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Mismatch between classroom furniture and anthropometric measurements of Bangladeshi primary school students

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ABSTRACT
Furniture has a significant effect on human health. So, it is necessary to use anthropometric data to design the school furniture. Students spend about more than five hours per day at school with little or no breaks. Most classroom activities involve sitting for long period of time. Due to prolonged sitting on inappropriate classroom furniture, students feel back pain and other musculoskeletal disorders. Every effort should be made to ensure that students do not face this problem. In Bangladesh, an anthropometry survey indicated that the furniture used by students, were not manufactured according to ergonomics principle. So, the purpose of this study is to compare furniture dimensions within three different primary schools with the anthropometric measurements of the Bangladeshi students, in order to evaluate the potential mismatch between them. The study consists of 300 students where 150 girls and 150 boys of the 1-5th grade ranging from 5-10 years from different schools. Fifteen anthropometric measurements and five dimensions from the existing classroom furniture were measured and then compared together to identify any potential mismatch between them. This paper focuses on the variation of the existing classroom furniture and students' anthropometry and also focuses on the problem of using the traditional school furniture.

Keywords: Anthropometry, school, classroom furniture, mismatch, ergonomic-oriented furniture.

1. Introduction

Human health risk is varying from case by case basis. The factors that can influence human health are the work environment, external factors and personal dispositions. Students spend 80% of their school time at sitting position. Considering the amount of time spending at school and especially while sitting, it is fundamental that school furniture fit the student's requirements [1]. In Bangladesh, most classroom furniture is manufactured without proper ergonomic consideration; as a result school children are suffering in various problems. Thus, necessary anthropometric measures have to be considered to design classroom furniture. The benches used by the students are too high and too deep. This situation has negative effects on the sitting posture of the students especially when reading and writing. The design of the furniture for students has received little or no interest. So, the situation of school work becomes more serious. For students comfort it is necessary to take step to design school furniture immediately.

This paper is based on match between school furniture and children's anthropometric measurement. It is also showed the ergonomic problems of using benches at school and how the mismatch between school furniture and student anthropometric measurements.

2. Methodology

It may be unrealistic to attempt to develop a classroom furniture design that "fits all" since children continue to grow and often leave for the next grade at the end of the academic session. It is therefore, unwise to design specific or custom made furniture for a particular elementary school student. This research aims is to evaluate the mismatch between classroom furniture dimension with anthropometric measurement of primary school students to examine proper ergonomic-oriented classroom furniture dimension.

2.1 Sample

In this study a sample of 300 primary school students is randomly selected where 150 girls and 150 boys with no physical disabilities from three primary schools (police line school, Badsha Foysal School, Churamonkathi govt. primary school) located in the city of Jessore, Bangladesh. They are in 1-5 classes and ranged in age from 5-10 years. The schools are representative of the three types of elementary school administration.

2.2 Measurement and procedure

Various anthropometric measurements of normal healthy students (Fig.1) were taken in standard sitting and standing positions. Student's heights were measured by standing the students on barefoot in front of a wall with a scale. To measure the existing furniture dimensions standard measuring tape was used. A statistical-software named Microsoft Excel spreadsheet was used to calculate the mean value, maximum and minimum values, standard deviation value and also the percentile value. The measurements were taken according to the method described by researchers [2-4].

2.3 Anthropometric measurements

Anthropometric measurements are considered as the basis for the design of furniture ergonomically. Thus, designing the classroom furniture for this study the authors have considered the following anthropometric measurements [5].

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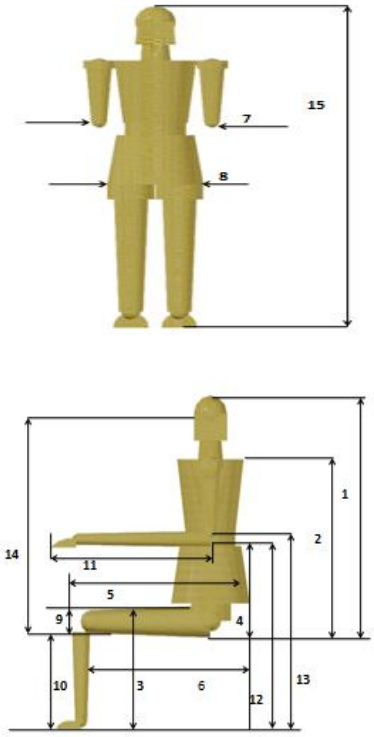


Fig.1 Anthropometric measurements

1. Sitting height 2.Shoulder height (sitting) 3.Knee height 4.sitting elbow height 5.buttock knee length 6.Buttock popliteal length 7.Elbow to elbow breadth 8.Hip breadth 9.Thigh clearance 10.Popliteal height 11.Forearm finger tip length 12. Sitting upper hip bone height 13.Sitting lowest rib bone height 14.Sitting eye height 15.stature

Sitting Height (SH): This is the vertical distance from the tip of the head to the surface of the sitting object (stool) [6].

