Intervention of Ergonomics in Hand Driven Cotton Spinning Operation

Dhananjay Ikhar dhananjayikhar@yahoo.com
Department of Mechanical Engineering
Datta Meghe Institute of Engineering Technology & Research,
Wardha-442001, India

Dr. V. S. Deshpande deshpandevs@rknec.edu
Principal, Ramdeobaba Kamla Nehru Engineering College,
Nagpur-440013, India

Abstract

Cotton spinning is an important operation in small scale and cottage textile industries in India. A large number of women workers in these industries perform cotton spinning task adopting squatting posture in traditional workshops. A Dutch Musculoskeletal Questionnaire (DMQ) was used to evaluate 40 operators regarding work related musculoskeletal disorders WMSDs. Among the operators, severe cervical and lumber joint problems along with knee, joint pains and shoulders were found more prevalent compared to other body regions. They were observed and evaluated with the Rapid Upper Limb Assessment (RULA) technique and their exposure to the WMSDs was assessed. Based on the problems found, a new workstation was developed and ten operators were asked to work in the same workstation. Certain aspects regarding the ergonomic evaluation for those workers are discussed in this study. It is revealed that the suggested workstation improves working posture and results in reduced postural stress on operators' bodies and, consequently, reduce prevalence of MSDs symptoms.

Keywords: Ergonomics Evaluation, Musculoskeletal Disorders, Workstation Design, RULA

1. INTRODUCTION

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[1]. Decades of research has identified certain physical workplace factors that increase the risk for MSDs. Perhaps nowhere is the problem of stooped and squatting postures of greater magnitude than in developing countries such as India [1]. An adaptation of such postures is frequently observed in small scale industries in India. Most of the manually energized operations in these industries are evident of such postures. An industry is identified in central India where operators are mostly women operators and 91% of them are suffering from WMSDs [2]. The majority of the work is performed on cotton spinning wheel by operator. The wheel is manually energized. It is hand-powered device for spinning cotton yarn from pressure clamp. Spinning operation is performed in a squatting position in which operators, rotate spinning wheel sitting down on the hard and flat surface with folded knees without any backrest. Figure 1 shows the details of posture adapted.

The task of rotating the wheel for cotton spinning is repetitive and continuous throughout 8 hours of working in a whole day. In this condition, the back is bent excessively and postures of different parts of body dramatically deviate from the neutral. Most of the experienced operators leave their jobs because of poor working conditions and musculoskeletal problems.

FIGURE 1: A typical working posture adapted in order to perform spinning operation

The ergonomic guidelines and principles are meant to provide an orientation towards the physiological and psychological needs of the operator. The design is essentially a compromise between the operators' biological needs, as determined by the ergonomics guidelines and physical requirements of the equipment [3]. Basically when one sits down on a hard surface without any back rest, the ischial tuber sites (inferior protuberances of the pelvic bones) acts as fulcra around which the pelvic girdle rotates under the weight of upper body [4]. This is the major cause of MSDs in women operators. It has been reported in ergonomics that squatting posture is very tiresome [5]. Ergonomics studies in industrial workers were many, but the specific study on the women operators working on the hand driven cotton spinning machine has not been carried so far. Hence the knowledge regarding their working posture, work intensity, rest pause is not available. Therefore, it was considered to carry out the issues of ergonomic study of women operators regarding WMSDs, LBDs aspects in small scale labor-intensive industry. From the literature review, ergonomic methods those can be applied to the concerned activity are identified. An ergonomics investigation has been conducted towards present mode of spinning operation. The present study had the following objectives:

1. To investigate the prevalence of musculoskeletal problems in operators' population
2. To improve the working condition by suggesting new workstation
3. To assess the working condition improvement

2. MATERIALS & METHODS

The present work is carried out in two phases.

