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Anthropometry and Mismatch Issues with the Elementary School Children in Bangladesh

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Abstract

Wrong furniture dimensions are seen in the elementary schools in Bangladesh due to the fact that local carpenters and suppliers have very little or no knowledge about the importance of anthropometric data in the design and fabrication of school furniture. There are many studies conducted for measuring anthropometric dimensions but sitting habits, posture, learning style, and other related issues were not explored in those studies and research. The authors thus compared Bangladeshi elementary school children's anthropometric data with the existing furniture dimension to identify whether any potential match or mismatch exists between them. In this research, human factors and ergonomic issues are also illustrated for implementing proper design guidelines in the fabrication of school furniture. A total of 150 girls and 150 boys were randomly selected from three different elementary school administrations located in the south-eastern districts of Bangladesh. Fifteen anthropometric measurement data from the elementary school children and five ergonomic parameters from classroom furniture were likewise measured. The seat and desktop heights were found too high that may result sitting discomfort and pain in the posterior surface, knee, and shoulder region. The authors thus believed that appropriate furniture dimensions would better match (sitting comfort) with the postural adjustment especially for changing local attitude and/or sitting behaviour. Results of this anthropometric survey will help the school authorities and other concerned parties to monitor adjustable classroom furniture in future endeavour.

Keywords: School Furniture; Anthropometry; Mismatch; Postural Discomfort; Bangladesh

Introduction

Elementary school children spend almost a quarter of the day at school, mostly in a sitting position. In Bangladesh, wooden desks and benches are used as school furniture those lack standard anthropometric dimensions. The school administrations prepare procurement orders for supplying classroom furniture and the vendors supply school furniture fabricated from the local carpenter shops. Wrong furniture dimensions are also seen in many schools [1-3] due to the fact that local suppliers, carpenters or vendors have very little or no knowledge about anthropometric data [4-6]. There is also poor awareness about non-ergonomic school

furniture among the teachers and students [7]. Studies [8,9] showed that wrong sitting height, poor posture,and improper dimension of furniture caused children's leg or feet unable toreachtheground. Inappropriate furniture dimensions forceds tudent to lift their arms and hunch their shoulders [10-13]. Studies [14-20] also concerned about the school children's sitting discomfort in other countries due to non-ergonomic furniture and poor posture adoption. Existing sitting culture [21-23] among the school children has been accommodated with non-ergonomic or non-adjusted school furniture in many cases. Anthropometric surveys [24-30] were conducted in many countries but those do not focus on seating dynamics to understand postural adjustment. Correct anthropometric data has yet to be given adequate attentionin the initial stage of designing and fabrication of school furniture. Researchers [31-36] found various problems of sitting discomfortbecause the school childrens sit on poorly designed benches and write on non-ergonomic tables and/or desks. Non-ergonomic school furniture surely aggravates psychological stress in some cases [19,37].

Poor sitting also impose ill effects on school childrens' learning performance [38-40]. Incorrect body alignment can reducethe ability of antigravity muscles while sitting on non-ergonomic bench [41-45]. It is therefore very essential for each of the developing countries to have their own anthropometric database (e.g., appropriate body parts dimension)that deals with human body parts measurement. Its also deals with human body composition, body sizevariability or body shape differences for user-based, ergonomic or convienient product design [46-50]. Anthropometric measurements are to be followed in furniture design that should bring students' motive towards listening the lecture, writing, drawing,and do class assignments. *Designing for extreme individual*is its first principle that can also be either designing for the maximum population as commonly the 95th percentile male, or designing the minimum population value as commonly referred as 5th percentile female. The second principle of anthropometry is *designing for an adjustable range* which put consideration of 5th female and 95th male in order to accommodate 90% of the user population. The 3rd principle is *designing for the average* which is mostly being used whenever the use of adjustability is impractical. In fact, anthropometric dimentions/measuremnts are required to establish the physical geometry, mass properties, and physical strength and menatl capabilities that can vary from one country to another at least with some small variations. Due to such variations, there is need of having correct / acurate anthropometric databasefor every province, state, or country. The accurate database [2-4,29] can be used for current and future design and fabrication of school furniture. Ergonomically designed school furniture also improves children's listening, writing and drawing performance in the class. Therefore, various body parts of the elementary school children and furniture dimension were measured in this study and research survey to propose ergonomics of furniture dimension. This study is also believed to be a good source of anthropometric data and information for getting an idea of match or mismatch with the existing school benches and desks in Bangladeshi schools.

