ORIGINAL ARTICLE

AN ERGONOMIC APPROACH FOR DESIGNING A SEAT FOR FISH PROCESSING WORKERS

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ABSTRACT

The present study aimed to design a sitting stool for fish processing worker to reduce the postural stress during work. The study was conducted on 74 male and female fish processing workers selected randomly. The Musculoskeletal Disorder (MSD) of the subjects was assessed by the modified Nordic Questionnaire method. The body joint angles were measured by a digital goniometer. The results revealed that MSD was highly prevalent in lower back region in both male (78.57%) and female (93.47%) workers. The results of body joint angles suggested a high degree of forward bending during work. Efforts were made to design a sitting stool considering the human factors of the users to reduce the postural problems. The stool was designed by considering 5th and 95th percentile values of different anthropometric dimensions of the male and female workers. Paired comparison tests were employed to determine optimum dimensions of the stool for ensuring the compatibility of the physical characteristics of the stool with human body. From the results of paired comparison test and anthropometric characteristics of the users, physical dimensions of the sitting stool were settled for final designing. From the results, the height of the stool was determined separately for male and female workers. In the suggested design the height of the seat was 25cm for male and 20cm for female where the length and depth of the seat were 40cm and 32cm respectively for both sexes.A mechanical system was incorporated in the design so that the same stool could be used by the male and female workers. Subjective evaluation indicated that most of the subjects (>75%) rated the seat as good or very good. The joint angle study with suggested seat showed improved working posture.

***Key words**: Fish processing, MSD, Seat design, postural stress, anthropometric dimension.*

INTRODUCTION

A large number of Indian populations involved in fishing. Fish processing is an important step before marketing. Fish processing workers may face a lot of work related health hazards due to various reasons. Many efforts have been made for ergonomic solutions of different problems of the workers of fishery occupation[1]. About 28% of fisherman had experienced at least one injury, of which half caused more than one day absence, while 14% had a near drowning experience[2]. The most common causes of accidents among hunters are falling from the top deck (71.0 %), and injury during transport and handling equipment (44.0%), and trading of fish (26.4%). They also shown that most of the fishermen in Alexandria city (62.9%) suffering from nervous high pressure[3]. About 52% fishermen were suffering from back pain and 38% had muscle cramps. All the fishermen experienced one or the 4 other health problems related to work[4]. In a surveyon southeastern US commercial crab fishermen some occupational stressors were identified. The five most physically strenuous tasks and conditions as rated by fishermen were pulling pots by hand, rough weather or rough water, unloading withoutmechanical assistance and long work days. Development and testing of ergonomic interventions is ongoing[5].

In West Bengal State (India) a large number of workers are involved in fish processing work. They have to work for a long time in the work place. In most of the time they have to work under time pressure also because sometimes the management ask them to finish the work within a stipulated time. Further, they used to do it in squatting posture for a long time, which leads to discomfort in different segments of the body. In the present study efforts have been made to evaluate the work related health hazards of the workers during performing fish processing tasks and to design a sitting stool from the view point of ergonomics. As the sitting stool was suggested to design according to the body dimensions of the user population, those may be helpful for reducing many of the occupational hazards and physiological cost and at the same time the productivity may be enhanced. The seat may be used by a large number of fish processing workers in the coastal areas of West Bengal State as well as other parts of India.

METHODS

Selection of site and subject: The study was conducted on 74 fish processing workers of which 28 subjects were male and 46 subjects were female having age 18 to 50 years. The subjects were selected by using random sampling method From different fish processing organizations located at Digha, a coastal area of PurbaMedinipur district of West Bengal, India. Ethical approval and prior permission was obtained from institutional Ethics Committee before commencement of the study and the study was performed in accordance with the ethical standards of the committee and with the Helsinki Declaration.

Measurement of anthropometric dimension: Anthropometric measurements were taken from the subjects following standard technique and appropriate land marks. Body mass index (BMI) was calculated from height and weight of the subject.

