental Study to Evaluate Musculoskeletal Disorder and Postural Stress of Female Craft Worker during adopting different Sitting Postures. *International Journal of occupational safety and ergonomics*. (JOSE), http://dx.doi.org/10.1080/10803548.2016.1152736
2. **Maity P.,** De S., Pal A., Mahata H., Chatterjee M., Dhara P.C., (2014): Identification of a suitable working posture for female workers engaged in golden thread work.*International Journal of Occupational Safety and Health*. 4(2):24-33.
3. Dhara P. C.,De S., Sengupta P., **Maity P.**, Pal A.(2015): An Ergonomic Approach for Designing Indian Traditional Vegetable Cutter. *Work*, 50: 177- 186.
4. Pal A, De S, Sengupta P, **Maity P**, Mahata H, Shaikh S and Dhara P C (2015): The physiological strain among the women potato cultivation in West Bengal, India. *Journal of Human Ergology*, 44 (2).
5. Pal A., De S., Sengupta P., **Maity P**. and Dhara P.C. (2015): Evaluation of work related musculoskeletal disorder and postural stress among female potato cultivators in West Bengal, India. *Ergonomics SA*. 27(1):46-64
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). (DOI: 10.2427/8915.)
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. (DOI:10.1111/jhn.12180)
8. Dhara P.C., De S., Sengupta P., **Maity P**., Pal A. (2014): An Ergonomic Approach for Designing Indian Traditional Vegetable Cutter. *Work.* (DOI:10.3233/WOR-131721)
9. Pal A., De S., Sengupta P., **Maity P**. and 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*. 4(2):05-14.
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Abstract (Related to thesis):

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2. **MaityP.,** DeS., SenguptaP., BanerjeeM., MahataH., ParvinB. And Dhara P. C: Evolution Of Musculoskeletal Disorder And Postural Stress Of Female Golden Thread (Jori) Workers During Adopting Different Sitting Postures. Proceeding of International conference on Humanizing the work and work environment, Organized by G. B. Pant University of Agriculture and Technology, Pantnagar, 6 - 8 Dec, 2012.pp-89.
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Original Article

Identification of a suitable working posture for female workers engaged in golden thread work

Abstract:

Background: The golden thread (jori) work is one of the major home based industries providing employment to thousands of artisans spread over several rural areas of the West Bengal. The study is essentially labor intensive and thus workers are prone to suffer from work related health problems. **Objective:** The present study was aimed to evaluate the musculoskeletal disorders (MSDs) and postural stress of the female golden thread workers. **Methods:** The study was carried on 123 adult female golden thread workers in different districts of West Bengal. The prevalence of MSD, body part discomfort rating (BPD) and postural stress (by OWAS, RULA, REBA method) of the workers were evaluated by standard methods. The EMG of shoulder and back muscle was recorded with the help of the BIOPAC system. **Result:** The results showed that the prevalence of MSDs, BPD rating and postural stress were comparatively lower in case of sitting on the floor with folded legs than squatting and sitting on the floor with stretched legs. The EMG and RMS values of EMG voltage of shoulder and back muscle were comparatively lower in this posture than that of other two postures. **Conclusion:** It was therefore, concluded that sitting on the floor with folded legs was less hazardous and it imposed less postural stress in comparison to other sitting postures adopted by the golden thread workers.

Key Words: Golden thread worker, MSD, BPD, Posture, stress, EMG

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Introduction

Now women have become a large workforce in the production sector. It is a fact that all women work. Some of their work goes unrecognized because they do a variety of jobs daily which does not fit into any specific 'occupation'. Most of them are involved in arduous household work. Women work for longer hours and contribute substantially to family income. To understand the issue of occupational health problems of women, it is necessary to make a detailed study of the women's work in terms of the actual activity undertaken, and the hours of work.

The working condition of the workers is related to their occupational health and productivity. The working condition of women in India is currently similar to those found in early 19th century in industrial country [1]. Decades of research have identified certain physical workplace factors that increase the risk for Musculoskeletal disorders (MSD). Perhaps nowhere is the problem of stooped and squatting postures of greater magnitude than in developing countries such as India [2]. An adaptation of such postures is frequently observed in small scale industries in India. Most of the manually energized operations in these industries are evidence of such postures. An industry is identified in central India, where operators are mostly women operators and 91% of them are suffering from work related MSDs [3].

Adoption of awkward posture in workplace may be the cause of different work related health problems of the workers. In hand driven cotton spinning operation, awkward postures in different parts of body (i.e. bent back, folded knees, bent neck) were very common. The survey revealed that among the operators, symptoms from knees, back and shoulders over the course of time were significantly more prevalent compared to other body regions [4]. A similar study on goldsmith [5] reported that the workers by adopting awkward postures at work, most often suffered from MSDs particularly affecting the low back and neck region.

Maity et al [6] investigated work related musculoskeletal disorder and postural stress on 111 brick moulders in West Bengal, India. The study revealed that primary illnesses amongst the sample population was essentially musculoskeletal disorders, including shoulder pain, back pain, neck pain, and knee pain.

During work the female workers are required to adopt different posture in relation to the task involved. Squatting is one of the posture patterns under the influence of the traditional lifestyle in Asian countries. Indians are found to adopt traditional sitting posture that is, sitting on the floor with folded legs. Women used to adopt such posture to perform various activities, e.g., different domestic tasks, handcrafting, different professional work, leisure activities etc.

The relationship between the worker, and the poor, ergonomically deficient work place design, forces the workers to succumb to unnatural postures. This leads to different types of musculoskeletal ailment which have been demonstrated in several studies earlier [7].

In West Bengal state a large number of women are engaged in golden thread (in local term 'Jori') work. They stitch on the cloth ('sharees') by golden thread to make it attractive. Different predefined art designs are made on the cloth piece. The cloth piece is set in a wooden frame of certain height. The workers perform the task by sitting on the floor. Golden thread work is one of the tedious professions, requiring long hours of static work. It is also a high risk occupation for developing MSDs as awkward posture, repetitive movements, long working time and no rest pauses are common.Golden thread workers are found to adopt 3 different postures during performing the task e.g., sitting on the floor with folded legs, squatting posture, and sitting on the floor with stretched legs.

In spite of the national and international importance of the handloom with golden thread work, there have almost no ergonomics studies on golden thread workers. The present study has therefore, been carried out in this home industry with the objectives of identifying a suitable work posture for female workers.

Methods

Selection of site: The study was conducted on female golden thread workers in different districts of West Bengal, viz., Purba Medinipur and Paschim Medinipur in India. The selection of these districts was made because a significant part of the female population is engaged in golden thread work in these districts.

Selection of Subject: The study was carried on 123 adult women workers having the age range of 18-60 yrs, who were engaged in golden thread work. The subjects were selected at random from different areas of Purba and Paschim Medinipur districts in West Bengal. All of them volunteered for the study. The subjects having at least 4 years of working experience in the present occupation was one of the inclusion criteria. The research protocol of the study was approved by the institutional ethical committee. The subjects were further divided into three sub-groups on the basis of the posture(s) they adopted during work. The job-work profile of the workers put them working in these three postures, a) sitting on the floor with folded legs (Fig.1), b) squatting posture (Fig.2), and c) sitting on the floor with stretched legs (Fig.3).

Body Mass Index (BMI): Body Mass Index (BMI) is the gold standard to be used in adults to assess the nutritional and anthropometric status of the workers [8] and it can be used in monitoring anthropometric changes and disease risk analysis for the population [9]. The BMI was computed by the following formula (Park 2005): BMI = Weight (kg) / Height^2 (mt).

Evaluation of the musculoskeletal disorder: The prevalence of musculoskeletal disorder (MSD) of the female workers performing golden thread work was evaluated by using modified 'Nordic' questionnaire [10] during adopting the following sitting postures: sitting on the floor with folded legs, squatting posture, and sitting on the floor with stretched legs.

Body Part Discomfort (BPD) rating: The intensity of pain or discomfort in different body segments was assessed by a 10 point scale which was a modified pain mapping scale of Wilson and Corlette, [11]. The scale was graded from no discomfort at all to maximum discomfort. The discomfort was assessed in three sitting postures, i.e., sitting on the floor with folded legs, squatting, and sitting on the floor with stretched legs.