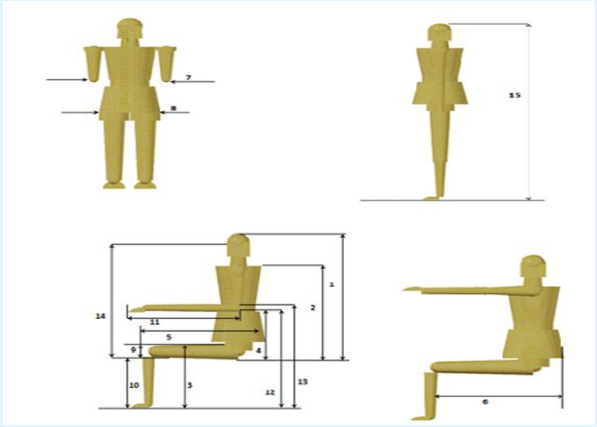
Methods and Materials

This study was conducted in three different elementary schools in the south-eastern districts in Bangladesh. A sample of 300 elementary school children (150 girls and 150 boys) was randomly selected with no physical disabilities from different elementary school jurisdiction. The school administrations supported to conduct the anthropometric survey. The school children were studying at grade 1 to 5 (age: 5 to 10 years). Anthropometric data was collected to specify the physical dimensions of school furniture and body part dimensions of the school children. In this study, anthropometric data were measured in standard sitting and standing positions using Harpenden anthropometric tool (Figure 1). It is a versatile tool to measure standing height, sitting height, and the arm length of elementary school children.

Figure 1: Harpenden Anthropometric Tool Box.

The anthropometric tool was made from a light alloy, anodised to its natural colour. It was used for providing direct reading to the nearest millimetre, over a range of 50mm to 570mm. Its sliding member operates via miniature ball-bearing rollers in order to ensure a free movement without cross-play. When using the anthropometric tool, a constant was added to the counter reading. The researcher felt easy to measure the desired measuring points by means of their free finger-tips, in order to obtain a degree of accuracy. It included a carrying case, complete with straight and re-curved branches, a spare counter and beam extensions for the

measuring of heights of up to two metres. In front of a wall, the subjects' were barefooted and their heights were measured by standing position on a scale. Sitting measurements were taken using anthropometric measuring tools. A standard measuring tape was also used to measure the existing furniture dimensions. Microsoft Excel was used to calculate the mean value, maximum and minimum values, standard deviation value, and the percentile value. Important anthropometric measurement data of the school children were shown in Figure 2.



Numbering for various body parts are defined /given as: 1—sitting height; 2—shoulder height (sitting); 3—kneeheight (sitting); 4—sittingelbow height; 5—buttock knee length; 6—buttock popliteal length; 7—elbowto elbow breadth;8-hip breadth; 9—thighclearance;10—popliteal height; 11—forearmfingertip length; 12—sittingupper hip height; 13—sittinglowest rib bone height; 14—sittingeye height; and 15—stature of the school children

Figure 2: Anthropometric measurement data of elementary school children in Bangladesh.

Anthropometric measurements of the school children also include definition of elbow height, buttock popliteal length, hip breadth, thigh clearance, and popliteal height. The research protocol was submitted to the University Ethics Committee and the committee members approved the research proposal with some corrections. Finally, anthropometric information obtained from the study was computed using a SPSS 16.0 statistical package. Combinational equations were applied for defining the acceptable furniture dimensions according to current anthropometric data of school furniture and children's sitting posture. Match percentages were computed and recorded according to either existing furniture mesurements assuming that the elementary school children could use the most appropriate furniture sizes.

Results

The results indicated that seat heights and desktop heights of the classroom furniture were too high, which resulted in pain on the posterior surface of the knee and shoulder region. The children also experienced with discomfort feelings. It was also observed that school children sit on the wooden bench that are too high for them. Based on observation and average anthropometric measurement values, the seat height only matched for grade 1 (school year 1) up to 8.33%, for grade 2 (school year 2) up to 38.33%, for grade 3 (school year 3) up to 55%, for grade 4 (school year 4) up to 78.33 and for grade 5 (school year 5) up to 50%. These values are certainly below the lower limit of the acceptance range [2-3]. For grade 1 to 5 (school year 1 to 5), it is clear that 45 to 100% of the seats used in the elementary schools were too high (high mismatch) and 3.33 to 30% were too low (low mismatch). The dimensions of existing classroom furniture in three different schools are shown in Table 1.

