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Ergonomic design of garments furniture for Bangladeshi workers based on anthropometric measurement

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ABSTRACT
Garments industry is one of the biggest sectors in Bangladesh for earning foreign currency. Generally in garments industry, workers work more than eight hours by shifting mostly by sitting or standing in one position. However, an anthropometry survey showed that the furniture used by garments worker in Bangladesh were not manufactured ergonomically. As a result, workers suffer various musculoskeletal disorders. The study evaluated the potential mismatch between garments furniture dimensions and anthropometric characteristics of garments workers. Seventeen anthropometric measurements and five furniture dimensions from existing garments furniture were measured and then compared together to find out any potential mismatch. The results indicate that a considerable mismatch between body dimensions and existing furniture, with seat height (79%), seat depth(94%), seat width(36%), and table height(79%) being the furniture dimensions with a higher level of mismatch. The main purpose of this paper is an ergonomics approach to design garments furniture to achieve appropriate balance between workers and their workplace.

Keywords: Anthropometric measurement; Garments Furniture; Mismatch.

1. Introduction

In garments industries workers have to work for more than eight hours repeatedly either by sitting or by standing in one position. So, definitely stress developed in their musculo-skeletal system. Garments industries in Bangladesh have in general very poorly designed workspace, sewing table, sitting chair, Inspection table, Ironing table, limits of work space etc. without considering any ergonomic issue. As a result, the workers feel, back pain, neck pain, fatigue, blood circulation problem, discomfort are related to the anthropometric factors of ergonomics. Ergonomics deals with making the workstation as efficient, safe and comfortable as possible. This can increase worker productivity, provide worker safety and physical and mental comfort and job satisfaction .The aim of ergonomic is the evaluation and design of facilities, environment, jobs, training method, and equipment to equal the capabilities of the users and workers, and thereby to condense the probable for fatigue, error, and unsafe acts[1]. Anthropometry is one of the basic parts of ergonomics that refers to the measurement and collection of the physical dimension of the human body. It is used to improve the human fit in the workplace or to determine problems existing between facilities or equipment and the employees using them [2]. Anthropometric data are used in ergonomics to specify the physical dimensions of workspaces, equipment, furniture and clothing to "in shape the task to the man" [3] and to ensure that the physical mistakes between the dimensions of equipment and products and matching user dimension are avoided. Generally anthropometric measurements are expressed as percentiles. A percentile is defined as a measure used in statics representing the value below which a given percentage of observations in a group of observations fall. For example, the 95^{th} percentile is the value below which 95 percent of the observation may be found.

2. Methodology

For the purpose of this study 400 (200 male and 200female) garments worker were taken from Babylon Dresses ltd. Mirpur, Dhaka, Bangladesh, in order to, collect various anthropometry measurements. Dimensions of existing furniture also taken by a standard measuring tape in order to, mismatch with anthropometric measurements. Dimension were taken in standard sitting and standing positions, wearing light cloths and barefooted. Worker body dimension measured when the worker seated erect on a flat horizontal surface, their lower and upper legs were at right angles (knees bent at 90^0) and feet (without shoes) placed on the flat floor. Comparisons have been made between worker anthropometry measurement and existing furniture dimension. Data have been analyzed by determining mean value, standard deviation value, percentile value using Microsoft office excel worksheet. During this study, 5^{th} percentile, and 95^{th} percentile was calculated as a limit range. Then the anthropometric measurements and furniture dimension were combined to calculate whether there is match or mismatch between them by using quantitative equation.

2.1 Anthropometric dimensions of the worker:

The anthropometric measures (Fig.1) were collected in the seated and standing positions in a bare foot. The following anthropometric measurements were taken for each worker:

Sitting height: This is the vertical distance from horizontal sitting surface to the highest point of the head.

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Sitting eye height: This is the vertical distance from a horizontal sitting surface to the eye.

Sitting shoulder height: The vertical distance from a horizontal sitting surface to the top of the shoulder at the acromion.

Sitting elbow height: The vertical distance from a horizontal sitting surface to the tip of the elbow with flexed at 90^0.

Hip breadth: The maximum horizontal distance between the hips in the sitting position.

Elbow to elbow breadth: The horizontal distance across the lateral surfaces of the elbows spreading sideways was measured.

Thigh clearance: The vertical distance from a horizontal sitting surface to the highest point on the thigh.

Knee height: The vertical distance from the foot resting surface to the top of knee cap just in back and above the patella with knee flexed at 90^0.

Buttock knee length: The horizontal distance from the posterior surface of the buttock to the front of the knee cap.