Evaluation of Musculo-skeletal Disorder: Themusculoskeletal disorder of the subjects engaged in fish processing work was assessed using modified 'Nordic' Questionnaire[6]. Subjects were interviewed with modified questionnaire prepared in local language (Bengali).

Joint Angle: in working and normal erect posture of different joint angle of the body e.g. shoulder, elbow, wrist, hip, knee and ankle angles were measured by a goniometer.

Evaluation of existing seat: Different physical dimensions of existing seats were measured. Then the drawback of the existing seats was identified by subjective evaluation.

Development of design concept: To overcome the drawbacksof the existing seat design concepts were developed.

Preparation of prototype model: On the basis of design concept some prototype models of the seat were prepared.
Psychophysical analysis: The behavioral pattern of the workers during using the different prototype models of the sitting stool were studied by paired comparison tests[7].

Design and Fabrication: From the result of paired comparison tests and anthropometric dimensions of the users the design characteristics of the sitting stool were finalized.

Evaluation of redesigned sitting stool: The effectiveness of the redesigned sitting stool was evaluated by subjective evaluation and the study of joint angles.

Statistical analysis of data: To identify the causative factors on the occupational stress of the fish processing workers, data analysis had been made with the help of a software package on 'STATISTICA' (version 6.0) and Microsoft Office Excel 2007. The mean and standard deviation was calculated for all the recorded data. *T-test*of different parameters had also been done. Chi-square test was used for comparison of categorical variables.

RESULTS AND DISCUSSION

The physical characteristics and age of the subjects were shown in Table 1 according to the gender of the subjects. The result revealed that the mean values of BMI of both male and female were within the normal range.

Table 1: Mean±SD of age and physical parameters of male and female fish processing workers

Parameters	Male (n=28)	Female (n=46)
Age (year)	33.14±14.08	34.55±12.59
Height (cm)	165.0±4.48	153.0±12.72*
Weight (kg)	55.57±8.67	51.83±18.51
BMI (kg/m^2)	20.85±4.48	22.12±3.46

Table 2: Frequency (f) and percentage (%) of MSDs in different body parts of both male and female fish processing workers

Body Segment	Male (n=`28)		Female (n=46)	
	Frequency (f)	Percentage (%)	Frequency (f)	Percentage (%)
Neck	16	57.14	25	54.35
Shoulder	14	50.00	27	58.70
Elbow	6	21.43	7	15.22
Wrist	4	14.29	8	17.39
Upper Back	16	57.14	25	54.35
Lower Back	24	85.71	43	93.47
Hip	20	71.43	38	82.61
Knee	16	57.14	30	65.22
Feet	4	14.28	11	23.91

The prevalence of musculoskeletal disorders (MSDs) of both male and female fish processing workers was studied by modified Nordic Questionnaire technique and the result has been presented in Table 2. The results revealed that the workers performing fish processing tasks reported to have MSD in lower back, hip and knee, which might be related to their postural pattern as well as duration of work in awkward posture. Long term adoption of bend and twist posture was associated with postural stress. Investigation suggested that bending and twisting of back awkwardly and working in same position were both significantly associated with prevalence of lower back problem and both were judged by workers to be the most problematic job factors contributing to pain and injury[8,9].

A significant association of awkward posture with back pain and the prevalence of lower back problems was significantly increased with work tasks described as “bending or twisting back in awkward way” [10].

From the results (Table 9) it was noted that some of the body joint angles, e.g., hip, knee, elbow and wrist angles were sharply deviated from that of the reference position, i.e., normal erect posture in relaxed condition. Those joint angles showed high extent of flexion in working condition.

Those deviations of joint angles for a long time lead to the development of joint pain during work. A free posture allows higher static force exertion capacity compare to stabilized posture in which restriction are typically imposed on the postures that can be assumed[11].

Designing of a sitting stool: In the fish processing units, most of the workers performed their tasks in squat sitting posture. Only a few workers used low height wooden block or brick as a support for the hip while working in sitting posture.