Twelve body segments were assessed in this study. The overall discomfort level was computed as the mean of the individual discomfort level assessed at various body segments. According to the degree of severity, the scores of the 10-point scale were divided into three subgroups [12], i.e., mild (1– 4), moderate (>4 – <7) and severe (>7).

Evaluation of Postural Stress:

- **Postural analysis**: Various techniques have been applied for postural analyses to identify the stress of the work. Working postures were evaluated by OVAKO Working postures Analysis System (OWAS) method [13]. Though OWAS method has a wide range of use but the results can be low in detail. Therefore, Rapid Upper Limb Assessment (RULA) [14] and Rapid Entire Body Assessment (REBA) methods [15] were also applied for analysis work posture of the workers. The postures were chosen from the working images recorded with camera (Sony Handycam and Nikon SLR). When taking pictures of working postures, the camera was positioned at a suitable angle to the operator so that three-dimensional working postures could be identified during playback. The selected postures used in this study were those that the field observers classified as stressful to the human musculoskeletal system.
- **EMG Study:** The EMG of the shoulder (trapezious) and back (latissimus dorsi) muscles of female golden thread workers was recorded with the help of the BIOPAC system (USA). This laboratory study was carried out on 10 randomly chosen female workers amongst previously selected subjects. The random selection was made according to the alphabetical order of the name of the selected subjects. The subjects were asked to sit in normal Indian traditional sitting posture on the floor which was taken as reference posture. Then they were asked to work in three different working postures, i.e., sitting

on the floor with folded legs, squatting posture, and sitting on the floor with stretched legs. The EMG was recorded in those postures.

(a) Muscle selection: The **s**ubjective evaluation pointed out that the prevalence of pain or discomfort was in the shoulder and lower back regions of the body. For that reason, Trapezious, a muscle of the shoulder and Latissimus dorsi, a muscle of the lower back were specifically selected for EMG study.

(b) Subject preparation: At first subjects were asked to wear minimum clothing, so that the muscle could be detected by anatomical landmark system, based on dominant bone areas and prominences or other structures that can easily be palpated from dorsal plane of body.

Then skin preparation was done by soft rubbing it with a very fine sand paper to remove dead skin, sweat and dirt. When the skin typically turned into a light red color, it was said to be in good impedance condition. After the skin preparation, silver/ silver chloride pre-gelled; disposable electrodes were placed over the muscle.The diameter of the conductive area of the electrode was 1cm.Electrodes were attached along the direction of the muscles fibers of the muscle .Three electrodes were placed in the required muscle with 2cm of inter-electrode gap (center point to center point).Then the leads (SS2L) were attached to electrodes.One of them was used for positive signal, another for negative signal and the rest was neutral.

(c) Analysis of EMG value: EMG signals were recorded in the frequency range of 5-1000 Hz. The absolute EMG and the root-mean-square (RMS) values were computed by using BSL Pro 3.7 software of BIOPAC system. Thelength of epochs for calculating the absolute EMG and the root-mean-square (RMS) was set in 1sec by setting the Delta T.

Statistical Analysis: Data were summarized into mean and standard deviation values using Microsoft Excel.The ANOVA study, Chi square test and Post-hoc analysis were made using the ORIGIN 6.1 software. Chi square test was performed for analyzing data of questionnaire study (MSD). ANOVA and Post-hoc analysis were done for the results of EMG study.

Results

The general physical characteristics, i.e., the height and weight of the golden thread workers have been presented in Table 1. The average age, height and weight of the subjects were 24.50 years, 150.59 cm and 46.52 kg respectively. The age range of the subjects was 18 to 60 years. The average BMI was 20.48 Kg/ m^2 which were within the normal range according to the cutoff value of WHO [16].

The results of different parameters studied were analyzed for three sitting postures, viz., sitting on the floor with folded legs, squatting, and sitting on the floor with stretched legs on a comparative basis.

The prevalence of musculoskeletal disorders (MSD) of the female golden thread workers in different sitting postures has been presented in Table-2. Significant differences in MSD were observed among different postures (p<0.001), according to the Chi square values, in most of the body segments. The results revealed that the prevalence of MSD in case of adopting squatting posture and sitting on the floor with stretched leg was comparatively higher in most of the body segments than that of sitting on the floor with folded legs excepting the neck, upper back and thigh segments. Those workers who adopted squatting posture had higher prevalence of pain in shoulder, elbow, wrist, upper back, lower back, and feet compared to other two working postures.

Table I : Physical characteristics of female golden thread workers (n=123)

Parameters	Mean ± SD	Range
Age (yrs)	24.50± 7.45	18 - 50
Height (Cm)	150.59±4.23	138.2– 161.1
Weight (Kg)	46.52± 6.48	31.0 - 61.0
BMI (Kg/m^2)	20.48± 2.45	14.70 - 26.90

The quantitative assessment of the perceived rating of discomfort of the workers was studied by using a 10-point scale and the results showed that the workers adopting different postures were suffering from different degrees of perceived exertion (Table 3). According to the degree of severity, the scores of the 10-point scale were divided into three subgroups [12], i.e., mild (1–4), severe (>4–7) and very severe (>7). It was revealed that in case of sitting on the floor with stretched legs, moderate degree of discomfort (>4 to ≤7) was observed in upper back, middle back and shoulder and severe degree of discomfort (>7) was observed in lower back whereas in squatting posture moderate degree of discomfort (>4 to ≤7) was observed in both shoulder and lower back. In case of sitting on the floor with folded legs, moderate degree of discomfort (>4 to ≤7) was observed only in right shoulder and lower back. There were significant differences in BPD rating in upper back (p<0.001), middle back (p<0.001) and buttock (p<0.05) when compared among three postures. The BPD rating in upper back, middle back and buttock was significantly lower (p<0.05 or less) in case of sitting with folded legs than in the other two sitting postures. The overall discomfort rating was also significantly different (p<0.01) among three sitting postures. The post-hoc analysis showed that the overall BPD rating was significantly lower in case of sitting with folded legs (p<0.001) and in squatting posture (p<0.05) than in the sitting on the floor with stretched legs.

Different postures adopted by the female golden thread workers were analyzed by different posture analysis methods, viz., OWAS, RULA and REBA and the results have been presented in Table-4. From the results of OWAS method it was found that the female golden thread workers had greater action level (3) in case of squatting posture than that other two postures indicating that the former posture needed corrective measures as soon as possible.

From the analysis of REBA method it was found that the squatting posture and sitting on the floor with stretched legs were categorized as 'very high risk' whereas sitting on the floor with

Table II: Frequency (f) and percentage (%) of musculoskeletal disorders (MSD) of Golden thread workers during adopting different postures

Body segment	Working Posture (n=114)									Chi Square Value (χ2)
	Sitting on the floor with folded legs (n=68)			Squatting (n=28)			Sitting on the floor with stretched legs (n=18)			
	f	%	Grade	f	%	Grade	f	%	Grade	
Neck	19	27.94	4	7	25	6	6	33.33	5	0.38 NS
Shoulder	56	82.35	2	25	89.29	2	18	100.00	1	197.33*
Elbow	13	19.12	7	7	25	6	12	66.67	4	16.11 *
Wrist	5	7.35	8	3	10.71	8	3	16.67	7	19.79*
Upper back	31	45.59	3	9	32.14	3	18	100.00	1	56.69*
Lower back	61	89.71	1	26	92.16	1	18	100.00	1	223.27*
Thigh	14	20.59	6	8	28.57	5	3	16.67	7	3.05 NS
Knee	17	25.00	5	9	32.14	3	6	33.33	5	0.79 NS
Feet	1	1.47	9	1	3.57	9	0	0.00	9	39.18*

* p<0.001

Table III: The Body part discomfort (BPD) rating (Mean ±SD) in different segments of the body (in a 10 point scale) of female golden thread workers during adopting different sitting postures

