

Anthropometric Consideration for Designing Class Room Furniture in Rural Schools

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ABSTRACT In today's educational environment a student is required to do class work with the school furniture (benches and desks) for at least four to six hours per day. The existing furniture designs have been in use in most of the classrooms of rural school in the state of West Bengal for the last few decades or so. But it is noticed that in most of the cases, anthropometric dimensions of the body of the user were not considered during designing of this school furniture. So, school furniture becomes ill fitted for the children. It is well known fact that body dimensions of the children varies from age, region etc. So the dimensions of furniture should also be different in different cases. The present investigation was carried out on 621 Bengalee (Indian) schoolboys having the age range of 10-15 years. Different anthropometric data were collected from these boys. It is observed from the results that all anthropometric dimensions of the school children increase with their age. Moreover, there exists a little difference between mean values of different anthropometric dimensions between the boys of 10 years and 11 years (ranges from 2.9% to 8.8%), between 12 years and 13 years (ranges from 1.3% to 9.9%), and between 14 years and 15 years (ranges from 1.4% to 5.5%). But the said differences become much higher (16.2% to 42.4%) when the same were compared between the children of 10 years and 15 years. So, it can be said that the design of furniture for the children of 10 years will not match the anthropometric dimensions of the children of 15 years. If single furniture is designed by considering anthropometric dimensions of the children from 10 years to 15 years, it will also not suit the children of all age groups. So, in the present investigation, all the students have been divided into three combined age groups, e.g., 10-11 years, 12-13 years, and 14-15 years, and the percentile values (5th, 50th and 95th) of anthropometric measures, which will be helpful for designing of the classroom furniture and layout of furniture in the classroom, were computed for these three groups separately.

1. INTRODUCTION

A school is a home away from home for the children, with a purpose to facilitate their learning activity. Children spend a considerable part of their daily life (between 4 and 6 hours per day) in school. When in school, children spend about 80% of their school time in the classroom performing various activities like reading, writing, drawing and other related activities, which requires them to sit continuously for long hours (Savanur et al., 2004). In a research work Hira (1980) concluded that four types of activities namely, listening, writing, calculating and miscellaneous were being carried out by the students in a classroom. So, children use to spend the major time on the bench and desk during school hours. Hence, it is necessary that the school furniture should suit the requirements of school children (Savanur et al., 2004). Therefore, the school furniture should be made on the basis of anthropometric dimensions of the user population (school children) of different age groups. There are some primary considerations in workstation

design. It should be recognized that the body measurements (anthropometric data) of a population group should be specific to the type of workplace (Nag, 1996). To obtain fitness between man-machine components, the maximum number of user population should use a workplace. It strives to accommodate 95 percent of the user population, in general. The dimensions of the small people establish the reach dimensions, e.g., if the shorter people can reach the objects located on higher shelves, virtually every one else can also do the job. On the other hand, when the taller people can fit in a confined area, like aisle, tunnel area, emergency exit, all others can also be accommodated. Moreover, design of this furniture should be different for male and female student, as Jeong and Park (1990) observed differences in the requirements of furniture dimensions for boys and girls. The existing school furniture, i.e., benches and desks may not be suitable for the children as these are designed without due consideration to the body dimensional requirements of the school children. It has been reflected from many studies that there is a mismatch between the classroom furniture dimensions and the anthropometric dimensions of the school children. In a study,

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Chaudhary et al. (2004) showed that the school furniture did not match up with the school children's anthropometric measures on an average. So, most of the time they have to spent in the classroom sitting for a long duration at a time confining themselves to traditional cumbersome sitting and writing furniture units (Chakrabarti et al., 2004). So, furniture induced postural problems associated with behavioral misfit become very common. Studies have shown that being confined in awkward posture for specific task demand at a given situation or as influenced by bad designed furniture for a long duration provokes psychological stress and imposes ill effects on human performance (Das et al., 2004). There are numerous medical problems that have resulted because of the use of school furniture that do not match the anthropometry of the school children. Wrongly designed school furniture induces improper posture leading to operational uneasiness and musculoskeletal and some physiological disorders among school children (Chaudhary et al., 2004). Long sitting hours in these improperly designed benches may cause health hazards in the younger generation hampering their other physical activities.

In the present investigation efforts have been made to acquire body dimension of the boys rural schools, which are useful for designing furniture and layout of the classroom.