School Name	Furniture dimensions	Benches				
		Class 1	Class 2	Class 3	Class 4	Class 5
Police Line School	Seat height	45.72	45.72	45.72	45.72	45.72
	Seat width	39.11	39.11	39.11	48.89	48.89
	Seat depth	25.40	25.40	25.40	25.40	25.40
	Seat to desk height	30.48	30.48	30.48	30.48	30.48
	Seat to desk clearance	20.32	20.32	20.32	20.32	20.32
	Desk width	39.11	39.11	39.11	48.89	48.89
	Desk depth	30.48	30.48	30.48	30.48	30.48
Badsha Foysal School	Seat height	43.18	36.83	38.1	48.26	47
	Seat width	30.1	26.25	30.48	45.72	45.72
	Seat depth	24.13	24.13	25.4	25.4	24.13
	Seat to desk height	33.02	29.11	33.02	27.94	29.21
	Seat to desk clearance	13.97	13.97	13.97	7.62	11.43
	Desk width	30.1	26.25	30.48	45.72	45.72

	Desk depth	30.48	27.94	30.48	30.48	30.48
Churamonkathi Govt. Primary School	Seat height	38.1	38.1	38.1	38.1	45.72
	Seat width	40.64	40.64	40.64	40.64	47.62
	Seat depth	25.4	25.4	25.4	25.4	25.4
	Seat to desk height	20.82	20.82	20.82	20.82	27.94
	Seat to desk clearance	17.02	17.02	17.02	17.02	17.78
	Desk width	43.18	43.18	43.18	43.18	47.62
	Desk depth	35.56	35.56	35.56	35.56	30.48

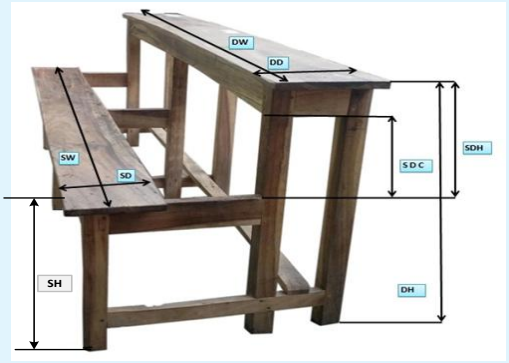
Table 1: Dimensions (cm) of existing classroom furniture in different elementary schools

The seat height matched for grade-1 (school year-1, or class-1) up to 8.33%, for grade-2 (school year-2, or class 2) up to 38.33%, for grade-3 (school year 3, or class 3) up to 55%, for grade-4 (school year 4, or class 4) up to 78.33% and for grade-5 (school year 5 or class-5) up to 50%. The desk height matched for grade-1 (class 1) up to 71.67%, grade-2 (class 2) up to 31.67%, grade-3 (class 3) up to 65%, grade-4 (class 4) up to 73.34%, and grade-5 (class 5) up to 10%. Due to mismatch with the existing furniture dimension, there was an increased risk for developing sitting discomfort and other health and safety related problems (e.g., back, neck, and shoulder pain) among the selected subjects/children. The mismatch percentages decreased with the grade levels (school year 1 to 5, or class 1 to 5) of the elementary school children. Anthropometric measurement (cm) are illustrated in table 2 that contains descriptive statistics including minimum, maximum, mean, standard deviations (SD), and percentile values (5^{th}, 50^{th}& 95^{th}) of three different elementary school children in Bangladesh.

Anthropometry	Grade	Min	Max	Mean	SD	5^{th}%	50^{th}	95^{th}
Elbow height	1	12.7	23.4	17.48	2.08	14	17.78	20.38
	2	11.4	19	14.65	2.05	11.97	14	18.24
	3	12.7	22.85	18.63	2.65	15.13	19	22.85
	4	11.4	23.85	18.25	4.69	12.89	17.8	21.70
	5	13.98	23.9	18.72	2.31	15.24	17.92	22.87
Buttock popliteal length	1	20.32	41.9	30.11	4.51	23.09	30.59	38.01
	2	27.95	43.2	33.90	2.67	30.42	33.45	37.63
	3	28.25	43	35.57	2.92	31.64	35.56	40.64
	4	27.9	40.65	35.18	2.98	30.50	35.5	39.46
	5	22.85	43.7	36.42	4.69	25.50	36.82	43.19
Hip breadth	1	15.24	30.9	20.94	4.13	16.49	19.8	29.27
	2	10	27.94	20.16	3.04	16.5	20.3	25.4
	3	17.8	33	23.89	3.44	19	23.25	30.56
	4	16.5	34.3	25.19	4.49	18.3	25.4	33
	5	16.51	33	26.58	3.29	21.59	26.68	33
Thigh clearance	1	7.4	13.9	9.67	2.01	7.6	8.89	13.97
	2	6.3	11.45	8.74	1.31	6.35	8.9	10.24
	3	7.6	14	10.61	1.81	7.6	10.2	13.95
	4	7.1	15.25	10.89	2.21	7.6	10.8	14.03
	5	7.62	15.25	11.50	1.90	8.89	11.43	15.25
Popliteal height	1	22.85	40.65	31.78	3.81	24.1	32.5	35.79
	2	22.85	40.64	33.57	3.62	38.8	34.15	38.8
	3	29.2	45.7	36.48	3.68	30.9	35.6	43.21
	4	30.45	45.2	38.10	3.51	33	38.7	39.39
	5	30.45	48.3	39.21	4.13	33	39.39	45.71