Body Segments		Posture			F value
		Sitting on the floor with folded legs (n=68)	Squatting (n=28)	Sitting on the floor with stretched legs (n=18)	
Neck		0.96±1.64	0.93±1.74	1.33±2.03	0.37
Shoulder	R	4.24±2.46	4.96±2.38	5.17±1.25	1.74
	L	3.31±2.59	4.54±2.10	4.00±2.38	2.64
Upper arm	R	1.04±2.08	1.11±2.17	1.67±2.28	0.62
	L	0.79±1.85	0.96±1.95	1.67±2.28	1.43
Lower arm	R	0.46±1.56	0.50±1.53	0.83±1.92	0.40
	L	0.43±1.45	0.46±1.40	0.83±2.04	0.52
Upper back		2.47±2.43	1.33±2.04 #	5.00±1.19 ### $$$	15.46 ***
Middle back		1.94±2.64	2.46±2.78	5.00±2.97 ### $$	8.98 ***
Lower Back		6.46±2.54	6.64±2.83	7.83±1.25	2.24
Buttock		0.07±0.61	0.32±1.70	1.00±2.30##	3.54*
Thigh	R	0.85±1.94	0.93±1.90	0.83±1.92	0.02
	L	0.85±1.94	0.93±1.90	0.83±1.92	0.02
Cuff	R	1.34±2.28	1.46±2.22	2.67±2.77	2.32
	L	1.34±2.28	1.46±2.22	2.67±2.77	2.32
Feet	R	0.07±0.61	0.21±1.13	0.00±0.00	0.55
	L	0.07±0.61	0.21±1.13	0.00±0.00	0.55
Over all discomfort rating of the body		1.57±0.74	1.73±0.73	2.43±1.25 ### $	7.18 **

* p<0.05 ** p<0.01 ***p<0.001
w.r.t. folded legs #p<0.05,##p<0.01,###p<0.001
w.r.t Squatting $p<0.05,$$p<0.01,$$$p<0.001

folded legs was categorized as 'high risk'. However, postural assessment by RULA method indicated that there was no difference in action level among three postures. So, from the results of postural analysis by tree methods it revealed that the workers who sat on the floor with folded legs showed lowest action level than that of other two postures.

The EMG voltages and RMS values of EMG of the shoulder (Trapezius) muscle of female golden thread workers have been presented in Table -5. From the results of ANOVA, it was revealed that there was a significant differences (p<0.01 or lesser) in the EMG values and RMS values of shoulder muscle among different sitting postures. While studying the relative percentage difference with respect to normal sitting posture, which was taken as reference posture, it was found that the deviation was the minimum in case of sitting with folded legs, except the left shoulder muscle, than that of other two postures.

A post hoc analysis of EMG and RMS value of EMG of shoulder muscle in different working postures has been presented in Table 6A and 6B. The EMG values of right side and RMS values in both side was significantly lower (p<0.01) in case of sitting on the floor with folded legs than that of squatting posture whereas a significantly lower values of EMG values in the left side (p< 0.05) level was observed while sitting on the floor with stretched legs than that of squatting posture. The RMS value showed significantly lower value (p<0.05 or lesser) while sitting on the floor with folded legs than that of other two postures.

The EMG voltage and RMS values of back muscle (lattisimus dorsi) of the golden thread workers have been presented in Table 7. The right side EMG and both side RMS values of the same in back muscle showed a significant difference (p <0.05 or lesser) amongst the postures under study. The percentage difference of EMG values from that of reference posture (normal sitting) were greater in case of squatting posture than that of other two postures. However, RMS values were the highest in case sitting on the floor with folded legs.

The results of the post hoc analysis of the EMG voltage and RMS value of back muscle in different working postures have been presented in Table 8A, and 8B respectively. It was noted that the EMG voltage of right side was significantly higher in squatting posture and in sitting on the floor with folded legs (p<0.05) when compared to values in normal sitting posture. There was no significant difference in EMG voltage between sitting on the floor with folded lags and stretched legs as well as between sitting with stretched legs and squatting posture. In case of RMS values significant differences (p<0.01 or lesser) were noted between sitting on the floor with folded lags and stretched legs as well as between sitting with stretched legs and squatting posture.

Table IV : Results (action level and risk levels) of postural analysis of the golden thread workers working in different work postures

Posture	Postural analysis of golden thread workers					
	OWAS		REBA		RULA	
	Action Level	Risk level	Action Level	Risk level	Action Level	Risk level
Sitting on the floor with folded legs	2	Corrective measures in the near future	10	High risk, investigate and implement change	7	Investigate and implement change
Sitting on the floor with stretched legs	2	Corrective measures in the near future	12	Very high risk, implement Change	7	Investigate and implement change
Squatting	3	Corrective measures as soon as possible	12	Very high risk, implement Change	7	Investigate and Implement change

Discussion

Body weight and height are normally used as an indicator of an individual's health. Efforts were also made to evaluate the nutritional status of the subjects by anthropometric data. Anthropometric index like body mass index (BMI) is the simple, safe, inexpensive method [17] and useful indicator for the nutritional assessment [18]. It may be noted from the study that the average values of BMI of the subjects were approximately within the normal range (20.48 Kg/m^2). The work related musculoskeletal disorders are defined as a musculoskeletal injury that results from hazardous work postures. From the present study it was found that the prevalence of MSD was high in some of the body segments of golden thread weavers, viz, shoulder (100%), elbow (66.67%), upper back (100%), lower back (100%), and neck (33.33%). A similar study was conducted on carpet weavers by Choobineh et al [19] who studied the prevalence of MSD symptoms in different body regions and showed that shoulders (47.8%), lower back (45.2%), wrists (38.2%), upper back (37.7%), neck (35.2%) and knees (34.6%) were the most commonly affected regions among the weavers. Metgud et al. [20] also studied on the MSD of women workers in a woolen textile factory and reported occurrence of pain in the lower back (47%) and neck (19%). In a study on handloom weavers [21] it was reported that the occurrence of MSD was high in lower back (75%), upper back (73.4), shoulder (68%) , elbow (65%), wrist (70.3%), and neck (57.8%). It may be noticed that the prevalence of MSD was very high in back, elbow, shoulder, and neck where workers were performing weaving type of task. It may be pointed out that the occurrence of pain in different segments of the body in the present study was higher than that of other studies. The higher prevalence of work related MSD in different segments of the body of the workers might be due to use of

Table V : Mean and standard deviation of EMG and RMS values (mV) of shoulder muscle of golden thread workers adopting normal sitting (resting) and three different working postures (n=10) [R and L indicates right and left side of the body]

Postures	EMG-R		EMG-L		RMS-R		RMS-L	
	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal sitting (resting)	0.0264 ±0.012	-	0.0298 ±0.008	-	0.0307 ±0.007	-	0.0368 ±0.008	-
Sitting on the floor with folded legs	0.0512 ±0.024	94.13	0.0407 ±0.044	36.60	0.0473 ±0.007	54.28	0.0458 ±0.008	24.59
Sitting on the floor with Stretched legs	0.0608 ±0.067	130.63	0.0303 ±0.037	1.43	0.0913 ±0.019	197.72	0.0951 ±0.014	158.49
Squatting	0.1061 ±0.044	302.44	0.0901 ±0.054	201.98	0.0836 ±0.048	172.58	0.0749 ±0.032	103.54
F-value	5.75**	-	4.65**	-	18.67***	-	19.20***	-

**p <0.01, ***p<0.001

Table VI A: Post-hoc analysis of EMG value of shoulder muscle of golden thread workers adopting normal sitting (resting) and three different working postures (n=10) [R and L indicates right and left side of the body]

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Sitting with stretched legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.0264	0.0298	0.0512	0.0407	0.0608	0.0303	0.1061	0.0901
Normal sitting (resting)	MD	-	-	-0.02	-0.01	-0.03	-0.0004	-0.08	-0.06
	SL			P<0.05	NS	NS	NS	P<0.001	P<0.01
Sitting on the floor with Folded legs	MD	-	-	-	-	-0.0096	0.0105	-0.0549	-0.0493
	SL					NS	NS	P<0.01	NS
Sitting on the floor with Stretched legs	MD	-	-	-	-	-	-	-0.0453	-0.0598
	SL							NS	P<0.05

MD=Mean difference, SL=Significant level

Table VI B: Post-hoc analysis of RMS value of shoulder muscle of golden thread workers adopting normal sitting and three different working postures (n=10) [R and L indicates right and left side of the body]