2. METHOD

2.1 Selection of Subject

The present study was carried out on schoolboys only. For that purpose, 20 rural schools of different districts in the state of West Bengal (India) were selected at random. Six hundred twenty one (621) schoolboys (between 10 and 15 years of age) from different schools were selected at random for the present study. The total numbers of

subjects were classified into six major groups on the basis of their age (Table 1).

2.2 Measurement of Body Dimensions

Different anthropometric measures of the school children were taken by adopting proper landmark definitions and standard measuring techniques (Singh and Bhasin, 1989; Weiner and Lourie, 1969; Ermakova et al., 1985; Chakrabarti, 1997). All the body dimensions of the children were taken only from the right side of their body. The equipment used for that purpose was an anthropometer (Holtain). Accuracy and repeatability of measurement was achieved by practice prior to the data collection sessions. The data recorded for a subject was the mean of three trials. All subjects were wearing light clothes and were bare footed during measurements. During measuring body dimensions under sitting condition, the subjects were asked to sit in such a way that the upper leg and lower leg remained at right angle to each other. The following anthropometric dimensions were taken for this study:

- a) *Shoulder Height, Sitting*: Subject sat erect on a seat. Head in the frankfort plane, upper arms hanging relaxed, forearms and hands were placed horizontally forming the right angles with the upper arms. The vertical distance from the seat surface to the shoulder was measured with an anthropometer. The measuring rule of the anthropometer was placed on the acromial end of the right clavicle.
- b) *Infrascapular Height, Sitting*: The vertical distance from the seat surface to the most prominent part of the lower portion of the right infrascapular bone was measured by a shortened anthropometer. Subject sat erect on a seat. The arms were pressed against the trunk. The forearms were placed horizontally forming the right angles with the upper arms.
- c) *Lower Lumbar (5th) Height, Sitting*: The most prominent part of the upper portion of the right innominate bone was extended to the back of the subject to get the 5th lumbar vertebral point. The vertical distance from the seat surface to that point was measured by a shortened anthropometer. Sitting position of the subject was the same as during the measurement of the sitting infrascapular height.

Table 1: Classification of school children on the basis of their age and grade.

Age	Grade
10 years	Grade V
11 years	Grade VI
12 years	Grade VII
13 years	Grade VIII
14 years	Grade IX
15 years	Grade X

- d) *Popliteal Height, Sitting:* Subject sat erect on a seat, feet on the adjustable platform, knees flexed 90 degrees, and thighs parallel. With an anthropometer, the vertical distance from the floor to the lateral underside of the right thigh at a point contiguous to where the tendon of the biceps femoris muscle joins the lower leg was measured.
- e) *Elbow to Elbow Length (Writing Position), Sitting:* Horizontal distance across the lateral surfaces of the elbows (when the children used to write on the desk), spreading sideways was measured by a shortened anthropometer.
- f) *Hip Breadth, Sitting:* The horizontal distance between the maximum bulges on the soft tissues in the hip area on either side. It was measured during sitting condition of the subject by a shortened anthropometer.
- g) *Bi-deltoid Breadth, Sitting:* Subject sat erect on an adjustable seat. The arms were pressed against the trunk. The forearms were placed horizontally forming right angles with the upper arms. The maximum horizontal distance between the deltoidale on either side was measured by a shortened anthropometer during sitting condition of the subject.
- h) *Buttock-Popliteal Length, Sitting:* Subject was asked to sit erect on an adjustable seat with knees flexed 90° and thighs parallel. With the anthropometer, the horizontal distance from the most posterior aspect of the right buttock to the posterior surface of the right knee was measured.
- i) *Elbow Height from the Floor, Sitting:* Subject sat erect on an adjustable seat. The arms were pressed against the trunk. The forearms were placed horizontally forming right angles with the upper arms. The vertical distance from the seat to the olecranon of the right hand was measured with a shortened anthropometer. The measured value was then added with popliteal height of the same subject to get elbow height from the floor (sitting).
- j) *Knee Height, Sitting:* The vertical distance from the floor to the point on the anterior surface of the distal part of the thigh which projects furthest upward (but not on the upper edge of the patella) was measured with an anthropometer. Sitting condition of the subject was the same as during the measurement of popliteal height.
- k) *Thigh Clearance Height Sitting:* The vertical distance from the seat surface to the maximum bulge on the anterior surface of the thigh was measured with a shortened anthropometer. Sitting condition of the subject was the same as during the measurement of the popliteal height.
- l) *Buttock-Feet Length, Sitting:* It is the maximum distance from the buttock to the acropodion of the children. The acropodion is usually on the big toe and less frequently on the adjacent or middle toe. The thigh and shin were at right angles to each other. It was measured against a scale.
- m) *Foot Length, Sitting:* The projection of the distance between acropodion and pternion. Acropodion can be on the big toe, usually on the adjacent toe or on the middle toe. It was measured by a sliding caliper.
- n) *Buttock-Knee Length, Sitting:* Subject was asked to sit erect as stated in case of measuring buttock-popliteal length. With the anthropometer, held parallel to the long axis of the thigh, the horizontal distance from the most posterior aspect of the right buttock to the most anterior aspect of the right knee was measured.
- o) *Elbow Breadth, Sitting:* The horizontal distance between the two most prominent points on the right elbow joint was measured by a sliding caliper. Subject sat erect on an adjustable seat. The upper arms were pressed against the trunk. The forearms were placed horizontally and form right angles with the upper arms. The palms were directed inward.
- p) *Maximum Horizontal Distance Between the Calf and the Thigh, Standing:* The subject stands erect, head in the frankfort plane and both hands stretched anteriorly. Then, a plumb-line was hanged from the maximum bulge on the anterior surface of the thigh. The horizontal distance from this vertical line to the maximum bulge on the calf muscle was measured by a shortened anthropometer.
- q) *Maximum Transverse Diameter of the Body, Standing:* The horizontal distance between the maximum projecting points on either side of freely hanging arms. The maximum bulge on the lateral surface of the left arm of the individual touches the lateral wall of the stand and his hips or scapula touch the central wall. The reading against the