Table 2: Anthropometric measurement (cm) of the elementary school children in Bangladesh

Representation of the classroom furniture measurement in Bangladesh is shown in Figure 3.



Legend: SH=Seat Height, SW= Seat Width, SD= Seat Depth, SDH=Seat to Desk Height, SDC= Seat to Desk Clearance, DH= Desktop Height, DD=Desk Depth, DW=Desk Width.
Figure 3: Classroom furniture measurement in Bangladesh.

Match or mismatch issues as the percentage calculation of the furniture dimension and the percentage of children's anthropometric data were presented by school years (grade levels). Theresults showed that the level of mismatch percentage of the proposed dimensions has decreased. The proposed dimensions for the classroom furniture are more appropriate for average school children. The proposed anthropometric dimensions (cm) of the school benches' match and mismatch percentages are shown in Table 3.

Furniture dimensions	Grade	Dimensions	Match	Low mismatch	High mismatch	Total mismatch
Seat height	Grade1	33.5	66.67	5	28.33	33.33
	Grade2	34.5	75.00	8.33	16.67	25.00
	Grade3	36.5	65.00	18.33	16.67	35.00
	Grade4	38	78.33	15	6.67	21.67
	Grade5	40	61.67	10	28.33	38.33
Seat depth	Grade1	28	73.33	13.33	13.34	26.67
	Grade2	29	90.00	10.00	0	10.00
	Grade3	32	91.67	13.33	03.33	08.33
	Grade4	34	90.00	06.67	13.33	10.00
	Grade5	35	86.67	10.00	16.67	13.33
Seat width	Grade1	25	70.00	15.00	15.00	30.00
	Grade2	26	81.67	6.00	13.33	18.33
	Grade3	28	81.67	2.00	16.33	18.33
	Grade4	29	78.33	1.33	20.00	21.67
	Grade5	30.5	80.00	4.33	15.67	20.00
Desktop height	1	46.5	95.00	1.67	03.33	05.00
	2	47.5	90.00	06.67	3.33	10.00
	3	51	81.67	18.33	0	18.33
	4	52.5	83.33	30.00	3.33	16.67
	5	54	85.00	30.00	0	15.00
Seat to desk clearance	Grade1	12	95.00	0	5.00	05.00
	Grade2	12.5	100.00	0	0	0
	Grade3	13.5	96.67	0	3.33	3.33
	Grade4	15	98.33	0	1.67	01.67
	Grade5	15	100.00	0	0	0

Table 3: Proposed dimensions (cm) of the school benches' match and mismatch percentages.

In this study, there was no link found between desk height and seat height due to the fact that mismatch forces the elementary school children to slide forward on the seat of the classroom furniture. However, the seat height match appears to be necessary since the proposed dimensions would better match the student's

anthropometry. So, design criteria and fabrication issues should be based on the anthropometric data obtained in this research.

Discussion

In this study, a considerable mismatch was identified between the furniture dimension and children's anthropometry. There was mismatch between correct sitting posture, desk and bench height. Elbow-seat height was much smaller than the acceptable lower the upper bench height (Figure 4). Adjustable furniture was proposed to improve the match between classroom furniture dimensions and school children's anthropometry. For this, the mismatch percentages (i.e. low mismatch and high mismatch values) should be calculated for each type/category of dimension in order to obtain some insight into the nature of mismatch. In this context, it is necessary to find the optimum dimension (adjustable height) that can maximise the match percentage for that particular dimension/measurement.

Figure 4: Wrong furniture dimension forced the school children to lift their arms and hands.