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Sitting with stretched legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.0307	0.0368	0.0473	0.0458	0.0913	0.0951	0.0836	0.0749
Normal sitting (resting)	MD	-	-	-0.02	-0.01	-0.06	-0.06	-0.05	-0.04
	SL			P<0.001	P<0.05	P<0.001	P<0.001	P<0.01	P<0.01
Sitting on the floor with Folded legs	MD	-	-	-	-	-0.0440	-0.0493	-0.0363	-0.0290
	SL					P<0.001	P<0.001	P<0.01	P<0.05
Sitting on the floor with Stretched legs	MD	-	-	-	-	-	-	0.0077	0.0202
	SL							NS	NS

MD=Mean difference, SL=Significant level

Table VII : Mean and standard deviation of EMG and RMS values (mV) of back muscle of golden thread workers adopting normal sitting (resting) and three different working postures [R and L indicates right and left side of the body]

Postures	EMG-R		EMG-L		RMS-R		RMS-L	
	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal sitting (resting)	0.0234 ±0.006		0.0258 ±0.005		0.0265 ±0.006		0.0315 ±0.005	
Sitting on the floor with folded legs	0.0361 ±0.015	53.94	0.0287 ±0.017	11.15	0.0857 ±0.027	223.56	0.0800 ±0.021	153.56
Sitting on the floor with Stretched legs	0.0428 ±0.035	53.54	0.0383 ±0.030	48.22	0.0279 ±0.010	5.34	0.0262 ±0.011	16.83
Squatting	0.0758 ±0.049	223.40	0.0642 ±0.064	148.42	0.1016 ±0.024	283.51	0.0999 ±0.022	216.72
F-value	3.825*		1.69 NS		28.95***		34.86***	

* p<0.05 ***p<0.001

Table VIII A : Post-hoc analysis of EMG value of back muscle of golden thread workers adopting normal sitting (resting) and three different working postures (n=10) [R and L indicates right and left side of the body]

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Stretching legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.0234	0.0258	0.0361	0.0287	0.0428	0.0383	0.0758	0.0642
Normal sitting (resting)	MD	-	-	-0.0126	-0.0029	-0.0193	-0.0125	-0.0524	-0.0383
	SL			P<0.05	NS	NS	NS	P<0.05	NS
Sitting on the floor with Folded legs	MD	-	-	-	-	-0.0067	-0.0096	-0.0397	-0.0355
	SL					NS	NS	NS	NS
Sitting on the floor with Stretched legs	MD	-	-	-	-	-	-	-0.0331	-0.0259
	SL							NS	NS

MD=Mean difference, SL=Significant level

Table VIII B : Post-hoc analysis of RMS value of back muscle of golden thread workers adopting normal sitting (resting) and three different working postures (n=10) [R and L indicates right and left side of the body]

Category of posture		Normal sitting (resting)		Sitting on the floor with Folded legs		Stretching legs		Squatting	
Body side		R	L	R	L	R	L	R	L
Mean		0.0265	0.0315	0.0857	0.0800	0.0279	0.0262	0.1016	0.0999
Normal sitting (resting)	MD	-	-	-0.0592	-0.0484	-0.0014	-0.0053	-0.0751	-0.0684
	SL			P<0.001	P<0.001	NS	NS	P<0.001	P<0.001
Sitting on the floor with Folded legs	MD	-	-	-	-	0.0578	0.0537	-0.0159	-0.0199
	SL					P<0.001	P<0.001	NS	NS
Sitting on the floor with Stretched legs	MD	-	-	-	-	-	-	-0.0737	-0.0737
	SL							P<0.01	P<0.01

MD=Mean difference, SL=Significant level

significant force, repetitive movements and longer duration of exposure [22]. Caicoya and Delclos [23] stated that those perform highly repetitive tasks for longer duration has reported pain at different segments of their body. Abnormal posture creates a strain on ligaments and muscles that indirectly affects the curvature of the lumbar spine. Chronic low back pain affects the lower lumbar spine and limits the maximal range of lumbar extension [24]. Nag et al. [7] studied the work stresses of women who were engaged in sewing machine operation in small garment manufacturing units in India. They found that high prevalence of discomfort and pain in different body parts. About 68% of the women complained of back pain, among which 35% reported a persistent low back pain.

The results of the BPD rating revealed that there was a higher degree of pain in lower back and shoulder among the female workers. The high prevalence of pain was also noted on those segments of the female workers. Bandopadhyay and Sen [25] also reported severe (Garde 3) pain in different body segments of women workers due to adopting awkward sitting posture for a long time during work. Other investigators [26, 27] also reported high degree of low back pain among a large percentage (70%) of female brick workers due to awkward working posture for prolonged period of time. Dewangan et al [28] observed maximum work related BPD at lower back among the female agricultural workers. A study by Desai [29], on women in small scale industries also showed a significantly higher body pain and discomfort, attributable to their prolonged sitting postures. While comparing three sitting postures, the extent of pain was the lowest in most of the body segments in case of sitting on the floor with folded legs. The overall discomfort / pain, considering all body segments studied, was also significantly lower during sitting on the floor with folded legs. Thus the findings of the comparison indicated that the female workers had lesser extent of pain / discomfort while sitting on the floor with folded legs.

Postural analysis by OWAS, RULA and REBA method indicated that the workers adopting squatting posture showed highest degree of risk level whereas the workers adopting sitting on the floor with folded legs posture showed lowest degree of risk level. Such findings might be related to postural stress owing to long term adoption of squatting and squat bending posture during performing the tasks. Other investigations suggested that working in squatting and squat bending posture and in same awkwardly 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 [6,30,31]. Pal et al [32] evaluated postural stress of female cultivators by OWAS , RULA, QUC and REBA methods while performing potato harvesting task and observed high postural stress due to adopting squatting posture. Other investigators [33, 4] also found that the female workers engaged in squatting posture for prolonged period of time had high scores of OWAS , RULA and REBA indicating high risk of postural stress. Sahu and Set [27] categorized the postures adopted by the female brick moulders as having 'high' to 'very high' risk levels according to the OWAS and REBA methods.

Borah et al. [35] studied on women workers engaged in cashew nut processing industry and observed that the workers had high prevalence of MSDs due to adoption of unnatural squatting posture on the ground for a long time. Workers reported complaints about musculoskeletal problems after adopting the squatting posture since they were supported with non-suitable facilities [36, 37].

Electromyographic signal (EMG) analysis can provide information as to the relative amount of muscular activity an exercise requires, as well as the optimal positioning for the exercise [38].The EMG study of the shoulder (Trapezius) and back (Lattisimus dorsi) muscles of the female golden thread workers indicated different extent of muscular activities in three sitting postures.

The EMG voltage of shoulder muscle was the minimum in case of the workers sitting on the floor with folded legs among three working postures and in this posture minimum deviation of the EMG voltage from that of the reference posture was also noted in the dominant hand, i.e., right hand. In case of left hand the minimum EMG voltage or deviation of EMG voltage from the reference position was noted during sitting with stretched leg. This might be due to the fact that the left hand remained in the lower side of the work surface under working condition and it had a supporting role for weaving golden thread. The EMG voltage of the right side was greater than that of left side. A greater relative amplitude of an EMG signal of a muscle is associated with greater relative contractile force [39]. Salvendy [40] had shown that the degree of forward shoulder flexion, or reach, significantly influences muscular fatigue, noting that as the horizontal distance was increased, the onset of fatigue was more rapid.

On the other hand the results of EMG study of back muscle (lattisimus dorsi) indicated that back muscle had lesser myoelectric activities while sitting on the floor with folded legs in comparison to other two postures. This might be due to lesser stress imposed on the back muscle during performing the task. The stress on the back muscle depends on the degree of forward bending, twisting and instability of the body. As there was a wider base contact area of the body with the ground the worker was more stable during sitting on the floor with folded legs than that in squatting posture [12]. Further, there was lesser degree of bending of the trunk during sitting on the floor with folded leg in comparison to work under squatting posture. Those might be the probable reasons for imposing lesser stress on back muscle during sitting on the floor with folded legs. Bidard et al. [41] also revealed that the stabilization effort was greater for unsupported sitting than for standing because of not optimal alignment of the centers of mass. Thus in squatting posture more stabilizing efforts might be adopted by the body than that of sitting on floor, which possessed large contact area with the ground. Therefore, it might be one of the reasons for the lesser BPD rating (Table 2) and lower prevalence of MSD (Table 1) at the lower back region while sitting on the floor with folded legs than in that of the squatting postures.