2.1 Phase 1

A cross-sectional observational type of survey was conducted in spinning section of small scale labor-intensive workshops by name "Gram Seva Mandal" and "Magan Sangrahalay" in city Wardha, Maharashtra State. From both workshops, 40 woman operators in the age ranging between 18 to 60 years were randomly selected for the study by convenient sampling from volunteers after taking consent from them. To ascertain the effect of work posture, the qualitative assessment procedure was followed [5]. The Qualitative evaluation consists of the direct observation method and questionnaire survey. During the survey, it is observed that the operator adopts squatting posture sitting down on the hard and flat floor with folded knees without backrest which results in stress generated in trunk muscles and bones, affecting efficiency of the operator. Through direct observation, it was revealed that long term seated work had a cumulative load on the musculoskeletal structures, including the vertebral column, which was reflected in the form of high prevalence of discomfort and pain in different body parts. A Dutch Musculoskeletal Questionnaire (DMQ) was used for the assessment of work. The DMQ allows ergonomists and

occupational health professional to measure work-related musculoskeletal risk factors and symptoms in worker populations in a quick and standardized way [6]. The questionnaire seeks to obtain a simple representation of the relationship between work tasks and musculoskeletal symptoms. The DMQ includes background variables like age, gender, education, service in employment, work history. Besides this, task demands, musculoskeletal workload, psychosocial working conditions, health etc.are included. All 40 women participants were questioned and the relevant information on task performance, equipment, and working posture was obtained. The data collected through questionnaire reflects the health problem like MSDs, LBDs etc.

Job analysis indicated that spinning operation consisted of 7 tasks. Out of which most of the tasks are light & normal and hence not considered for the posture analysis. Further analysis shows that operator experienced bending stress & strain in body if raw cotton thread breaks during the spinning. Operator has to stop rotating the handle and use both hand for rejoining the thread for which they have to bend. Major tasks like rotating the spinning wheel, rejoining of thread are selected for further assessment. In these tasks, working postures were accessed by RULA technique [7]. In RULA assessment technique, a score is calculated for the Shoulder, Elbow, Wrist, Neck, Trunk and Leg movements during operation. The RULA score ranges from 1 to 4. Score 1 indicates the most neutral posture and score 4 shows the worst position. The combined individual scores for shoulder, elbow and wrist give score A and those for neck, trunk and legs give score B. Muscle use and force exerted in each task are attributed a score of 1 and 0, respectively, because they are static posture or highly repetitive without considerable loading. These scores are added to scores A and B to obtain scores C and D, respectively. Combination of scores C and D, called grand score (ranging from 1 to 7), shows the musculoskeletal loading associated with the operators posture. Low grand scores (1 or 2) indicate acceptable working posture (action level 1). For grand scores of 3 or 4, further investigation is needed and changes may be required (action level 2). Prompt investigation and changes are required soon for scores of 5 or 6 (action level 3). Finally, immediate investigation and changes are required for grand score of 7(action level 4).

Present Work routine is studied. Women operators having age group 18-60 year, carry out spinning task. As per normal routine, they work for 8 hours continuously in a whole day. The lunch period is approximately about half an hour. At first 3 hours they, continuously work without any single rest pause. The experiments revealed that, walking without load on horizontal place at 2-7 km/hr consumes 7.6 to 14.2 KJ/Min of energy. Thus energy consumption is within +-10% of the same activity for intra and inter differences. In spite of this, female factory workers expend 2980 Kcal/ day of the maximum energy to 1970 Kcal/day of minimum energy. However such kind of light effort tasks (for upper body work) aerobic requires are 2.6 Kcal/min or 185 watts [5]. Murrel (1965) states that the output of morning and at afternoon period decreases due to empty stomach that tends to nervous condition [3]. So these sedimentary female workers get fatigue at 1.30 PM that results in reduced cotton hanks production and thus they need pause for meal & rest. Later on they again start their work at 2 PM and work continuously till 5 PM. It is revealed that irrespective of their ages, output varies.