Buttock Popliteal length: The horizontal distance from the posterior surface of the buttock to the popliteal surface.

Popliteal height: The vertical distance from the foot resting surface to the popliteal space.

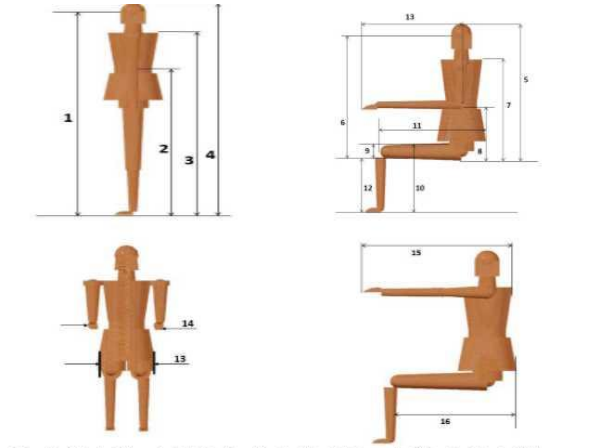
Functional forward reach: The horizontal distance from the scapula to forward fingertip, when arm at 90^0 angle position.

Stature: The vertical distance from the floor to the top of the head, while the participant stood erect, looking straight ahead.

Standing eye height: This is the vertical distance from floor surface to the eye.

Standing shoulder height: The vertical distance from floor surface to the top of the shoulder at the acromion.

Standing elbow height: The vertical distance from floor surface to the tip of the elbow with flexed at 90^0[4].



1. Eye Height, 2. Elbow height, 3. Shoulder height, 4.Stature, 5. Sitting height, 6. Sitting eye height, 7. Sitting shoulder height, 8. Sitting elbow height, 9. Thigh Clearance, 10. Knee height 11. Buttock knee length, 12. Buttock popliteal height, 13. Hip breadth, 14. Elbow to elbow breadth,15. Functional forward reach, 16. Buttock popliteal length.

Fig.1 Anthropometric measurements

2.2 Garments Furniture Measures:

The following dimensions (Fig.2) of the garments furniture which were measured:

Chair Seat height (SH): The vertical distance from the floor to the highest point on the front of the seat.

Chair Seat depth (SD): The horizontal distance from the back of the sitting surface of the seat to its front.

Chair Seat width (SW): The horizontal distance from the outer left side of the sitting surface of the seat to outer right side.

Chair Backrest height (B): The vertical distance from the top side of the seat surface to the highest point of the backrest.

Table height (T): The vertical distance from the floor to the top of the front edge of the table.

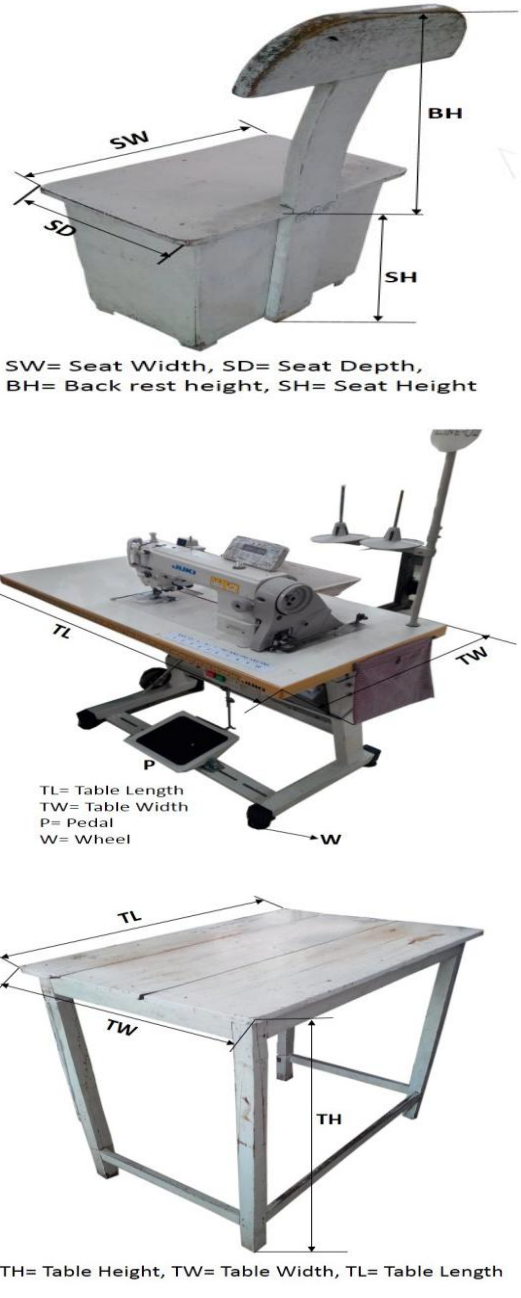


Fig.2 Garments furniture measurements.