SEMG has been used in numerous settings to measure voltage output of relative muscle recruitment, in ergonomic analyses when comparing musculoskeletal stress in a specific muscle(s) associated with postures and to evaluate the efficacy of ergonomic interventions [42, 43]. Van Dieen et al. [44] who observed that trunk kinematics and back muscle EMG were strongly affected by the task performed, but not by the chair type. Kroemer and Grandjean [45], Schoberth [46], Zacharkow [47], and Pheasant [48] believed that sitting postures put more load on the spinal discs than standing postures. Kimura et al. [49] also found that biomechanical axial stress for the intervertebral disc increased most at L4– L5 due to a decrease in a disc height in upright posture. This might be a reason for higher muscular activity of back muscle of the workers dung working in squatting posture in comparison to working in sitting on the floor. Therefore, it was revealed from the EMG study that the muscular stress in shoulder and lower back muscles was lesser in case of sitting on the floor, especially when legs were folded, than that of squatting posture.

Conclusion

During performing tasks, the female golden thread workers had lesser prevalence of MSD , lesser extent of BPD rating , lower postural stress , and smaller myoelectric activities in shoulder and muscles while sitting on the floor with folded legs than that of sitting on the floor with stretched leg and squatting posture. So, sitting on the floor with folded legs, a traditional Indian sitting posture may be the suitable working posture for the female golden thread workers.

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An experimental study to evaluate musculoskeletal disorders and postural stress of female craftworkers adopting different sitting postures

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This study aimed to evaluate musculoskeletal disorders (MSDs) and postural stress among female craftworkers. The study was carried out on 75 adult female craftworkers in different districts of West Bengal. The prevalence of MSDs, body part discomfort (BPD) rating and body joint angles of the workers were evaluated with standard methods. Electromyography (EMG) of the shoulder and back muscles was recorded with the BIOPAC system. The prevalence of MSDs, BPD rating and deviation of joint angle were comparatively lower in the case of sitting on the floor with folded legs than squatting and sitting on the floor with stretched legs postures. The EMG and rms values of the shoulder and back muscles were comparatively lower in this posture. Therefore, it was concluded that sitting on the floor with folded legs was less hazardous and it imposed less postural stress in comparison to other sitting postures.

Keywords: posture; MSD; BPD; EMG; craftworker

1. Introduction

Women in the contemporary society are often saddled with multitasking – the responsibility of a full-time professional job besides domestic chores. The study focused on those engaged in small or domestic-level handicraft industries. The handicraft industries covered under this study were essentially labor intensive, so women are prone to suffer from work-related health problems. Therefore, it was considered necessary to study workers' health problems. As a conservative estimate, 1 in 300 females suffers from some occupation-related disease.[1] Decades of research have identified certain physical workplace factors that increase the risk of musculoskeletal disorders (MSDs).

The problem emanating out of stooping and squatting postures is of greatest relevance in developing countries in general and in India in particular.[2] Unfortunately, such hazardous postures are frequently observed in small-scale industries in India. Most of the manually energized operations in these industries necessitate such postures. In an industry in central India, where operators are mostly women, 91% of them suffer from posture-induced MSDs.[3]

The human body can adapt to various types of posture. Craftworkers are required to adapt to a multitude of postures for performing different tasks. Awkward work postures are responsible for short-term body discomfort, segmental pain and long-term damage.

Indian women adopt different forms of sitting postures during work and leisure. Squatting is one of the most common postural patterns and has been a part of the traditional lifestyle in India and other Asian countries. Indian women are also found to adopt a traditional sitting posture, i.e., sitting on the floor with folded legs. Women adopt such posture to perform various activities, e.g., a variety of domestic tasks, handcrafting, a complete range of professional work and leisure activities.

In hand-driven cotton spinning operation, awkward postures in different parts of the body (i.e., bent back, folded knees, bent neck) are very common. A survey revealed that amongst the operators the disease symptoms in the knees, the back and the shoulders developed over time and were significantly higher than in other areas of the body.[4] This indicates that any interventional program for the improvement of working conditions should focus on eliminating awkward postures of the above-mentioned areas of the body.

A similar study regarding goldsmiths working in awkward postures in India used an ergonomic intervention to improve workstation design.[5] This study indicated that workers who adopted awkward postures at work, most often suffered from MSDs particularly affecting the lower back and neck region. Another study was carried out on 514 cotton textile workers in Wardha.[6] It showed that the prevalence of lower back pain was about 11.1%.

Songkham et al. [7] investigated occupational hazards and health status of 307 pottery workers in Chiang Mai, Thailand. The study revealed that primary illnesses amongst the sample population were essentially MSDs,

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including hand–arm–shoulder pain, back pain, neck pain and leg pain.

Every industry plays a significant role in the development of a country by contributing immensely to generating employment, producing goods and subsequently creating wealth. The production of handicrafts very often becomes the chief means of livelihood in a society. Employment provides sustenance to members of the society, and their daily requirements are satiated by their earnings. Consequently, handlooms and handicrafts play a very significant role in the socio-economic development of a society.[8]

Workers are found to adopt three postures, namely, (a) sitting on the floor with folded legs (Figure 1), (b) squatting (Figure 2) and (c) sitting on the floor with stretched legs (Figure 3).

Figure 1. Working in a sitting on the floor with folded legs posture.

Figure 2. Working in a squatting posture.

Figure 3. Working in a sitting on the floor with stretched legs posture.

There are hardly any studies on the effect of postural stress on female craftworkers in the state of West Bengal. This study has specifically been carried out to determine the prevalence of musculoskeletal symptoms and the range of discomfort in the different body segments of female craftworkers vis-à-vis the postures referred to above. The comparative evaluation of the aforesaid postural stress was made with electromyography (EMG) studies.

2. Materials and methods

2.1. *Selection of site*

The study was conducted on women craftworkers in different districts of West Bengal, namely, Purulia, Bankura, Purba Medinipur and Paschim Medinipur. These districts were selected because a significant part of the female population is engaged in the small-scale handicraft industry in these districts. The sampling targeted female craftworkers, specifically those who are engaged in knitting, making soft toys and bags. The job profile of the workers put them working in these three postures: (a) sitting on the floor with folded legs (Figure 1), (b) squatting (Figure 2) and (c) sitting on the floor with stretched legs (Figure 3).

2.2. *Selection of subjects*

This study was carried out on 75 randomly selected adult women workers, who have been in craftwork for not less than 4 years. The mean age of the subjects was 40.21 ± 11.97 years (range: 18–60 years). The subjects were further divided into three groups on the basis of the postures they adopted during work.

2.3. *Evaluation of the MSDs*

The MSDs of the female workers were evaluated with a modified Nordic questionnaire [9] during the adoption of the following postures: sitting on the floor with folded legs, squatting and sitting on the floor with stretched legs.

2.4. Body part discomfort (BPD) rating

The intensity of pain or discomfort in different body segments was assessed on a 10-point scale, which is a modified pain mapping scale of Wilson and Corlett.[10] The scale was graded from *no discomfort at all* to *maximum discomfort*. Discomfort was assessed in three sitting postures, i.e., sitting on the floor with folded legs, squatting and sitting on the floor with stretched legs.

Eleven body segments were assessed in this study. The overall discomfort level was computed as the mean value of the entire individual discomfort level assessed in various body segments. 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).

2.5. Joint angle

Different body joint angles were measured with a digital goniometer (Lafayette, USA) while the workers were adopting a normal erect posture and the three working postures. During the measurement of different joint angles of the body, the center of the goniometer was adjusted over the estimated center of the joint and the reference arms were aligned to the long axes of the adjoining body segments, which was taken as the reference position representing the zero angle. The reference position has been indicated in each of the joint angles separately in the following sections.

2.5.1. Shoulder joint angle

The shoulder angle is the angle between the vertical trunk (lateral) line and the upper arm at the acromial joint region. The line was drawn on the back where one arm of it was fixed (reference position) along the body line and the other line was drawn along the midline of the upper arm. The shoulder joint angle was measured in one plane, i.e., in the sagittal plane.

