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Ergonomic evaluation of weaving activity and ergonomic intervention for drudgery reduction of weaver

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ABSTRACT

Weaving is a common enterprise performed predominantly by women of Assam. Weaving is done mainly for preparation of articles both for household and commercial purpose. Fly shuttle loom is an improved loom used by weavers for higher production as compared to traditional hand loom. It was observed that seating arrangement was fixed with the loom is not comfortable to the fly shuttle weavers. An attempt was made to design an improved ergonomically weaving chair for the fly shuttle weavers (40 inches- height of the loom) for enhancing greater efficiency. For the testing effectiveness of the ergonomically designed weaving chair, the physical fitness of weavers, physiological workload, muscular and postural stress involved in the weaving activity by using both fixed and ergonomically designed chair were assessed. Rating of Perceived Exertion (RPE) was calculated using Borg's 5 point rating scale. Body Map was used to identify pains in different parts of the body. Twenty rural women without any health problem in the age group of 20-45 years were selected for this experimental study. Lean Body Mass (LBM) of the respondents was 30.60 kgs. Aerobic capacity (VO_2) and fat percentage of the women were found to be 31.80 (ml. kg^{-1}. min^{-1}) and 20.20. About 55 per cent of the respondents were having very good physical fitness. Results indicate that working heart rate and energy expenditure of the respondents while using fixed seat were 98.36 $b.min^{-1}$ and 6.87 kJ/min and ergonomically designed weaving chair were 90.44 $b.min^{-1}$ and 5.67 kJ/min, respectively. On the basis of average and peak heart rate and energy expenditure, the physiological workloads of weaving in both the conditions were categorized as 'light'. Average rating of perceived exertion (RPE) was 3.2 in fixed seats and ergonomically designed chair 2.5 in in 5 point scale. The angle of deviation of the weavers were 4.35^0 in fixed seat and 3.80^0 in ergonomically weaving designed chair. The incidences of musculo skeletal problems in different parts of the body were observed to be 'severe' to 'moderate' in fixed seat and 'mild' to 'very mild' while using improved ergonomically designed weaving chair. And intensity of pain was decreased in ergonomically designed weaving chair. Use of fixed seat compelled the weavers to adopt awkward postures while performing weaving activity. Ergonomic interventions of such an ergonomically designed improved chair can enhance work efficiency comfort level of the fly shuttle weavers.

INTRODUCTION

Weaving is the most important cottage industry next to agriculture in Assam and is a common enterprise performed predominantly by women of Assam. The handloom products are well known for their glorious heritage, artistry and fine workmanship. Weaving is done mainly for preparation of articles both for household and commercial purpose. Fly shuttle loom is an improved loom used by weavers for higher production as compared to traditional hand loom. The traditional skill of indigenous weavers and their deep perception of beauty in color and design have been acclaimed in and outside the country. The handloom products of Assam particularly *gamosa, mekhela chador, saris, table mat, napkins* etc. are in great demand but they require a long time to weave and are very expensive. They spent 5-6 hours a day in their loom for weaving. It was observed that seating arrangement was fixed with the loom (Plate 1) is not comfortable to the fly shuttle weavers to weave the products. According to Mahata (2005) ergonomics is the science on how to fit the task and working environment to the worker using scientific data or adoption of job and work place to the worker by designing tasks within the workers capabilities and limitations. An ergonomically designed workplace and system result in work efficiency, health and safety, comfort and ease of use and job satisfaction. Ghosh and Barman (2009) concluded that if work station is not designed ergonomically, workers may expose to undue physical stress, strain and over exertion, including vibration, awkward postures, forceful exertions, repetitive motion and heavy lifting-all of which can lead to musculoskeletal disorders (MSDS). An attempt was made to design an improved weaving chair (Plate 2) for the fly shuttle weavers (40 inches- height of the loom) for enhancing greater efficiency. For the testing effectiveness of the ergonomically designed weaving chair, the physical fitness of weavers, physiological workload, muscular and postural stress involved in the weaving activity by using both fixed and ergonomically designed chair were assessed.