The existing plant layout was studied which indicates that sufficient gaps between spinning machine and the operators are provided. Sufficient space for accessories arrangement and leg relaxation was provided. However, the individual use of equipment in particular working area requires flexibility indeed providing freedom from individual variation from conventional norm acknowledges that female workers differ in physique i.e. anthropometric data.

Work environment was also studied with respect to illumination intensity and ventilation which occupied a wider importance during day time. Current illumination level at workstation is 450 lux approximately, which is enough for the workstation but not for some particular workplace [5].

The methods discussed above are incorporated in this study to perceive the correct ergonomics evaluation values which are needed for redesigning workstation to increase production and comfort values for women operators working on spinning machine.

2.2 Phase 2

In order to improve working conditions, a workstation was designed and constructed. To determine design specification of the new workstation, anthropometric data of women operators was collected. Table 1 shows the anthropometric data of female operators with 5^{th}, 50^{th} and 95^{th} percentiles. The 95^{th} percentile of the data has been selected for the workstation design as it fit the smallest and also the largest one in the workstation [5]. It seems obvious that to give maximum output with minimum strain, it is desired to use leg muscle power. Pedal power is a philosophical work which explores the full human potential inherent in the use of bicycle for work. The literature suggests scores of tasks which can be easily and effectively accomplished by pedal devices [12]. Mechanism similar to sewing machine which has significant use in India was preferred for new workstation. Pedal sewing machine has been studied thoroughly and the dimensions used in this lever crank mechanism were noted down. Power transmission system was fully depended on the four bar chain mechanism of sewing machine. It adapts class four bar chain mechanism. This mechanism is analyzed ergonomically and mechanically. For adapting this mechanism for cotton spinning machine, synthesis of mechanism was carried out with variations in transmission angle [13]. Finally, based on optimized transmission angle, new workstation was designed. Figure 2 shows newly designed workstation specifications. Spinning machine is mounted on wooden table top. Pedal was redesigned for better comfort of operator feet. Changes were made in existing sewing machine to reach the small operator and fit the large considering anthropometric data. Pulleys were redesigned to maintain velocity ratio 1:7.