Shoulder Height (ShH): This is the vertical distance from the top of the shoulder at the acromion process to the subject's sitting surface.

Knee height (KH):This is the vertical distance from the foot resting surface to the top of the knee cap[6].

Elbow Height (EH): This is the vertical distance from the bottom of the tip of the elbow (olecranon) to the subject's seated surface

Buttock knee Length (BKL): Distance was measured horizontally from the back of the uncompressed buttock to the front of the kneecap.

Buttock Popliteal Length (BPL): This is the distance from the posterior surface of the buttock to the posterior surface of the knee or popliteal surface [6].

Elbow to elbow breadth/elbow width (EW):

Horizontal distance across the lateral surfaces of the elbows (when the students write on the desk), spreading sideways was measured.

Hip Breadth (HB): The hip breath is the distance between the right side of the pelvic and the left side, measured when seated [6].

Thigh Clearance (TC): This is the vertical distance between a surface of the stool and the highest point on the top of the right thigh.

Popliteal Height (PH): This is the vertical distance from the popliteal space which is the posterior surface of the knee to the foot resting surface [6].

Forearm finger tip length (FFTL): Distance measured horizontally from the back of the elbow to the tip of the middle finger in a standard sitting position.

Sitting upper hip bone height (SUHBH): Distance measured vertically from a rest of foot to the upper hip bone.

Sitting lowest rib bone height (SLRBH): Distance measured vertically from a rest of foot to the lowest rib bone.

Eye Height (EH): Vertical distance from the sitting surface to the inner canthus (corner) of the eye.

Stature (St): Distance measured vertically from the footrest to the vertex.

2.4 Furniture measurements

Generally benches are used in Bangladesh primary schools. Those are made by local furniture companies and they lack of various standard dimensions, because the designers and manufacturers have not minimum knowledge about ergonomics. The dimensions of the classroom furniture (Fig.2) of the three different schools were measured. Thus, the following dimensions were measured for different school but same classroom furniture.

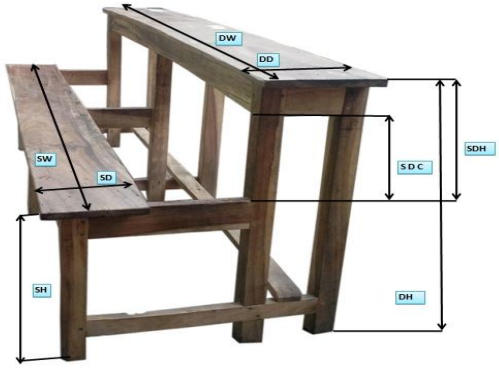


Fig.2 Representation of the classroom furniture measurements

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

Seat height (SH): Seat height measured as the vertical distance from the floor to the middle point of the front edge of the seat.

Seat width (SW): Seat width measured as the horizontal distance between the lateral edges of the seat.

Seat depth (SD): Minimum distance measured horizontally from the front edge of the sitting surface to its back edge.

Seat to desk height (SDH): The vertical distance from the top of the front edge of the seat to the top of front edge of the desk .
Seat to desk clearance (SDC): The vertical distance from the top of the front edge of the seat to the lowest structure point below the desk .
Desk width (DW): Desk width measured as the horizontal distance between the lateral edges of the desk.
Desk depth (DD): Desk depth is the distance from the back to the front of the top surface of the desk.