maximum bulge on the lateral surface of the right arm was noted.

2.3 Percentile Values of Anthropometric Dimensions of the User

For selecting design dimension of the school furniture and classroom layout, different percentile values of the measured body dimensions of the students were calculated. Three percentile values, viz., 5th, 50th and 95th, for each body dimension were computed with the help of standard statistical packages.

3. RESULTS AND DISCUSSION

3.1 Anthropometric Survey

There are enormous variations in body size among individuals. The body dimension should match with furniture, equipment etc in a workstation. On the other hand, any mismatch in the work environment leads to users' discomfort, low productivity, work hazards, and accidents. So, it can be said that body dimensions of children are important for the design of furniture, particularly which are used in schools. This possesses problems because children of different body sizes may be combined in the same classroom. Thus, desks and benches of very different sizes should be made available to fit different children. This is often difficult to do for a variety of organizational reasons. Provision of adjustable benches and desks, for example, might appear a suitable solution, but especially young children might have great difficulties in adjusting that furniture to their size and liking (Corlett et al., 1986).

Moreover, adjustable seats and desks are costlier than the ordinary one. The most of the Indian schools situated in rural and semi-urban areas are unable to provide such furniture because of financial reasons. Therefore, it will be suitable to make fixed design of school furniture considering the anthropometric data of school children. Different anthropometric dimensions which are related to classroom furniture and layout design are presented in Table 2. Results reflect that all anthropometric dimensions of the school children increase as their age increases.

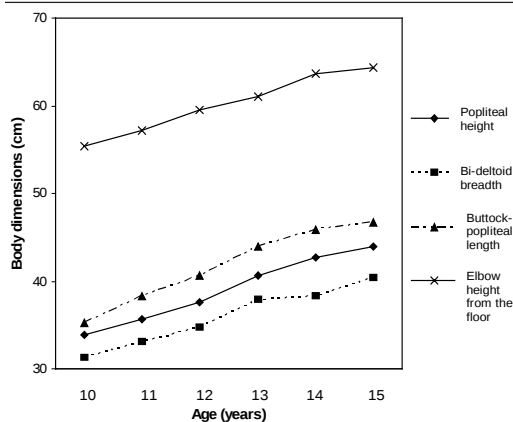
Four important body dimensions, which are related to school furniture design, are found to vary as the function of age of the children. These are shown in Figure 1. It may be noted from the

figure that all the variables increases with age. With the increase of age, development of skeletal system, muscular system, and other systems of the body occurs, and as a resultant effect anthropometric measures increase. So, it may be said that furniture of the same size will not fit the body dimension of the children of all age groups. The results indicate the need for separate design of furniture for different age groups.