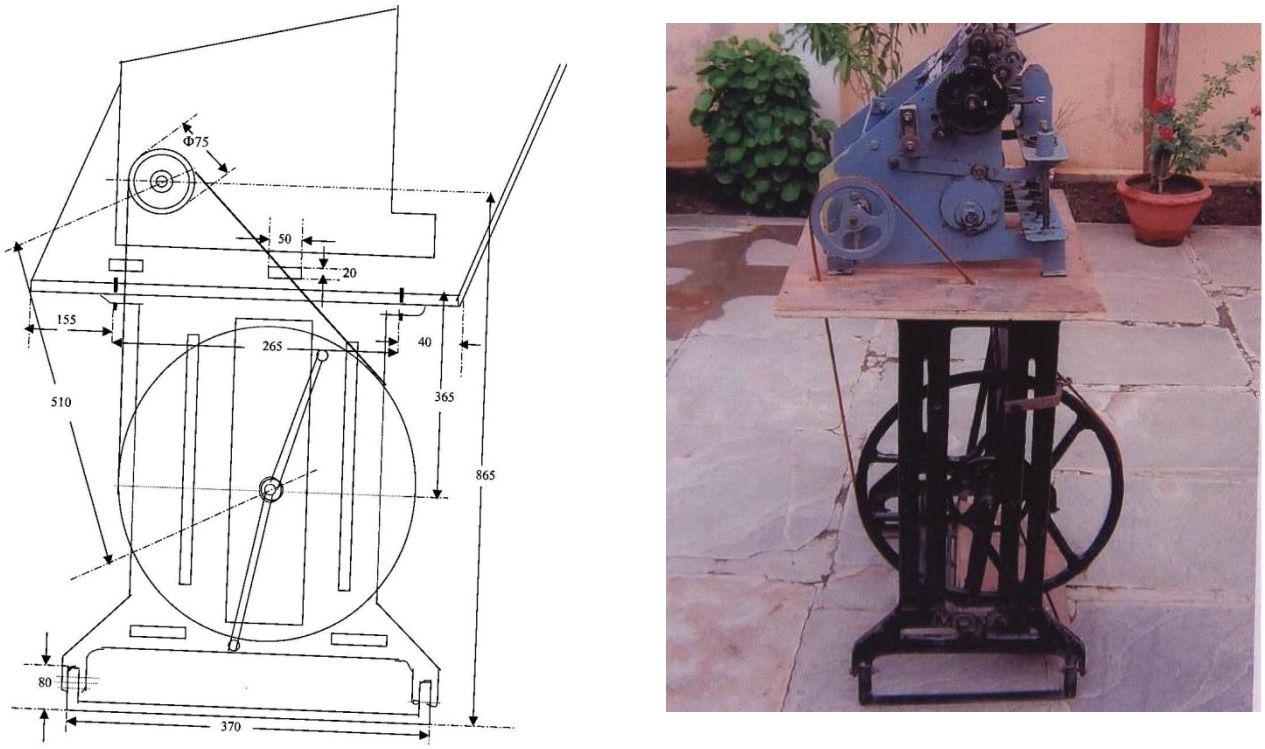

FIGURE 2: Specifications for New workstation design

Energy expenditure of an individual operator on conventional workstation and newly designed workstation was calculated. The amount of energy expended in doing physical work closely related to the amount of oxygen consumed, so the method of measurement attempts to assess this amount directly or indirectly. The radial pulse rate of individual worker was recorded as it is

simple, less time consuming and equally reliable method as energy expenditure advocated by Christensen [14]. The records were collected before, during and after work. The process was repeated for the operator working on pedal driven machine. Using relevant formula, energy expenditure values for ten operators were calculated. These values differed from operator to operator.

Body Dimensions (cm)	Female Subject under study (N=40)		
	5th	Mean	95th
Tibial Ht	41	44	48
Knuckle Ht	59	63	70
Elbow Ht	85	94	105
Shoulder Ht.	118	124	137
Stature	145	151	165
Func. overhead reach	54	57	62
Hip Breadth	34	36	40
Elbow to Fist Breadth	36	38	41
Front View	55	60	69
Side View	47	51	56

TABLE 1: Anthropometric Data of Female operators (N=40)

Working posture of operator for newly designed workstation was assessed by the RULA technique and the results were compared with the conventional working condition (squatting on the ground). Upon completion of each test, operators' perception about the new working condition was investigated.

3. RESULT

3.1 Phase 1

Table 2 shows the personal details of spinning operators that were participated in the study. The daily working hours of operators are long; about 57% of operators worked more than 8 Hr/day.

Age (year)			Work Experience (yr)			Weekly working Hours	
Mean	SD	Range	Mean	SD	Range	Mean	SD
38.5	8.96	18-60	8	4.69	1-18	48	1.35

TABLE 2: Details of women operator population studied (n=40)

RULA technique resulted as score of 7 for arm & wrist analysis (score A) and score 8 for neck, trunk and leg analysis (score B) for the task of rotating the spinning wheel. From these, final grand score for the task is found out to be 7 which need action level 4 attention i.e. immediate investigation and changes are required in existing workstation. For the other task that is rejoining of broken thread, the grand score is found to be 5 which leads to action level 3 i.e. prompt investigation and changes are required in existing workstation. Table 2 shows the RULA scores in different tasks of spinning operation while working on the suggested mechanism and in the conventional posture.

3.2 Phase 2

In all tasks, grand scores of conventional working condition those working are higher than those of working on the pedal driven cotton spinning machine and consequently action levels were higher. In all, 33% women operators perceived their postures in the new working conditions as a

no change in comfort level. Figure 3 shows the general judgment of the operators about the new workstation in comparison to the traditional working condition. 57% of the operators found working on the pedal driven machine better than working in the traditional conditions.