2.3 Mismatch between garments furniture and body dimensions:

The anthropometric measurements of each individual worker were compared with relative furniture dimension in order to identify match or mismatch. In the literature different suggested relationships have been found to identify match or mismatch. Following equations are commonly used:

2.3.1 Popliteal Height (PH) against Seat Height (SH):

In literature, the seat height (SH) needs to be adapted comparatively to popliteal height, allowing knees to be flexed so that the lower legs form a maximum of 30^0 angle relative to vertical axis [5]. As shown the equation (1) below declares that the seat height(SH) should be lower than popliteal height(PH) so that the lower leg forms a 5-30^0 angle relative to the vertical and the shin-thigh angle is between 95^0 and 120^0 [5]. For this study, 3 cm correction for pedal height is including to the popliteal height. Therefore the match criteria were defined according to the eqn.1.

$$(PH+3)\cos 30^{o} \leq SH \leq (PH+3)\cos 5^{o} \quad \ldots\ldots (1)$$

2.3.2Buttock popliteal length (BPL) against seat depth (SD):

In the literature [6] the seat depth should be designed for the 5thpercentile buttock popliteal length distribution so that the backrest of the seat can support the lumbar spine without compression of the popliteal surface. Therefore a mismatch between buttock popliteal length and seat depth is either<80%or >95% of buttock popliteal length [7]. Thus the match criterion was determined by Eq^{n}.2

$$0.80BPL \leq SD \leq 0.95BPL \quad \ldots\ldots (2)$$

2.3.3 Sitting shoulder height (SSH) against backrest height (BH):

In order to facilitate of the trunk and arms, the backrest height needs to be adapted below the scapula [9]. Other researches [5] recommended to keep the backrest lower than or at most on the upper edge of the scapula (which is 60% to 80% of shoulder height). Therefore, a match criterion is established by equation (3).

$$0.60SSH \leq BH \leq 0.80SSH \quad \ldots\ldots (3)$$

2.3.4 Hip Breadth (HB) against Seat Width (SW):

In literature,[8] seat width should be designed for the 95% of hip breadth distribution and also recommended the seat width should be at least 10%(to accommodate hip breadth) and at the most 30% larger than the hip breadth (for economy space[5]. Therefore, a match criterion is established by equation (4).

$$1.10HB \leq SW \leq 1.30HB \quad \ldots\ldots (4)$$

2.3.5 Sitting elbow height (SEH) against table height (TH):

In the literature[7] suggested that the table height should be adopted to elbow-floor height, so that it would be minimum when shoulders are not flexed and maximum when shoulders are at 25^0 flexion and 20^0 abduction (elbow rest height x 0.8517 + shoulder height x 0.1483). The equation is modified [5] based on the fact that elbow-floor height is the sum of elbow rest height and seat height. Thus, a match criterion is determined by equation (5).

$$EH + (PH+3)\cos 30^{\circ} \leq TH <= (PH+3)\cos 5^{\circ} + 0.8517\ EH + 0.1483\ SH \quad \ldots\ldots (5)$$

3. Results

3.1 Anthropometric measures of the garments workers related design:

The results of 200 female worker's anthropometry data are summarized in Table 1 and Table 2 also summarized the results of 200 male worker's anthropometry data. For the purpose of analysis and design, the data are offered mean, 5th, and 95th percentile value.

Table 1 Anthropometric results for female workers

Dimension	5th %tile	Mean	95th %tile
Sitting			
Sitting height	71.95	77.26	84
Eye height	61.95	66.79	72
Shoulder height	49	53.99	59
Elbow height	16	19.79	24
Hip breadth	30	32.4	38
Elbow to elbow breadth	35	40.92	46
Thigh clearance	12	13.66	16
Knee height	47	49.03	51
Popliteal height	39	41.42	49
Buttock knee length	48	50.88	55
popliteal length	38	40.64	45
Forward reach	64	68.67	75
Standing			
Stature	150	154.46	161
Eye height	137.95	143.76	151
Shoulder height	125	129.79	138
Elbow height	91	95.39	101
Forward reach	64	68.67	75

Table 2 Anthropometric results for male workers

Dimension	5th %tile	95th %tile	Mean
Stature	155.95	173	107.99
Eye height	145.85	161	159.97
Shoulder height	130.95	146	146.89
Elbow height	96	109.05	120.85
Forward reach	72	83	89.91

3.2 Dimensions of existing garment furniture:

The critical dimensions of current garment furniture's are summarized in Table 3 that represents the existing furniture dimensions.