There were some drawbacks in the design of the existing seat, that is, in the wooden block from the view point human factors. For example, the main problem of this wooden block was that the height of the wooden block was very low. It would not support the hip properly. Therefore, the workers were required to bend for a long time while performing the task with this stool, and thus caused biomechanical stress in different bone joints which might produce pain different body segments.

Table 3: Mean ±SD of physical dimensions of different existing sitting stools

Parameters	Mean ±SD	Range
Height (cm)	13.43±3.09	9.1-17.5
Length(cm)	33.48±2.99	29-38
Depth(cm)	22±2.00	2-25

Table 4: Mean and Percentile values of different body dimensions of fish processing workers

Measurement	Male (Mean ± SD)	Female (Mean ± SD)	Male		Female	
			5th	95th	5th	95th
Floor to popliteal height	42.64±1.18	39.05±1.00*	41.00	44.29	37.41	40.70
Hip to popliteal length	45.13±1.86	42.74±2.49*	43.49	46.78	41.10	44.39
Hip breath	39.51±1.11	40.26±1.34*	37.87	41.16	38.62.	41.91

To overcome the above problems, an effort has been made to modify the design of the seatingstools considering ergonomic principles. To modify the design of the sitting stools the following steps were undertaken.

Evaluation of existing sitting stools: Theexisting sitting stool was evaluated by the subjective

Body Dimensions: Mismatches betweenhuman anthropometric dimensions and equipment dimension are known to be a contributing factor in discomfort, accidents, biochemical stress, fatigue, injuries, cumulative traumas and decrease productivity. Anthropometric data are essential in order to design safe and efficient workplace, equipment and tools[12, 13].

assessment as well as by some objective measurements from the view point of ergonomics. Ten existing models of sitting stools were collected from the workers and their physical dimensions were studied. There was an appreciable variation in physical dimension of the sitting stool as shown in Table 3.

From Table 4 it was noted that there was a significant difference in different body dimensions ($p<0.001$) between the sexes. The percentile values (5th and 95th) of the body dimension were computed which were taken for designing a seating stool for the workers engaged in fish processing unit.

Designing of a sitting stool:

Design concept: A sitting stool with proper dimension may reduce the problems of awkward working posture during performing fish processing work. The dimensions of the seat should match with the percentile values of the anthropometric dimensions of the users. The most important was the optimization of the height of the seat. The design should satisfy the differences in body dimensions between male and female workers. In the proposed design an arrangement should be made so the same stool can be used by both male and female workers.

Preparation of prototypes for sitting stools:
For selecting the suitable height and other dimensions of the seat for male and female workers some prototype models (M1, M2, M3, M4 and M5) were made. The physical characteristics of different prototype models have been shown in Table 5.

Testing of prototypes by paired comparison test

Those prototypes were given to the workers and asked to perform the tasks. They were requested to compare those prototypes in different combination pairs (e.g.; M1:M2, M1: M3, M1: M4, M2:M3 etc) and to select a score from an eleven point scale (+5 to -5) for each of the pair. The subjective assessment for differentphysical characteristics of the seat, viz., height, length and depth was performed with those prototypes. From the raw scores given by the subjects the resultant scores foreach prototype model were computed.

The resultant scores were plotted in an eleven point scale as shown in Figure 1. From the results of the pair comparison test and anthropometric dimensions of the workers different design characteristics of the sitting stool was selected. The following table (Table 6) shows the criteria for selecting different characteristics of the sitting stool.

Table 5: Physical dimensions and other criteria of five prototype models of sitting stools

No of prototype model	Height of the seat (cm)	Length of the seat (cm)	Breadth of the seat (cm)
M1	10	40	30
M2	20	30	35
M3	25	45	40
M4	5	50	25
M5	15	35	20

Table 6: Design criteria and dimensions for modified seating stool

Dimensions of seating stool	Subjective preference score/ anthropometric dimension	Final dimension
Height	Best value: for male model M3; For Female model M2	Male -25cm Female- 20cm
Length	Best value: model no. M1 95th percentile value of hip breath	40cm
Depth	Best value: model no. M1 5th percentile value of buttock - popliteal length	32cm