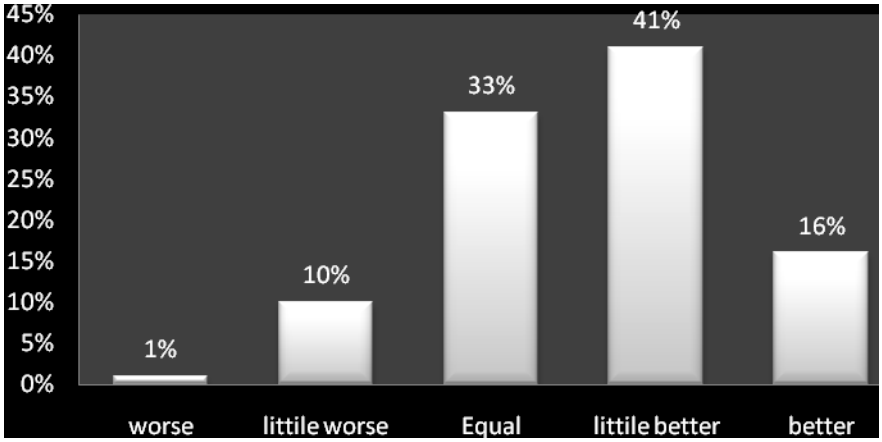

FIGURE 3: General Judgment of operators about working on new workstation compared to conventional working

3. DISCUSSION & CONCLUSION

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. This indicates that any interventional program for working condition improvement should focus on eliminating awkward posture of the mentioned body regions. A similar study regarding goldsmith working in awkward posture in India adopts ergonomic intervention to improve workstation design [15]. This study indicates that the workers by adopting awkward posture at work, most often suffer from MSDs particularly affecting the low back and neck region.

The literature had analyzed the dependency between occupational work performance and heart rate [16]. In our study, there was mean increase in pulse rate by 15 beats/minute from before work and after work recordings in a whole day. There was a progressive rise in pulse rate with time indicating physiological fatigue. But the maximum heart rate recorded while performing spinning activity was below 100 beats/minute which indicates that workload is light.

Similar studies at different workstations were also compared for the validation of the method adopted in this study. Intervening ergonomics especially RULA, in carpet mending operation in Iran were improved workstation posture noticeably [17]. RULA survey indicated that after the intervention, there was evidence of improvement of scores. Table 3 shows details. Working on the suggested mechanism body posture less deviated from neutral such that action level was reduced from 4 in conventional working condition to 2 in new working conditions. Working on the new workstation improved neck, trunk and leg postures reducing the risk of MSDs. Further investigation should be concentrated on improving the upper limb posture. Increasing the table height, as some operators suggested, may improve upper limb posture, but then to maintain optimal visual distance the inclination of neck and trunk may be increased and, therefore, should be taken into account. The results also demonstrated that there was a direct association between RULA risk level and prevalence rate of WMSDs with the significant associations.

Tasks	Working condition			
	Conventional		New workstation	
	Grand score	Action Level	Grand score	Action Level
Rotating an input wheel	7	4	4	2
Rejoining of broken thread	5	3	3	2

TABLE 3: Working posture evaluation by the RULA technique in different tasks of spinning operation while working on the suggested mechanism and in the conventional posture

The operators participated in the second phase of the study found their working postures in the new condition good and reported comfort. They believed that the new working conditions were better than the traditional conditions. It indicates that the operators feel that the ergonomic intervention has improved their working postures. The working conditions of operators on cotton spinning machine especially the working postures need improvement. In this study, the working posture was improved by developing a new workstation. Although the workload was light, incidence of musculoskeletal pain was high Indicating that there were definite ergonomic factors responsible for the musculoskeletal problems. So based on the observations made in this study it could be concluded that there is an ample scope for improvement in workstation design, work environment, plant layout and working conditions in small scale industries under study from ergonomic view point with the objective of providing maximum comfort to the women operators for promotion of their health and well being and consequently enhancement of productivity.

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