In designing for a known individual, one's own body dimensions may be measured and used. But for mass application the percentile values of a study population are usually required. A 95th percentile value of a body dimension (e.g., body height) would indicate that 95 percent of the study population have the same or less body height, and only the remaining 5 percent of the population have greater heights. The 50th percentile value represents closely the average, which divides the whole study population into two equal halves. As a matter of fact, no such person really exists, having all the body dimensions of 95th or 50th or 5th percentiles. Therefore, for design application, different percentile values of different dimensions may be necessary even on a simple design solution. Based on task requirement, appropriate percentile selection of body dimensions is required. Lower percentile values are considered for accommodating the maximum number of people having higher values, where easy reach is the concern. Higher percentile values are considered where the maximum number of population having lower values cannot reach the level, as required in ensuring safety and ease of operation (Nag, 1996). In the present investigation, various percentile values (5th, 50th and 95th) of different anthropometric dimensions of the school children of different age groups are computed for the purpose of designing school furniture and layout of the classroom. These are presented in different tables. Table 3 shows mean differences (%) of anthropometric dimensions between the schoolboys of 10 and 11 years. It is observed from this table that differences between mean values of various anthropometric dimensions of schoolboys of 10 years and 11 years are very small (only 2.9% to 8.8%). It indicates that there is no massive change in body growth of the school children in this small age group. The changes are as little as 0.4-3.8 cm for all body measures. Therefore, the boys of two age groups are merged together and may be considered as a single group while selecting design dimensions for the school furniture. The

Table 2: Mean $\pm$ S.D., and (ranges) of different anthropometric dimensions of schoolboys of different age groups.