2.5.2. Elbow joint angle

It is the angle between the upper arm and lower arm. The line was drawn on the elbow joint; one of the arms of the instrument was fixed in the midline of the arm (reference position) and the other one was drawn at the midline of the lower arm.

2.5.3. Wrist joint angle

It is the angle between the lower arm and hand. The line was drawn on the wrist joint; one of the arms of the instrument was fixed in the midline of the lower arm (reference position) of the subject and the other line was drawn at the midline of the backside of the palm.

2.5.4. Hip joint angle

It is the angle between the trunk and the thigh. The line was drawn on the waistline; one line was drawn on the vertical trunk (lateral) line (reference position) and the other one was at the midline of the thigh.

2.5.5. Knee joint angle

It is the angle between the thigh and lower leg. The line was drawn on the knee joint at the midline of the thigh (reference position) and the midline of the lower leg.

2.6. EMG study

The EMG of the shoulder and back muscles of female craftworkers was recorded with the BIOPAC system (USA). This laboratory study was carried out on 10 randomly chosen female workers amongst previously selected subjects. The random selection was made according to the alphabetical order of the name of the selected subjects. The subjects were asked to sit in the normal Indian traditional sitting posture on the floor, which was taken as the reference posture. Then they were asked to work in three working postures, i.e., sitting on the floor with folded legs, squatting and sitting on the floor with stretched legs. The EMG was recorded in those postures.

2.6.1. Muscle selection

A subjective evaluation pointed out the occurrence of pain or discomfort in the shoulder and lower back regions of the body. For that reason, m. trapezius (a muscle of the shoulder) and m. latissimus dorsi (a muscle of the lower back) were specifically selected for EMG study.

2.6.2. Subject preparation

At first the subjects were asked to wear minimum clothing, so that the muscle could be detected by an anatomical landmark system, based on dominant bone areas and prominences or other structures that can easily be palpated from the dorsal plane of the body.

Then skin was prepared by soft rubbing it with a very fine sandpaper to remove dead skin, sweat and dirt. When the skin typically turned a light red color, it was said to be in good impedance condition. After the skin preparation, silver/silver chloride pre-gelled disposable electrodes were placed over the muscle. The diameter of the conductive area of the electrode was 1 cm. The electrodes were attached along the direction of the fibers of the muscle. Three electrodes were placed on the required muscle with 2 cm of inter-electrode gap (center point to center point). Then leads (SS2L) were attached to the electrodes. One of them was used for the positive signal, another for the negative signal and the other was neutral.

2.6.3. *Analysis of EMG value*

EMG signals were recorded in the frequency range of 5–1000 Hz. The absolute EMG and the rms values were computed with BSL Pro 3.7 software of BIOPAC system. The length of epochs for calculating the absolute EMG and rms was set at 1 s by setting the Delta T.

2.7. *Statistical analysis*

Data were summarized into mean and standard deviation values using Microsoft Excel. The analysis of variance (ANOVA), χ^2 test and *post hoc* analysis were made using Origin 6.1 software. A χ^2 test was performed for analyzing data of the questionnaire study on MSDs. ANOVA and *post hoc* analysis were done for the results of the EMG study.

3. Results

The results of various parameters were analyzed for different sitting postures, namely, sitting on the floor with folded legs, squatting and sitting on the floor with stretched legs on a comparative basis. Sometimes standing posture was also compared with sitting postures.

Table 1 presents the occurrence of MSDs of female craftworkers in different sitting postures. It was revealed that the prevalence of MSDs in the case of squatting and sitting on the floor with stretched legs postures was comparatively higher in most body segments than that of sitting on the floor with folded legs, excepting the neck region. It was noted that 100% of the respondents reported problems in their neck, knees and lower back during sitting on the floor with stretched legs. Beside these, higher prevalence of MSDs was observed in the shoulder, thigh and feet. The results of the χ^2 test revealed that there was a significant difference ($p < 0.001$) in the occurrence of MSDs in the neck, elbow, wrist and upper back region in the three postures.

The perceived rating of discomfort of the female workers was studied and the output results in the three sitting postures have been compared as shown in Table 2. The results of ANOVA highlight that there were significant differences in BPD rating noted in the buttock ($p < 0.05$) and neck ($p < 0.01$) region when compared among the three postures. Although no significant difference was observed in BPD rating in other body segments, the mean values were the lowest in most of the segments while sitting on the floor with folded legs in comparison to the other sitting postures. The overall BPD rating was lower (though non-significantly) in the case of sitting on the floor with folded legs than in the other two sitting postures.

The degree of discomfort/pain perceived by the female workers was categorized into *mild* (1–4), *moderate* (>4–7) and *severe* (>7) categories. Table 3 shows the affected body parts in different categories.

Different body joint angles of craftworkers were measured in the course of their work in different sitting postures and standing posture. The deviations between the recorded measurements at each joint angle in different sitting postures from the standard measurement of the reference posture (standing erect) were calculated and presented in Table 4. It was inferred from the results that the deviation of joint angle from normal erect posture was higher in the shoulder (left side 82.07%), elbow (left side 38.53%, right side 38.60%), hip (left side 62.18%, right side 61.05%) and knee (right side 77.92%) flexion during squatting than in the other two working postures. There were also significant differences in different body joint angles, namely, shoulder, knee ($p < 0.001$), left elbow, wrist, hip ($p < 0.01$) and right knee ($p < 0.05$) vis-à-vis the three postures.

Table 1. Frequency (f) and percentage (%) of musculoskeletal disorders of craftworkers in different postures.

	Posture									
	Squatting ($n = 20$)			Sitting on the floor with stretched legs ($n = 6$)			Sitting on the floor with folded legs ($n = 49$)			
Body segment	f	%	Grade	f	%	Grade	f	%	Grade	χ^2
Neck	9	45	9	6*	100	1	42***	85.71	1	14.98***
Shoulder	17	85	1	5	83.33	4	41	83.67	2	2.647
Elbow	11	55	6	3	50	8	24	48.98	7	26.673***
Wrist	11	55	6	4	66.67	6	23	46.94	8	27.810***
Upper back	10	50	8	3	50	8	21	42.86	9	39.145***
Lower back	17	85	1	6	100	1	38	77.55	4	2.848
Thigh	14	70	5	5	83.33	4	38	77.55	4	0.636
Knee	17	85	1	6	100	1	40	81.63	2	3.635
Feet	16	80	4	4	66.67	6	30	61.22	6	6.327*

*$p < 0.05$, ***$p < 0.001$.

Table 2. Body part discomfort rating ($M \pm SD$) in different segments of the body (on a 10-point scale) of female craftworkers in different sitting postures.

Body segment	Posture: Squatting ($n = 20$)	Sitting on the floor with stretched legs ($n = 6$)	Sitting on the floor with folded legs ($n = 49$)	F
Neck	2.25 ± 2.61	4.83 ± 0.98	3.71 ± 1.81	5.37**
Shoulder				
R	4.4 ± 2.04	4.00 ± 2.19	3.47 ± 1.82	1.75
L	4.35 ± 1.98	4.00 ± 2.19	3.43 ± 1.80	1.77
Upper arm				
R	2.6 ± 1.93	2.67 ± 2.25	1.59 ± 1.71	2.72
L	2.6 ± 1.93	2.67 ± 2.25	1.59 ± 1.71	2.72
Lower arm				
R	1.35 ± 1.53	1.50 ± 1.64	1.27 ± 1.56	0.07
L	1.35 ± 1.53	1.50 ± 1.64	1.27 ± 1.56	0.07
Upper back	2.3 ± 2.43	1.83 ± 2.14	1.73 ± 2.13	0.46
Middle back	3.25 ± 2.49	3.83 ± 2.04	2.43 ± 2.50	1.40
Lower back	5.35 ± 2.60	6.00 ± 1.10	4.51 ± 2.55	1.50
Buttock	2.35 ± 2.16	1.50 ± 1.64	0.90 ± 1.66	4.62*
Thigh				
R	3.3 ± 2.3	3.17 ± 1.83	3.43 ± 2.03	0.06
L	3.3 ± 2.3	3.17 ± 1.83	3.37 ± 2.03	0.06
Calf				
R	3.85 ± 2.01	4.33 ± 1.03	3.02 ± 1.73	2.58
L	3.85 ± 2.01	4.33 ± 1.03	3.02 ± 1.73	2.58
Feet				
R	2.7 ± 1.56	2.33 ± 1.97	1.90 ± 1.46	2.01
L	2.7 ± 1.56	2.33 ± 1.97	1.90 ± 1.46	2.01
Overall discomfort rating of the body	3.05 ± 1.26	3.18 ± 0.90	2.50 ± 0.84	3.02

*$p < 0.05$, **$p < 0.01$.
Note: R = right, L = left.