2.5 Classroom furniture and body dimensions mismatch:
Anthropometric dimensions of each individual student were compared to the relative school furniture dimensions in order to identify a match or mismatch between students and the furniture they used. Mismatch is defined as discrepancy between the school furniture dimensions and the student's anthropometric measurement [7]. For designing and evaluation of school furniture and to define the range in which each furniture dimension is considered appropriate, applied anthropometric and ergonomic principles should be used. Different recommended relationships have been found in the literature to identify a match or mismatch. The most commonly used are describe below:

2.5.1. Popliteal Height (PH) against Seat Height (SH):

The Seat Height (SH) is required to be adjusted relative to the Popliteal Height (PH) and allowing the knee to be flexed so that the lower legs form a maximum of 30º angle relative to the vertical axis. Generally, PH should be higher than the SH [7]. The lower leg constitutes a 5–30^0 angle relative to the vertical and also the shin-thigh angle is between 95 and 120^0 [8]. Normally, PH does not have a value higher than 4 cm or 88% of the PH [7] to avoid compression in the buttock region [9]. So, a mismatch between PH and SH is defined when the seat height is either > 95% or < 88% of the popliteal height [7] and it is possible to establish a criterion for SH [8]. For this research work, 3 cm correction for shoe height is included to the popliteal height. Therefore, using this data a match criterion is established according to equation (1).

$$(PH+3)\cos 30^0 \leq SH \leq (PH+3)\cos 5^0 \qquad (1)$$

2.5.2. Buttock popliteal length (BPL) against seat depth (SD):
Seat Depth should be at least 5 cm less than the Buttock Popliteal Length [10]. However, the thigh would not be supported enough if the SD is substantially less than the BPL of the subjects. Various researchers [11-16] explain that the seat depth should be measured for the 5th percentile of the BPL distribution so that the backrest of the seat can support the lumbar spine without compression of the popliteal surface. Thus, a mismatch between SD and BPL is defined when SD is either < 80% or >95% of BPL [7]. Therefore, a match criterion is established according to equation (2).

$$.80BPL \leq SD \leq .95BPL \qquad (2)$$

2.5.3. Hip Breadth (HB) against Seat Width (SW):
The seat width must be large enough to accommodate the user with the largest hip breadth to attain stability and permit space for lateral movements [12-14]. Various researches [15-20] show that the HW should be thinner than the SW in order to have a proper fit in the seat and an optimal seat width is selected for the 95th percentile of HW distribution or the largest HW. The revised proposed equation displays that the SW should be at least 10% (to accommodate hip breadth) and at the most 30% (for space economy) larger than the hip breadth [8]. Thus, a match criterion is determined by equation (3).

$$1.10HB \leq SW \leq 1.30HB \qquad (3)$$

2.5.4. Sitting elbow height (SEH) against desk height (DH):
A number of studies [21-22] show that the elbow height is measured as the major factor for the desk height as the load on the spine reduces significantly when the arms are supported on the desk [20] and the desk height also be subject to on the shoulder flexion and shoulder abduction angles [7] and is strong-minded by the 5th percentile. So, the desk height should be 3-5 cm higher than the SEH [16]. Thus, a match criterion is established with a revised equation (4) that accepts the SEH as the lowest height of DH [20], and considering that the extreme height of DH should not be higher than 5 cm above the SEH.

$$SEH \leq DH \leq SEH+5 \qquad (4)$$

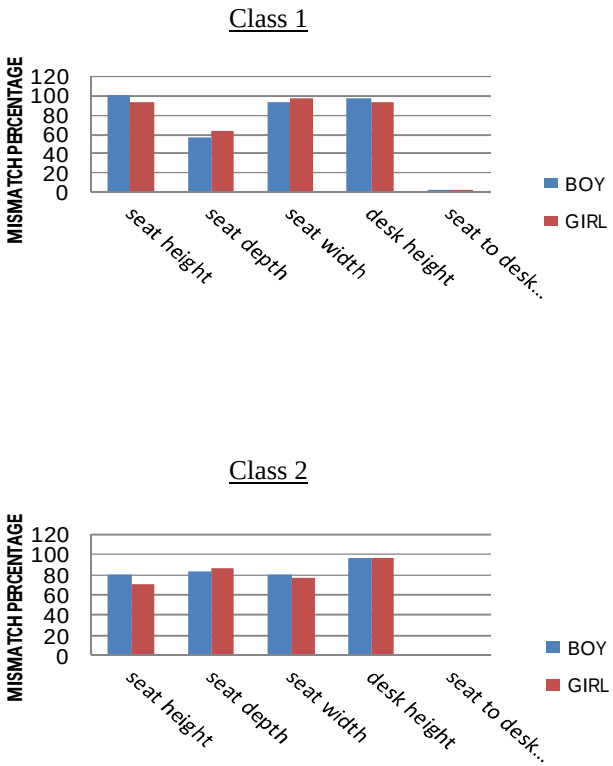
2.5.5. Thigh clearance (TC) against Seat to desk clearance (SDC):
The suitable seat to desk clearance needs to be greater than thigh clearance in order to make available leg movement [22]. The ideal seat to desk clearance should be 2 cm higher than knee height [7]. Therefore, a match criterion is recognized according to equation (5).

$$(TC+2) < SDC \qquad (5)$$

3. Results and Discussions
The aim of the current study was to evaluate the match between dimensions of the classroom furniture in school with student's anthropometric measurements. The result of this study showed considerable mismatch between students` body dimensions and classroom furniture.