In the proposed design the height of the sitting stool was increased from that of existing one. It was selected from the height of the prototype M3 for male subjects and from the height of the prototype M2 for female subjects. It was chosen as the best prototype model for this criterion during performing paired comparison test. The length of the prototype model M1 was preferred by users and the length of sitting stool was settled as 40cm. The selected length was close to the 95th percentile value of hip breadth of the users. The depth of the seat was selected on the basis of 5th percentile value of buttock to popliteal length of the users with a negative clearance of 10 cm. After clearance value it became 33cm for male and 31 cm for female approximately. To make compromise between two sexes the depth was fixed at the value of 32cm. The dimension was also confirmed from the result of pair comparison test. The prototype model M1 secured the highest score for both male and female subjects. The value of the depth of m1 was 30 cm,which was close to the selected value.

It appeared from the results that the length and breadth of the sitting stool may be the same for male and female workers, as preferred by the subjects of both the genders. However, the preferred height of the seat was different in male and female subjects. Therefore, instead of suggesting two separate stools for males and females, a composite seat with two stage adjustability was proposed. A simple whole and lock arrangement was employed in the design, so that both male and female workers could use the same seat during work. The male worker could increase the seat height by the simple locking arrangement. The redesigned sitting stool for the fish processing workers has been shown in Figure 2 and Figure 3.

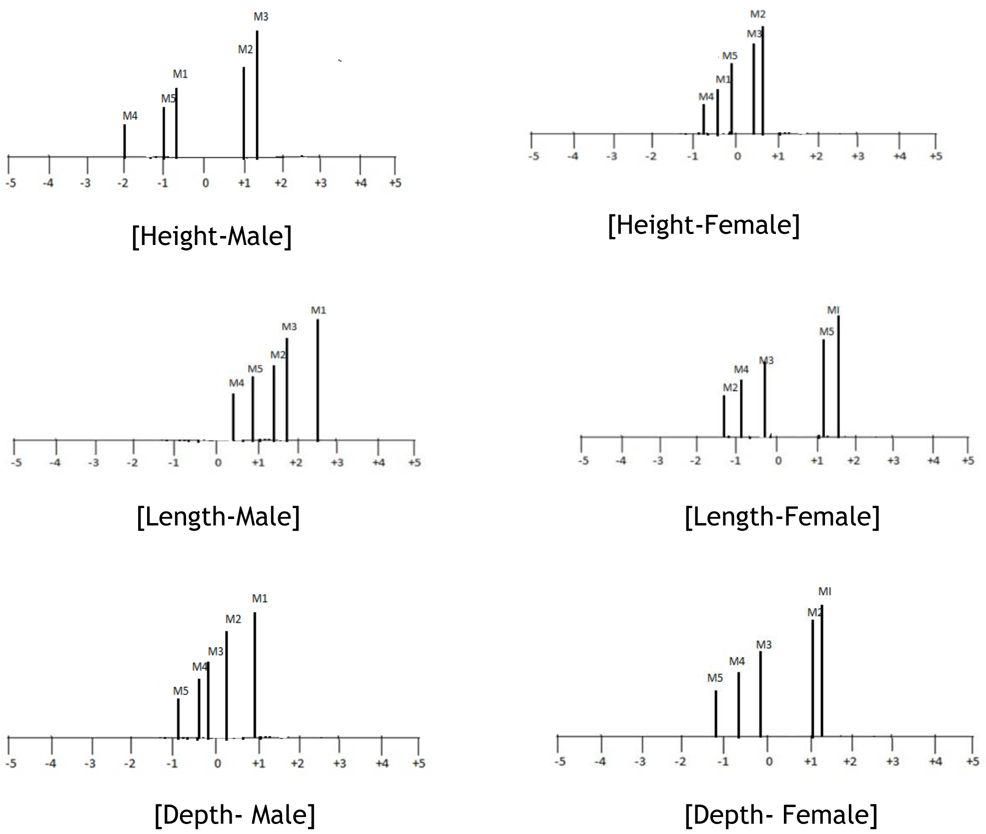

Figure 1: stimuli space of different models of stools with different height, length and breadth [pair comparison test in male and female subjects]