Table 3. Degree of severity of discomfort in different segments of the body in three postures.

Category of BPD	Affected body parts in different sitting postures: Squatting	Sitting on the floor with stretched legs	Sitting on the floor with folded legs
Mild (1–4)	Neck, upper arm, lower arm, upper back, middle back, buttock, thigh, calf and feet	Upper arm, lower arm, upper back, middle back, buttock, thigh and feet	Neck, shoulder, upper arm, lower arm, upper back, middle back, buttock, thigh, calf and feet
Moderate (>4–7)	Shoulder and lower back	Neck, shoulder, lower back and calf	Lower back
Severe (>7)	—	—	—

Note: BPD = body part discomfort.

Table 5 presents EMG voltages and rms values of the shoulder muscle of female craftworkers. The results of ANOVA revealed that there was a significant difference ($p < 0.01$) in the EMG values and ($p < 0.05$) in the rms values of the right shoulder muscle in different sitting postures. In the case of the left shoulder, the EMG and rms values did not show significant difference in the different postures. While studying the relative percentage difference with respect to normal erect posture, it was found that the percentage deviation was lowest in the case of sitting on the floor with folded legs. Tables 6A and 6B present a *post hoc* analysis of EMG and rms values of the shoulder muscle in different working postures. The analysis underlined the facts that the EMG value was significantly higher while sitting on the floor with stretched legs ($p < 0.05$) and squatting ($p < 0.001$) when compared to normal sitting (reference) posture. However, no significant difference in EMG voltage was observed between reference sitting posture and sitting on the floor with folded legs. The rms values of EMG in the right side also showed a significant difference ($p < 0.05$) between normal sitting posture (reference posture) and the three working postures referred to earlier. The percentage difference of rms values was notably lower during sitting with folded legs than it was in other postures.

Table 7 presents EMG voltage and rms values of the back muscle of the craftworkers. The EMG and rms values of the left and right back muscles showed a significant difference ($p < 0.05$) amongst the postures under study. Tables 8A and 8B present the results of the *post hoc*

Table 4. Deviation of different body joint angles ($M \pm SD$) of craftworkers in postures different from normal erect posture.

	Posture						
		Squatting ($n = 20$)		Sitting on the floor with stretched legs ($n = 6$)		Sitting on the floor with folded legs ($n = 49$)	
Body joint angle	Normal erect posture	Working posture	% deviation	Working posture	% deviation	Working posture	% deviation
Shoulder							
L	35.92 ± 6.29	65.4 ± 18.64	82.07	63.00 ± 6.16	75.38	60.43 ± 12.81	68.23
R	37.71 ± 5.60	62.75 ± 19.20	66.40	56.50 ± 9.79	49.82	65.29 ± 15.11	73.13
Elbow							
L	161.16 ± 6.71	99.05 ± 25.28	38.53	142.50 ± 16.27	11.57	118.27 ± 22.56	26.61
R	158.73 ± 8.86	97.45 ± 30.45	38.60	131.67 ± 21.57	17.04	113.02 ± 31.94	28.80
Wrist							
L	174.31 ± 4.93	165.26 ± 10.64	5.19	156.00 ± 24.18	10.50	141.63 ± 22.63	18.75
R	174.47 ± 5.71	156.45 ± 27.67	10.33	156.17 ± 24.24	10.49	150.71 ± 17.23	13.62
Hip							
L	174.25 ± 4.59	65.9 ± 30.98	62.18	104.00 ± 8.17	40.31	85.57 ± 20.96	50.89
R	173.81 ± 6.14	67.7 ± 30.38	61.05	93.83 ± 4.75	46.05	75.22 ± 11.49	56.72
Knee							
L	174.08 ± 3.89	42.55 ± 14.69	75.56	174.50 ± 2.74	0.24	11.49 ± 24.07	93.40
R	174.39 ± 4.00	38.5 ± 11.63	77.92	169.67 ± 7.99	2.70	42.89 ± 12.80	65.50

Note: L = left, R = right.

Table 5. Mean and standard deviation of electromyography (EMG) and rms values of shoulder muscle of craftworkers adopting normal sitting and three working postures ($n = 10$).

	EMG-R		EMG-L		rms-R		rms-L	
Posture	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal sitting (resting)	0.027 ± 0.014	—	0.031 ± 0.008	—	0.031 ± 0.009	—	0.036 ± 0.009	—
Sitting on the floor with folded legs	0.045 ± 0.021	66.67	0.040 ± 0.018	29.03	0.052 ± 0.016	67.74	0.044 ± 0.019	22.22
Sitting on the floor with stretched legs	0.046 ± 0.008	70.37	0.044 ± 0.013	41.95	0.059 ± 0.024	90.32	0.050 ± 0.018	38.89
Squatting	0.054 ± 0.014	100	0.042 ± 0.014	35.48	0.065 ± 0.003	109.67	0.050 ± 0.017	38.89
F	4.84**	—	1.37	—	3.05*	—	1.12	—

*$p < 0.05$, **$p < .01$.

Table 6A. Post hoc analysis of Electromyography (EMG) value of shoulder muscle of craft workers adopting normal sitting and three working postures ($n = 10$).

	Normal sitting (resting)		Sitting on the floor with folded legs		Sitting on the floor with stretched legs		Squatting	
Posture	R	L	R	L	R	L	R	L
M	0.027	0.031	0.045	0.040	0.046	0.044	0.054	0.042
Normal sitting (resting)								
MD			–0.018	–0.009	–0.019	–0.013	–0.027	–0.011
SL			*ns*	*ns*	$p < 0.05$	$p < 0.05$	$p < 0.001$	*ns*
Sitting on the floor with folded legs								
MD					–0.001	–0.004	–0.009	–0.002
SL					*ns*	*ns*	*ns*	*ns*
Sitting on the floor with stretched legs								
MD							– 0.008	0.002
SL							*ns*	*ns*

Note: R = right side of the body, L = left side of the body, *MD* = mean difference, *SL* = significant level.

Table 6B. Post hoc analysis of rms value of shoulder muscle of craft workers adopting normal sitting and three working postures ($n = 10$).

	Normal sitting (resting)		Sitting on the floor with folded legs		Sitting on the floor with stretched legs		Squatting	
Posture	R	L	R	L	R	L	R	L
M	0.031	0.036	0.052	0.044	0.059	0.050	0.065	0.050
Normal sitting (resting)								
MD			−0.021	−0.008	−0.028	−0.014	−0.034	−0.014
SL			$p < 0.05$	*ns*	$p < 0.05$	*ns*	$p < 0.05$	*ns*
Sitting on the floor with folded legs								
MD					−0.007	−0.006	−0.013	−0.006
SL					*ns*	*ns*	*ns*	*ns*
Sitting on the floor with stretched legs								
MD							−0.006	0
SL							*ns*	*ns*

Note: R = right side of the body, L = left side of the body, *MD* = mean difference, *SL* = significant level.

Table 7. Mean and standard deviation of electromyography (EMG) and root-mean-square (rms) values (mV) of back muscle of craftworkers adopting normal and three working postures.