The mismatch percentage between the classroom furniture dimensions which are: seat height, desk height, seat width, seat depth, seat to desk clearance and the anthropometric measurements of school students by gender and grade level are shown in Fig.3.The percentage of students which measurements match or mismatch the dimensions of the classroom furniture is presented by gender and grade level. From Fig.3, for class 1, seat height 64.44% (100% boy, 93.33% girl), seat depth 59.99% (56.66% boy, 63.33% girl), seat

width 94.99% (93.33% boy, 96.66% girl), desk height 94.99% (96.66% boy, 93.33% girl) and seat to desk clearance 3.33% (3.33% boy, 3.33% girl) were not appropriate for the students. For class 2, seat height 75% (80% boy, 70% girl), seat depth 84.99% (83.33% boy, 86.66% girl), seat width 78.33% (80% boy,76.66% girl), desk height 96.66% (96.66% boy,96.66% girl) were not appropriate for the students. For class 3, seat height 59.99% (63.33% boy, 56.66% girl), seat depth 94.99% (96.66% boy, 93.33% girl), seat width 86.66% (86.66% boy, 86.66% girl), desk height 74.66% (76% boy, 73.33% girl) and seat to desk clearance 3.33% (6.66% boy, 0% girl) were not appropriate for the students. For class 4, seat height 76.66% (76.66% boy, 76.66% girl), seat depth 91.66% (93.33% boy, 90% girl), seat width 94.99% (93.33% boy, 96.66% girl), desk height 91.66% (100% boy, 89.33% girl) and seat to desk clearance 36.66% (36,66% boy, 36.66% girl) were not appropriate for the students. For class 5, seat height 83.33% (86.66% boy, 80% girl), seat depth 96.66% (96.66% boy, 96.66% girl), seat width 100% (100% boy, 100% girl), desk height 100% (100% boys, 100% girls) and seat to desk clearance13.33% (3.33% boys, 23.33% girls) were not appropriate for the students.