Plate 1 : Conventional stool


Plate 2 : Improved weaving chair

MATERIAL AND METHODS

Participants:

Twenty subjects without any health problem in the age of 20-45 years were selected through purposive sampling method from Jorhat district of Assam. The subjects who were actively involved in activity of weaving were selected.

Reference period:

Reference period of the study is 2010-2011.

Body composition :

Estimation of Lean Body Mass (LBM) was determined from the skin fold thickness at four sites, *i.e.* biceps, triceps, subscapular and superilliac muscles with the help of skin fold calipers by using the methods prepared by Durnin and Rahman (1967). BMI or Quetlet's Index

Weight (kg/height^2 (m) was used to classify the body types as Ectomorph (<20), Mesomorph (20-25) and Endomorph (>25).

Determination of physical fitness :

Physical fitness of the participants was determined by using step-test method. The test was administered according to the designed protocol; working and recovery heart rate was monitored continuously by using Heart Rate Monitor (Polar Sports Tester – PE 4000) during all the three phases. The stepping exercise (30 steps/min.) was continued for a maximum of 5 minutes. The recovery pulse rate was recorded while the subject was sitting on a chair. PFI was measured with the following formula:

PFI = Duration of stepping in sec / Sum of 1st, 2nd and 3rd min. recovery pulse count x 100

The scores thus obtained were interpreted using the Physical Fitness Index (PFI) and categorized as poor, low average, high average, good, very good and excellent the scale proposed by Saha (1996) was used.

Prediction of VO_2 max :

Aerobic capacity is considered to be one of the more reliable measures for determining an individual's capacity for doing physical work. VO_2 max was measured on the basis of step test scores (PFI) with the following formula.

VO_2 Max ($ml/kg^{-1}min^{-1}$) = 0.377 x step score (PFI) – 12.767

For categorizing the physical fitness of the respondents on the basis of VO_2 Max, the scale proposed by Saha (1996) was used.

Evaluation of physiological workload :

The study was conducted in the Weaving shed where loom is located. For the experiment, Weaving was restricted to 30 minutes only. All the subjects were allowed to perform weaving for same duration in the same location by using same tool and in the same work station. The experiment was conducted with three replications for each subject for accuracy. The Physiological workload was determined by recording the Heart Rate (HR) responses while weving by using Heart Rate Monitor. The heart rates at the rest and recovery periods were recorded. The Energy Expenditure (EE) was estimated from the heart rate responses of the participants during the weaving activity by using the formula of Varghese *et al.* (1994). The physiological workload was categorized as very light, light, moderately heavy, heavy and very heavy on the basis of heart rate and energy expenditure values of the participants.

The energy expenditure was estimated from the heart rate responses by using the formula of Varghese *et al.* (1994). The formula is given below:

Energy Expenditure ($kJ.min^{-1}$)=0.159xHR ($beats.min^{-1}$)-8.72

The Physiological workload was determined as per the workload classification developed by Varghese *et al.* (1994) (Table A).

Table A : Physiological workload index

Physiological workload	Heart rate (beats/min)	Energy expenditure (kJ/min)
1. Very light	Upto 90	Upto 5
2. Light	91-105	5.1-7.5
3. Moderately heavy	106-120	7.6-10.0
4. Heavy	121-135	10.1-12.5
5. Very heavy	136-150	12.6-15.0

The heart rates of the subjects were recorded at rest, during work and after the completion of work (recovery). The Total Cardiac Cost of Work (TCCW) and the Physiological Cost of Work (PCW) were also worked out. The Total Cardiac Cost of Work (TCCW) is the sum of Cardiac Cost of Recovery (CCR) and Cardiac Cost of Work (CCW).