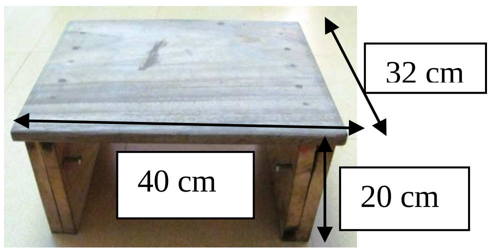

Figure2: Final designing of the sitting stool for female fish processing workers

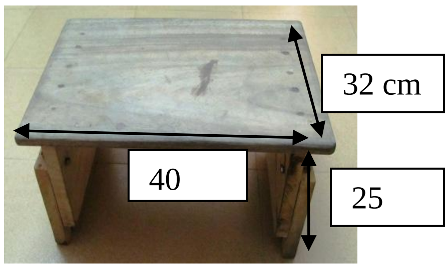

Figure3: Final designing of the sitting stool with extended height for male fish processing workers

Evaluation of redesigned sitting stool:

The effectiveness and acceptability of the modified design of the sitting stool was evaluated.
The following studies were employed.

Subjective study: The workers were given the redesigned sitting stool for performing their work and to express views regarding the comfort, easiness of work and acceptability in comparison to the existing sitting seat (wooden block). The subjects were asked to grade it as “bad”, “fair”, “good” and “very good”. The results of this study showed that most of the users expressed it as “good” (66.67%). Some of the workers categorized it as “fair” (20%). About 10% and 3.33% of the workers graded as “very good” and “bad” respectively (Table 7). Therefore, the results subjective assessment was in favour of modified sitting stool.

The prevalence of musculoskeletal disorder, while using redesigned sitting stool and the existing seat, was studied and a comparison was made between them (Table 8). From the results it was observed that the prevalence of pain/ discomfort in different segments of the body was comparatively lower during the use of modified model than that of existing seat. x2 – test was performed to find out the level of significance in the difference of subjective response between existing and redesigned seat. In case of male workers it was noted that the prevalence of problems in lower back ($p<0.05$) was significantly lesser during the use of modified sitting stool than that of existing one. Whereas, in case of female the prevalence of pain in lower back ($p<0.001$) and hip ($p<0.01$) was significantly lower during use of modified sitting stool than that of existing seat. From the results it was revealed that the occurrence of discomfort or pain in other body segments like knee, upper back, neck, shoulder etc. were also lower during the use of modified sitting stool than that of existing seat. Thus the results indicated that the workers would be able to use the modified sitting stool with easy and lower degree of discomfort.

Joint angle study: The body joint angle study was performed with the recommended sitting stool and the existing seat in view to observe the postural changes in different parts of the body due to using the sitting stool. The joint angles measured in normal erect posture were taken as reference. The difference of the angles between the reference position and during using sitting stool was taken as deviation of joint angles. The shoulder, elbow, wrist, hip, and knee angles were studied with existing and recommended sitting stool for the said purpose and it was noted that the workers had better working posture in most of the joint angles when performing the tasks with recommended sitting stool. The hip angle was found improved (less forward bending of the body) while performing work with redesigned sitting stool in comparison to existing seat. Other joint angles alsoshowed lesser deviation while working with redesigned stool in comparison to existing one (Table 9).

Table 7: Subjective evaluation of modified sitting stool (n=74)

Grade	Percentage(%)
bad	3.33
fair	20
good	66.67
very good	10

Table 8: Percentage of occurrence of musculoskeletal disorder in different body segment of the workers during using existing and modified seating stool

Body segment	**Existing seating stool**		**Modified seating stool**	
	Male (n= 28)	Female (n=46)	Male (n=28)	Female (n=46)
Neck	57.14	54.35	50.00	50.00
Shoulder	50.00	58.70	35.71	37.50
Elbow	21.43	15.22	14.29	18.75
Wrist	14.29	17.39	14.29	18.75
Upper Back	57.14	54.35	42.86	43.75
Lower Back	85.71	93.47	50.00*	56.25***
Hip	71.43	82.61	42.86	43.75**
Knee	(57.14	65.22	35.71	37.50
Feet	14.29	23.91	14.29	18.75

*With respect toexisting seating stool * p<0.05, ** p<0.01, *** p<0.001*

Table 9: Mean±SD of joint angleof male and female fish processing workers working on existing (EM) and modified(MM) models of the seat.