Table 3 Existing garment furniture dimensions

Furniture dimensions		Dimension(cm)
Sewing chair	Seat height	45
	Seat width	36
	Seat depth	43
	Back rest height	38
Sewing table	Table height	72
Inspection, cutting, and Ironing table	Table height	91

3.3 Comparison between garment worker's anthropometric measurement and garment furniture:
Match or mismatch was determinate based on above mentioned equation in the method section. Table 4 summarized the number and percentage of workers whose measurements match or did not match with the existing furniture.

Table 4 Number and percentage of female workers who match or mismatch with existing garment furniture.

Comparison between anthropometry and furniture dimensions	Match (%)	Low Mis match (%)	High Mis match(%)	Total Mis match (%)
SH and PH	**21**	**0**	**79**	**79**
SD and BPL	**6**	**0**	**94**	**94**
SW and HB	**64**	**36**	**0**	**36**
BH and SH	**100**	**0**	**0**	**0**
TH and EH	**21**	**0**	**79**	**79**

From Table 4 results show that the existing sewing table height and seat height of chair was appropriate for 21% of the workers, and only 6% of workers match with seat depth. Of these, 79% of workers used seats and tables were too high (high mismatch) than popliteal height and elbow height. The mismatch percentage for seat width is 36 % (low mismatch) which is smaller than hip breadth of workers. The results also show that 94% of workers used seats were too depth (high mismatch) than buttock popliteal length.

4. Discussion

The study estimated the possible mismatch between garment furniture and anthropometric characteristics of 400(200male and 200 female) Bangladeshi garment workers. Results, (from Table 4) show that there is a considerable mismatch between body dimensions of the garments workers and the existing garment furniture available to them. Table 4 indicates that, mismatch (high mismatch) percentages for the seat height is 76%that means workers are sitting on chairs are too high. The results indicate that, seat depth mismatch percentages are too high 94% (high mismatch) consequently, majority of the workers usually place their buttock forward on the edge of the seat during sewing operations. Thus, the back of workers does not touch the back rest shown in Fig. 4

Fig. 4 working positions at existing sewing workstation

Seat width mismatch percentages are 36% (low mismatch) for workers that mean chairs are narrow designed. Due to, worker who have large hip breadth cannot get enough space to sit. The mismatch percentages for the sewing table height are too high 79% (high mismatch) thus; the height of the table exceeds their elbow rest height, so the workers are forced to lift their arms during sewing operations (shown in Fig 4), which may cause more muscular load, discomfort and pain in the shoulder area [7] or have to bend their trunk forward, a posture which increase the spinal load.

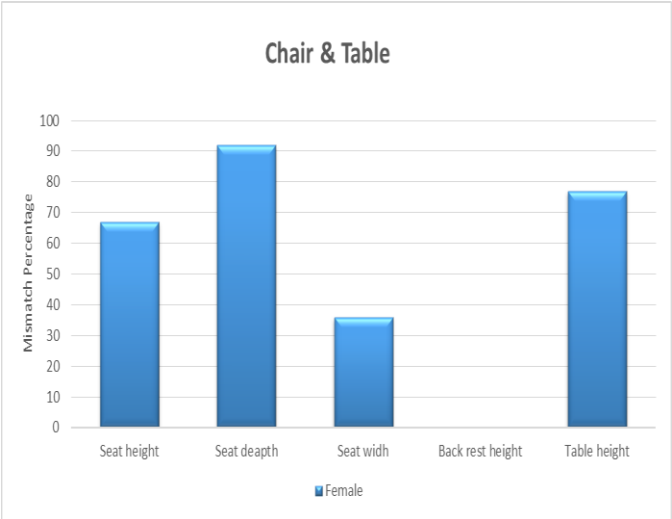


Fig. 5 Mismatch percentages for different dimensions (existing)

The mismatch (percentages) between the anthropometric characteristics of garments workers and the existing garments furniture are shown in Fig. 5

5. Conclusion

The study indicates that, there are considerable mismatches between the garments furniture and anthropometric characteristic of workers. The seat height, seat depth, and sewing table height are being the dimensions with a higher level of mismatch. Based on estimation by applying mismatch equations(equation 1-equation 5) and reported to the workers that the existing furniture are not safe and comfort to use and they can cause health problems for the worker. The seats heights, table height, are too high for majority workers. On the other, hand seat depths are too length and the seat widths are too narrow for female workers. This occurred due to design the furniture without maintaining ergonomic issues. As a result the workers feel discomfort.

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