Improper design is considered as mismatch of benches that lead to an imbalanced posture of the lumbar spine. It requires more muscle control to maintain the upright stability and sitting on the bench [9,12,51]. Updated furniture design guidelines should match with the cultural requirements so that anthropometric data match with sitting height and elbow height. The proposed dimension of the seat surface height in this study is lower than 44.50 cm. In Sri Lanka [52,53], it was proposed for 43.5cm and 38.6 cm in India [5,29]. The same concept was proposed in Turkey as 38.6cm [54] and 37.7cm for Iranian higher educational institutions [55,56]. A prototype of bench and desk heights should be fabricated for adjustable and reasonable choices for the school children. The design guidelines can be followed based on Evans, et al. [57] and Oxford [58]. Bench/chair height (Ch) should be measured from the floor level to the highest point on the centerline at the front of the bench area (Figure 3).

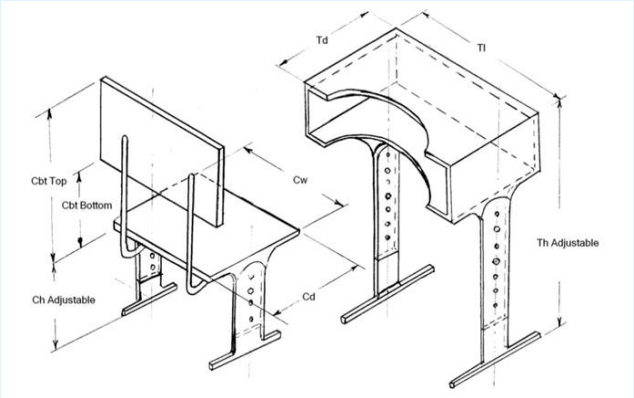


Figure 3: Prototype of school bench/chair and desk/table height [50], as an example.

In this study and research, the range of adjustability for the bench height was considered from the5th percentile to the 95thpercentileofpopliteal height. A value of 2.0 to 2.5cmshould thus be considered reasonable for shoes allowance as indicated by Taifa [59] even wearing sandals are common in rural Bangladesh. Sitting culture in Sri Lanka [52,53] and India [5,29] may be same for Bangladeshi school children but reasonable shoe allowances are not same. For Bangladeshi school children, recommended bench and desk heights may not be acceptable in India [11,29,59] & Sri Lanka [52,53]. When designing elementary school furniture, the potential height of the school children's body is also vital for ergonomic design. It is therefore important to know minimum and maximum sitting and standing height, elbow rest height, popliteal height, forward arm reach, scapula height (sitting), buttock-knee length, buttock-popliteal length, height depth, breadth across elbows and the hip breadth. For this, research should be conducted for adopting better sitting culture, sitting behaviour or

local system still exit in remote areas and religious school in Nepal, Bhutan or Myanmar. Whatever the case, children should adopt correct postures regardless of local sitting culture or system, or the furniture. Postural adjustment is sought, and the authors believed that it was the best option rather than removing all furniture. Economic issues/cost consideration should be considered if it is a big issue for ordering or supplying of new set of furniture at a time.

Conclusions

The study highlighted the fact that classroom furniture in the elementary schools in Bangladesh is selected without considering correct anthropometric data. Different grades (class 1-to 5 or school year of 1-to 5) does not accommodate the variability of anthropometric dimension among the children of the same age. School furniture designed using the 'one-size-fits-all' approach. It can be extremely difficult task to design and fabricate school furniture with proper anthropometric dimensions that match majority of the target population. There is a need of considering the voice of school childrens about their comfort and discomft feelings. Supplying furniture without any involvement of the students will be a bad substitute. There is also need of fabricating school furniture integration of human factors and ergonomics application.

For ergonomic classroom furniture, integration of quality function deployment with Kano Model [*https://en.wikipedia.org/wiki/Kano_model*] was ilustrated by Taifa and Desai [59]. Whenever possible, arrangement of seminar and workshop will be fruitful to educate school children regarding the negative impact of incorrect posture and toadopt ergonomic posturein their school life.Sitting position and postural adjustment with the school furniture should also be considered as vital. School inspectors should visit those schools to examine whether the furniture supplied by the vendors are appropriate or not. Furniture at different schools may contribute to postural variation. Awkward sitting postures may contribute to various levels of discomforts. However, certain types of sitting posture those are already adopted in remote areas of few developing countries may be acceptable. Anthropometric measurement data of each individual child should thus be compared to identify a match or mismatch between the students and the furniture. Healthy sitting culture and ergonomic issues are vital for reducing problems of school children whatever country and region is. Further study and research should be carried out in other districts in Bangladesh to monitor school furniture and minimise student's postural and sitting discomforts.

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