	EMG-R		EMG-L		rms-R		rms-L	
Posture	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation	Value (mV)	% deviation
Normal sitting (resting)	0.025 ± 0.007		0.026 ± 0.004		0.028 ± 0.006		0.032 ± 0.004	
Sitting on the floor with folded legs	0.028 ± 0.006	12.00	0.028 ± 0.007	7.69	0.033 ± 0.009	17.86	0.033 ± 0.006	3.13
Sitting on the floor with stretched legs	0.030 ± 0.009	20.00	0.031 ± 0.008	19.23	0.034 ± 0.013	21.43	0.036 ± 0.008	12.5
Squatting	0.037 ± 0.006	48.00	0.036 ± 0.006	38.46	0.040 ± 0.006	42.86	0.040 ± 0.004	25.00
F	4.33*		3.78*		2.89*		4.32*	

*$p < 0.05$.

analysis of the EMG voltage and rms value of the back muscle in different working postures. It was noted that the EMG voltage was significantly higher in squatting (right side $p < 0.01$, left side $p < 0.001$) when compared to the standard measurement values in normal sitting posture. A significant difference (right side $p < 0.01$, left side $p < 0.05$) was noted in the EMG voltage between sitting on the floor with folded legs and squatting. The rms values of EMG also showed the same trends in the results. The percentage deviation in the EMG values from that of the reference posture (normal sitting) was lower in the case of sitting on the floor with folded legs than that of the other two postures, i.e., squatting and sitting on the floor with stretched legs. The rms values of EMG also showed the same trends of results. The deviation was found to be highest while working in a squatting posture.

4. Discussion

Work-related MSDs are defined as a musculoskeletal injury that results from hazardous postures that are essentially work related. In the present study on craftworkers it was found that the prevalence of MSDs was notably higher in their neck, knee and lower back during sitting on the floor with stretched legs. Björkstén et al. [11] also stated that there appeared to be an increased risk of problems in the neck, shoulders and arms in monotonous and tensed work tasks performed in a sitting position. In the present study the female craftworkers performed the work in the sitting posture and reported pain in different body segments.

It can be inferred from the result of BPD rating that the prevalence of MSD symptoms was higher in the neck, shoulder and back in our study. A similar study was done by Choobineh et al.[12] They studied the prevalence of MSD symptoms in different body segments of carpet weavers and showed that the shoulders (47.8%), lower back (45.2%), wrists (38.2%), upper back (37.7%), neck (35.2%) and knees (34.6%) were the most commonly affected segments among the weavers. Metgud et al. [13] also studied the MSDs of women workers in a woolen textile factory and reported occurrence of pain in the lower back (47%) and neck (19%). In the present study the occurrence of pain or discomfort

Table 8A. Post-hoc analysis of Electromyography (EMG) value of back muscle of craft workers adopting normal sitting and three working postures ($n = 10$).

	Normal sitting (resting)		Sitting on the floor with folded legs		Sitting on the floor with stretched legs		Squatting	
Posture	R	L	R	L	R	L	R	L
M	0.025	0.026	0.028	0.028	0.030	0.031	0.037	0.036
Normal sitting (resting)								
MD			−0.003	−0.002	−0.005	−0.005	−0.012	−0.010
SL			*ns*	*ns*	*ns*	*ns*	$p < 0.01$	$p < 0.001$
Sitting on the floor with folded legs								
MD					−0.002	−0.003	−0.009	−0.008
SL					*ns*	*ns*	$p < 0.01$	$p < 0.05$
Sitting on the floor with stretched legs								
MD							− 0.007	− 0.005
SL							*ns*	*ns*

Note: R = right side of the body, L = left side of the body, *MD* = mean difference, *SL* = significant level.

Table 8B. Post hoc analysis of rms value of the back muscle of craft workers adopting normal sitting and three working postures ($n = 10$).

	Normal sitting (resting)		Sitting on the floor with folded legs		Sitting on the floor with stretched legs		Squatting	
Posture	R	L	R	L	R	L	R	L
M	0.028	0.032	0.033	0.033	0.034	0.036	0.040	0.040
Normal sitting (resting)								
MD			−0.005	−0.001	−0.006	−0.004	−0.002	−0.008
SL			*ns*	*ns*	*ns*	*ns*	*ns*	$p < 0.001$
Sitting on the floor with folded legs								
MD					−0.001	−0.003	−0.007	−0.007
SL					*ns*	*ns*	$p < 0.01$	$p < 0.01$
Sitting on the floor with stretched legs								
MD							−0.006	−0.006
SL							*ns*	*ns*

Note: R = right side of the body, L = left side of the body, *MD* = mean difference, *SL* = significant level.

recorded and measured amongst the handicraft workers was comparatively higher than that in the studies referred to above.

While comparing the three postures, it was revealed that a *moderate* degree of discomfort (>4–7) was observed in the shoulders and lower back in the case of working in a squatting posture and in the neck, shoulder, lower back and calf in the case of sitting on the floor with stretched legs. However, a *moderate* degree of discomfort was observed only in the lower back region while the subjects were sitting on the floor with folded legs (Table 3). A *severe* degree of discomfort was not found in any of the sitting postures. The occurrence of *mild* discomfort in different body parts was more or less the same in all the sitting postures. This type of finding was also previously found in the study conducted on carpet weavers by Avais et al.[14] They pointed out that continuous sitting for knotting in an awkward posture leads to frequent backaches even at a young age.

The greater deviation of body joint angle imposes postural stress among the workers. The joint angle study observed that sitting on the floor with folded legs was less stressful than the other two postures. On the other hand, squatting had the greatest degree of deviations in most of the joint angles, particularly in the joints of the lower extremities. The high degree of flexion of the knees and the external pressure on the knees, especially in kneeling and squatting, are known contributors to knee complaints.[15–17] Zelle et al. [18] conclusively proved that the average maximal contact forces for each leg were 34.2% body weight during squatting and 30.9% body weight during kneeling. According to Gallagher,[19] squatting appears to be the least stable of the restricted postures.

The EMG study of the shoulder and back muscles of female craftworkers was performed in three sitting postures on a comparative basis. EMG records which were taken in normal sitting posture were taken as reference posture and the deviations of the EMG voltages in working postures from that of the reference posture were computed. For EMG studies, 10 subjects were randomly chosen from the selected female craftworkers. The surface EMG reflects the algebraic sum of electric muscle action potentials that pass within the recording areas of the EMG electrodes.[20]

The result of the EMG study of the shoulder muscle of the female craftworkers indicated that there was lesser stress on the shoulder muscle while sitting on floor with folded legs. This might be due to the fact that while sitting on the floor with folded legs, the workers had lesser shoulder abduction, as shown in Table 4, as well as lesser raising of the shoulder during work in comparison to the other two postures. A study by Kleine et al. [21] investigated the EMG changes in shoulder and back muscles for posture analysis in workers at visual display units and found that an increase in the activity of m. trapezius was partly related to a lifting of the shoulders to compensate a slight slumping of the back. In our study, m. trapezius showed increased rms values of EMG while working in a squatting posture and in sitting on the floor with stretched legs. The shoulder abduction was comparatively greater than that in sitting on the floor with folded legs.

On the other hand, the results of the EMG study of the back muscle indicated that the back muscle had lesser myoelectric activities due to lesser stress imposed on it while working sitting on the floor with folded legs posture, in comparison to the other two postures. It might be one of the reasons for the lesser BPD rating (Table 2) and lower prevalence of MSDs (Table 1) at the lower back region while sitting on the floor with folded legs than in that of the other two postures.

From the above results it appeared that working in a squatting posture is more strenuous than that of sitting on the floor either with stretched legs or with folded legs. This might be due to better stability of the body during sitting on the floor. Gallagher [19] stated that squatting appears to be the least stable of the restricted postures. The squatting posture had been considered as a remarkable lower extremity posture with a high postural load.[22–25]

During squatting high pressure is imposed on the knee joints of the workers. Cooper et al. [26] and Thambyah et al. [27] showed evidence that osteoarthritis and cartilage damage can occur in the knee as a result of frequent or high contact stresses. Squatting is a stressful posture during work and this might be due to the development of high pressure on the knee joint while adopting this posture. Kneeling or squatting places a high level of force on the knee. High force, when combined with repetition of movement further increases the potential for a knee injury.[28]

The results of the present study also revealed that there was lesser stress while sitting on the floor with folded legs than that of stretched legs. It might be because of better stability of the body during sitting with folded legs in comparison to sitting with stretched legs.

5. Conclusions

From the present study it has been concluded that while performing craftwork sitting on the floor with stretched legs and squatting are more strenuous and, therefore, more hazardous to health in comparison to the traditional sitting posture with folded legs, which was evident from the results of MSDs, BPD rating, joint angle study and EMG analysis. Hence, it may be suggested that craftworkers adopt a traditional posture to lessen work-related hazards as well as postural stress.

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