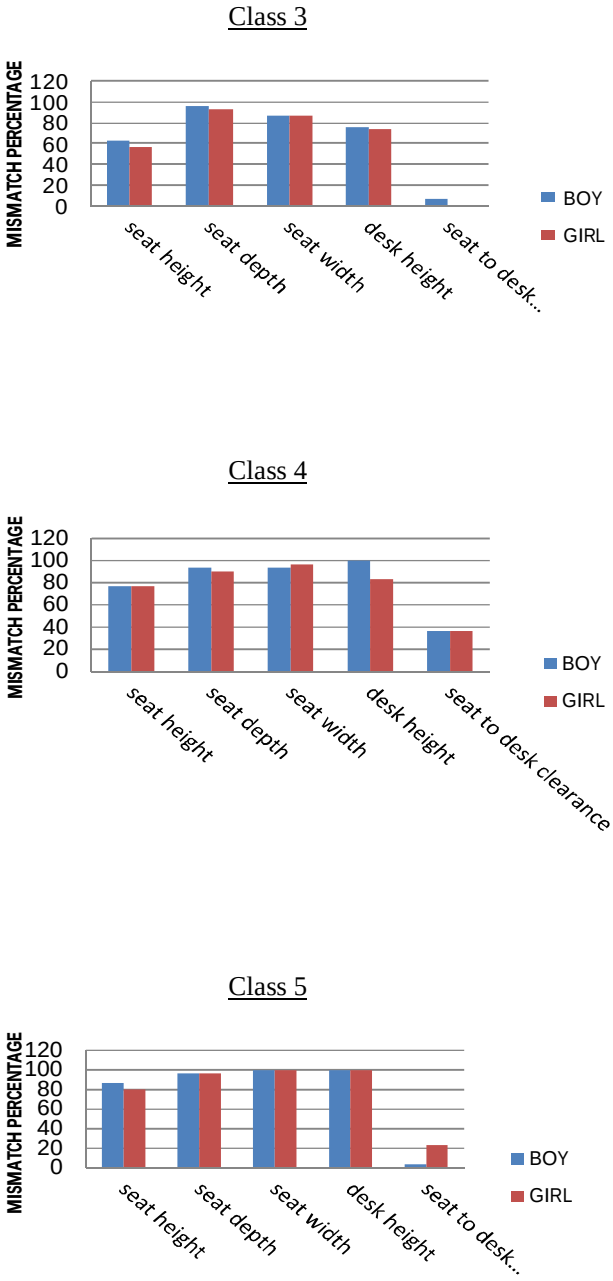


Fig.3 Mismatch percentages for different dimensions

For class 1, 100% boys and 93.33% girls used seat that were too high (high mismatch) and no low mismatch. For class 2 and 5 there were no low mismatch but had high mismatch. For class 3, there were 13.33% low mismatch and 50% high mismatch for boys and 3.33% low mismatch and 53.33% high mismatch for girls. And for class 4, 6.66% low mismatch for boys. The results indicated that the mismatch percentages decreased with grade level for both girls and boys. According to the current study based on average, the seat height only matched to 18.67% of boys and 24.67% of girls, which are obviously greatly below the lower limit of the

acceptance range. In other words, subjects are sitting on seats that are too high for them. According to filed observations most of subjects sitting with their legs not touching the floor. These positions can place high amounts of stresses on the popliteal arc that runs through the underside of the thigh and may cause serious discomfort and possibly risk injuries which are shown in Fig.4. This may lead to an increase in tissue pressure on the posterior aspect of the thighs. Since the mismatch forces students to slide forward on the seat of the classroom furniture, therefore seat height match appears to be necessary [12]. According to the current study, the seat width only matched to 25.33% of boys and 8.67% of girls, which are obviously greatly below the lower limit of the acceptance range. The high mismatch percentage for seat width dimension was as large for girls and boys for each class. An important element in the magnitude of the pressure under the buttocks is the form of the supporting surface. Some investigators have recommended that the seat width should be at least 45 cm, or 5 cm wider than the hip breadth [23, 24]. The breadth of sitting surface is determined according to the 95% percentile values of hip breadth. The seat should be wide enough to accommodate a user's hips and clothing, and comfortably allow use of the armrests. There is a need that a reasonable proportion of the population of potential users can easily get up and sit down and be satisfied with their seat design [25]. The anthropometric measure width of the hips should be lower than what should be allowed for width of the seat. There must be added, on each side, an extra width for movement of the arms if the seat is equipped with armrests.

(a) (b)

Fig. 4 Wrong furniture dimensions (a and b)
(a)Wrong seat height dimension causes student's feet unable to reach the ground.
(b)Wrong furniture dimensions force student to lift their arms and hunch their shoulders.

According to the current study, the seat depth only matched to 14.67% of boys and 14% of girls, which are obviously greatly below the lower limit of the acceptance range. The percentage of students 1-5th grade whose measurements had a bad fit with the seat depth of the classroom furniture shown in figure 3. Where benches were too deep (high mismatch) for 33.33% of boys and 6.66% of girls while they were too shallow (low mismatch) for class 1, 23.33% boys and 56.6% girls and for class 2, 3, 4 there was high mismatch and no low mismatch. But for class5, both girls and boys, there were 89.99% low mismatch and 6.66% high mismatch. As is apparent, the mismatch percentage increased with grade level for both girls and boys. On the other hand, too deep benches force students usually place their buttocks forward on the edge of the seat, especially while reading and writing.

4. Conclusion

The finding of the study is that there is a substantial inconsistency between the student's anthropometric measurements and school furniture dimensions. It is impractical and difficult to select the proper furniture for a large number of students, so, to design the furniture dimension's adjustable range design would be preferable. This paper intended to analyse the relation between body dimensions from a sample study of 300 Bangladeshi students from three schools with three different economical levels within the five classes. A considerable mismatch was identified between body dimensions (popliteal height, buttock popliteal length, hip breadth, sitting shoulder height, sitting elbow height and thigh clearance) of the school students and the classroom furniture dimensions (seat height, seat depth, seat width, backrest height, desk height and seat-to-desk clearance) available to them. The results indicated a considerable mismatch between body dimensions of the students and the existing classroom furniture. For both boys and girls seat heights and desktop heights of the classroom furniture were too high, which may result in pain on the posterior surface of the knee and shoulder region, discomfort respectively and tend to increase the risk for developing musculoskeletal problems amongst school students. The results of the study highlight the fact that classroom furniture is typically acquired and selected without any previous ergonomic concern, which will most likely result in its inadequacy.

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