Rating of perceived exertion (RPE) :

Subjective perception of exertion is a method for providing reliable information for the assessment of workload. Subjective rating of feeling of tiredness was studied by using the Rating scale of Perceived Exertion (RPE) developed by Varghese *et al.* (1994). The exertion perceived by the participants before and immediately after completion of activity was recorded and categorized as very light, light, moderately heavy, heavy and very heavy based on the scores 1, 2, 3, 4 and 5, respectively.

Postural analysis :

Postural analysis was considered during the performance of pounding activity with Dual Inclinometer (Dualer IQ TM) The spinal curvature of the subjects in sitting position at lumbo-sacral region (flexion and extension). The ranges of motion at the lumber region joint were recorded for each subject during the weaving activity.

Musculo-skeletal problems :

The subjects were selected purposively without any health problems before starting the experiment. Incidences of musculo-skeletal problems of the subject were identified by using the body map indicating different parts of the body after the completion of activity was used to record the intensity of pain is different body parts *viz.*, 5, 4, 3, 2 and 1 for the intensity of pain as very severe, severe, moderate, mild and very mild, respectively.

Environmental parameters :

Environmental conditions such as temperature and humidity level were recorded during the activity *i.e.* in the beginning, during the activity and at the end of the activity by using thermo- hygrometer. The data were recorded at 15 minutes interval. The duration of the activity was 30 minutes and activity is performed in the weaving shed.

Statistical analysis :

Mean, standard deviation, and correlations were worked out for different parameters and data were interpreted accordingly.

OBSERVATIONS AND ANALYSIS

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Details of activity :

Weaving is the most important cottage industry next to agriculture in Assam and is a common enterprise performed predominantly by women of Assam. The handloom products are well known for their glorious heritage, artistry and fine workmanship. The handloom products of Assam particularly are in great demand but they require a long time to weave and are very expensive. They spent 5-6 hours a day in their loom for weaving. It was observed that seating arrangement was fixed with the loom is not comfortable to the fly shuttle weavers to weave the products. The women were assessed in the normal environment. The data on physical characteristics revealed that the average height and weight of the respondents were 153 cm and 46 kg, respectively. Mean Lean Body Mass (LBM) of an average Assamese woman was 30.60 kg. Aerobic Capacity (VO_2 Max) was found to be 31.80 ($ml.kg^{-1}min^{-1}$). Fat percentage of the respondents was found to be 20.20.

Determination of physical fitness index (PFI) :

Physical fitness index (PFI) of the respondents assessed by using step stool ergometer revealed that most of the respondents were (55%) were having 'very good' physical fitness followed by 25 per cent in 'below average' category. Only 20 per cent women had 'good' physical fitness. Data on body type showed that majority of the respondents belonged to 'Ectomorphic' (62%) group with slender body type followed by 'Mesomorphic' (25%) and 'Endomorphic' (13%).

Classification of physiological workload based on average and peak heart rate :

The physiological workload of weaving was assessed on the basis of heart rates (beats/min) and

Table 1 : Physiological workload while weaving in conventional seat and ergonomically designed chair

Physiological parameters		Conventional seat	Ergonomically designed chair
Working heart rate ($beats.min^{-1}$)	Average	98.36	90.44
	Peak	111	96.20
Energy expenditure	Average	6.87	5.67
($kJ.min^{-1}$)	Peak	8.93	6.57
Classification of workload	Average Peak	Light	Light
		Moderately heavy	Moderately Heavy
Cardiac strain index		16.03	12.99
Rating of perceived exertion	(RPE)	3.20	2.5
TCCW (beats)	Average	780.36	752.96
PCW ($b.min^{-1}$)	Average	22.77	20.25
Environmental parameters			
Humidity (%)	Average	56	46
Temperature (°C)	Average	31.82	32.22