			Female		Male	
			Right	**Left**	**Right**	**Left**
Shoulder	Joint angle (reference)		25.49± 6.84	25.43± 7.05	25.07 ±3.10	24.57± 3.27
	EM	Avg. Working angle	58.59 ±27.72	58.10±30.43	55.07 ±20.34	58.00 ±35.68
		Deviation of angle	27.12 ±26.72	27.12 ±26.72	30.00 ±20.09	33.43± 35.04
	MM	Avg. Working angle	56.12± 6.40	56.12 ±6.46	66.37 ±11.21	54. 5 ±11.96
		Deviation of angle	30.12 ±12.96	36.12 ±4.12	42.12 ±13.57	31 ±12.66
Elbow	Joint angle (reference)		163.33± 7.06	163.35 ±6.79	165.93 ±4.36	166.57±3.18
	EM	Avg. Working angle	117.88 ±36.60	103.76 ±38.89	118.86 ±46.98	96.87±43.79
		Deviation of angle	37.12± 39.21	48.67 ±43.94	47.07±46.36	46.50±53.34
	MM	Avg. Working angle	110.5 ±22.36	96.87 ±25.60	125.25 ±24.99	125.25 ±24.99
		Deviation of angle	30.12 ±12.99	68 ±26.19	41.87 ±25.01	41.87 ±25.01
Wrist	Joint angle (reference)		170.53± 8.98	170.41± 9.10	172.21 ±6.77	172.79 ±6.87
	EM	Avg. Working angle	140.92 ±37.96	159.05 ±27.66	147.07 ±38.65	158.57 ±26.36
		Deviation of angle	24.18± 37.25	9.27 ±26.44	25.14 ±38.65	14.21 ±26.33
	MM	Avg. Working angle	151± 25.82	163.5 ±16.15	159 ±26.01	162 ±16.80
		Deviation of angle	17.75 ±30.07	5.12 ±17.50	17.12 ±25.55	13.75 ±17.31
Hip	Joint angle (reference)		172.48± 8.92	172.86± 9.16	173.00± 5.48	173.86± 4.74
	EM	Avg. Working angle	57.87 ±9.37	58.37±10.25	53.36 ±30.31	59.86 ±40.20
		Deviation of angle	117.12 ±8.95	116.87± 9.59	119.64 ±29.38	114.00 ±40.18
	MM	Avg. Working angle	60.02 ±18.30	59.98 ±18.44	71.37 ±6.18	70.25± 5.31
		Deviation of angle	92.12 ±47.69	92.15 ±47.74	101.37 ±9.19	104±9.07
Knee	Joint angle (reference)		162.82 ±13.20	162.80 ±13.17	159.00±18.36	159.00±18.08
	EM	Avg. Working angle	57.62 ±7.15	56.12± 6.40	52.50 ±45.40	48.64 ±39.74
		Deviation of angle	110.75± 50.56	112.5 ±50.73	113.43 ±37.26	110.36 ±41.02
	MM	Avg. Working angle	40.70 ±10.55	39.47 ±11.29	85.12 ±12.68	86.75 ±11.23
		Deviation of angle	100.72 ± 8.63	99.73±8.75	69.75±26.79	67.75 ±27.60

CONCLUSION

It was noted that the use of redesigned sitting stool for performing fish processing work was effective to reduce the musculoskeletal disorders of the workers. The work posture was improved during using the redesigned seat. Another advantage of the design was that the same stool could be used by the male and female workers with a simple adjustment in height of the seat.

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