energy expenditures (kJ/min) values as classified by Varghese *et al.* (1994). The average working heart rate values while weaving in existing seat and ergonomically designed chair were found to be 98.36 $b.min^{-1}$ and 90.44 $b.min^{-1}$, respectively. There was a differences between peak heart rate values of weaving in existing seat (111 $b.min^{-1}$) and ergonomically designed chair (96.20 $b.min^{-1}$) (Table 1). The resting heart rate values of rural weavers 80 $b.min^{-1}$. The corresponding energy expenditure values were 6.87 $kJ.min^{-1}$ and 5.67 $kJ.min^{-1}$, respectively while weaving in existing seat and ergonomically designed chair. The peak energy expenditure values were found to be little higher while weaving in existing seat (8.93 $kJ.min^{-1}$) and ergonomically designed chair (6.97 $kJ.min^{-1}$).

The physiological workload of weaving in both the seats was categorized as 'light' from the average working heart rate and energy expenditure values. The activity of weaving in existing seat and ergonomically designed chair were found to be 'moderately heavy 'based on peak heart rate and energy expenditure values.

Further perusal of Table 1 reveals that the Cardiac Strain Index of the weaver was 16.03 while weaving in existing seat and 12.99 ergonomically designed chairs. The average total cardiac cost of work (TCCW) were 780.36 beats and 752.96 beats and physiological cost of work (PCW) were observed to be 22.77 $b.min^{-1}$ and 20.25 $b.min^{-1}$, respectively while weaving in existing seat and ergonomically designed chair.

Rating of perceived exertion :

Perceived exertion of respondents was assessed by using 5 point modified RPE scale. Data revealed that average rating of perceived exertion was 3.20 in existing seat and 2.5 in ergonomically designed chair 5 point scales indicating that the existing seat more exhaustive compare to in improved one (Table 1).

Incidence of musculoskeletal problems :

Incidences of musculoskeletal problems were identified by using 5 point scale to record intensity of pain in different parts of the body *viz.,* 5, 4, 3, 2, 1 as very severe, severe, moderate, mild and very mild, respectively. The weavers felt pain in shoulder joints, upper back, upper arm, lower arm, low back, wrist/hands, hips/buttock, upper legs/thigh and knees in both the existing and improved chairs but it was observed that intensity of pain was decreased in improved chairs while weaving (Table 2).

Postural stress and range of motion (ROM) :

Postural stress was studied on the basis of total spinal range of motion of lumbo-sacral region while weaving. The ranges of motions were recorded with the help of Dual Inclinometer. Data regarding total spinal range of motion shows that the angle of deviation of the participants while weaving in existing seats average (4.35^0) and improved ergonomically designed chair (3.80^0).

Environmental parameters :

The temperature and relative humidity level was recorded thrice in every 15 minutes during the weaving activity. The mean temperature was found to be 31.82°C

Table 2: Incidence of musculoskeletal problems

Body parts	Conventional seat	Ergonomically designed chair
Shoulder joint	4.6	3.5
Upper back	4.5	3.1
Upper arm	4.0	3
Lower arm	3.8	2.4
Low back	4.1	2.8
Wrist/hands	2.6	2.2
Hips/Buttocks	4.3	2.7
Upper legs/thigh	2.4	1.8

Table 3 : Postural analysis of the respondents

Parameters	Conventional seat	Ergonomically designed chair
Angle of normal curve	208.55^0	205.42^0
Angle of bend	212.90^0	209.22^0
Angle of deviation	4.35^0	3.80^0

and 32.22 °C mean relative humidity (RH) was observed to be 56 per cent and 46 per cent (Table 3).

Conclusion :

The foregoing study highlights that the physiological cost of weaving was a 'moderately heavy' activity based on average heart rate and energy expenditure values. Ergonomically designed weaving seat with improved work station enhance the work efficiency and comfort of the weavers. Further, it reduces the occurrences of musculoskeletal problems and postural stress of weavers. Thus, ergonomic intervention at workplace enhances work efficiency, health and safety and comfort of the weavers at work place.

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