Anthropometric dimensions (cm)	Age groups					
	10 years (n=106)	11 years (n=105)	12 years (n=104)	13 years (n=103)	14 years (n=102)	15 years (n=101)
Shoulder height, sitting	42.2 $\pm$ 2.7 (38.5-50.5)	44.8 $\pm$ 3.4 (37.8-52.9)	47.0 $\pm$ 3.4 (39.5-56.8)	49.9 $\pm$ 3.9 (40.5-56.0)	50.9 $\pm$ 3.1 (44.0-60.2)	53.7 $\pm$ 3.7 (45.0-61.0)
Infrascapulare height, sitting	31.9 $\pm$ 2.4 (26.0-39.5)	33.7 $\pm$ 3.1 (28.2-42.1)	35.0 $\pm$ 2.8 (29.5-43.5)	38.3 $\pm$ 4.0 (30.5-45.5)	38.9 $\pm$ 3.3 (32.0-45.0)	40.8 $\pm$ 3.2 (33.2-47.2)
Lower lumbar (5 th) height, sitting	17.0 $\pm$ 1.7 (15.7-24.2)	18.5 $\pm$ 1.6 (16.5-25.1)	19.2 $\pm$ 1.8 (18.5-25.9)	21.1 $\pm$ 2.4 (18.7-26.8)	22.6 $\pm$ 2.2 (19.2-28.7)	23.8 $\pm$ 1.5 (21.0-30.0)
Popliteal height, sitting	33.9 $\pm$ 2.2 (27.7-39.5)	35.7 $\pm$ 2.5 (28.8-41.0)	37.6 $\pm$ 2.3 (30.7-45.5)	40.6 $\pm$ 3.7 (34.2-48.2)	42.7 $\pm$ 3.5 (36.5-51.5)	44.0 $\pm$ 3.1 (40.0-50.0)
Buttock-popliteal length, sitting	35.3 $\pm$ 2.7 (30.0-43.1)	38.3 $\pm$ 2.8 (32.3-45.0)	40.6 $\pm$ 2.8 (33.5-46.5)	44.0 $\pm$ 4.5 (35.3-53.2)	45.9 $\pm$ 3.8 (40.0-54.0)	46.7 $\pm$ 2.8 (41.8-53.0)
Buttock-knee length, sitting	42.7 $\pm$ 3.1 (35.6-50.2)	46.3 $\pm$ 3.5 (39.2-54.4)	49.5 $\pm$ 3.5 (40.5-58.1)	52.8 $\pm$ 4.4 (43.8-63.0)	53.8 $\pm$ 5.7 (44.0-68.9)	54.6 $\pm$ 3.2 (45.5-62.8)
Buttock-feet length, sitting	54.1 $\pm$ 2.0 (48.5-60.2)	57.9 $\pm$ 2.8 (50.2-62.3)	61.8 $\pm$ 3.3 (58.1-63.8)	62.6 $\pm$ 3.9 (60.7-67.1)	65.2 $\pm$ 3.5 (63.1-70.5)	68.0 $\pm$ 4.2 (65.1-72.2)
Elbow height from the floor, sitting	55.4 $\pm$ 2.2 (35.9-62.1)	57.2 $\pm$ 2.4 (37.1-65.1)	59.5 $\pm$ 2.3 (39.7-66.9)	61.1 $\pm$ 2.3 (40.5-70.1)	63.6 $\pm$ 2.1 (42.2-71.1)	64.4 $\pm$ 2.2 (43.9-72.8)
Elbow breadth, sitting	5.2 $\pm$ 0.4 (4.5-6.7)	5.6 $\pm$ 1.1 (4.3-5.7)	5.8 $\pm$ 0.6 (5.0-8.0)	6.3 $\pm$ 0.7 (5.0-7.9)	6.8 $\pm$ 0.7 (5.2-8.6)	7.0 $\pm$ 0.7 (6.0-8.9)
Elbow to elbow length (writing position), sitting	40.5 $\pm$ 6.2 (34.5-60.5)	41.9 $\pm$ 4.9 (39.5-61.0)	43.4 $\pm$ 7.2 (40.9-62.0)	45.7 $\pm$ 6.5 (42.0-63.1)	46.4 $\pm$ 5.4 (45.0-63.9)	47.9 $\pm$ 7.5 (45.8-64.5)
Knee height, sitting	41.3 $\pm$ 2.3 (33.2-45.4)	42.5 $\pm$ 2.2 (34.4-47.5)	45.0 $\pm$ 2.7 (36.1-48.4)	46.2 $\pm$ 2.4 (37.2-50.2)	48.9 $\pm$ 2.3 (38.8-52.3)	50.7 $\pm$ 2.4 (40.5-54.4)
Foot length, sitting	18.6 $\pm$ 1.2 (17.0-24.3)	19.2 $\pm$ 1.5 (18.5-25.0)	20.2 $\pm$ 2.0 (20.0-24.0)	21.0 $\pm$ 1.5 (20.6-25.0)	22.5 $\pm$ 1.5 (21.0-26.8)	23.1 $\pm$ 1.0 (20.6-27.2)
Thigh clearance height from seat, sitting	9.9 $\pm$ 0.8 (7.3-11.7)	10.6 $\pm$ 1.3 (8.4-12.0)	11.2 $\pm$ 1.3 (9.1-12.9)	12.3 $\pm$ 0.7 (10.0-13.2)	13.5 $\pm$ 0.9 (12.2-15.6)	14.1 $\pm$ 1.1 (13.5-15.7)
Hip breadth, sitting	21.8 $\pm$ 1.6 (18.9-27.4)	23.2 $\pm$ 1.9 (19.5-28.4)	24.7 $\pm$ 2.2 (20.5-30.0)	27.0 $\pm$ 3.2 (21.4-32.6)	28.9 $\pm$ 2.1 (23.8-35.5)	29.5 $\pm$ 1.9 (26.3-36.1)
Bi-deltoid breadth, sitting	31.2 $\pm$ 2.3 (25.9-39.3)	33.0 $\pm$ 2.6 (23.2-39.7)	34.7 $\pm$ 3.0 (29.6-43.0)	37.8 $\pm$ 4.3 (29.3-45.9)	38.3 $\pm$ 3.0 (30.1-46.9)	40.3 $\pm$ 3.1 (32.8-48.0)
Maximum horizontal distance between the calf and the thigh, standing	11.8 $\pm$ 1.7 (10.0-14.5)	12.5 $\pm$ 1.2 (11.1-15.3)	14.0 $\pm$ 1.1 (12.2-16.0)	14.3 $\pm$ 1.7 (12.8-16.8)	15.1 $\pm$ 1.3 (13.0-17.2)	15.8 $\pm$ 1.8 (14.2-18.1)
Maximum transverse diameter of the body, standing	33.8 $\pm$ 1.9 (30.9-34.3)	35.9 $\pm$ 2.6 (31.2-36.7)	37.7 $\pm$ 2.8 (32.6-38.9)	40.5 $\pm$ 2.1 (34.3-41.2)	41.3 $\pm$ 1.9 (36.1-42.6)	42.9 $\pm$ 2.2 (39.8-44.0)


Fig. 1. Different body dimensions of school children as function of age

percentile values of the anthropometric dimensions of the merged age group (10-11 years) are shown in Table 3. Similarly the mean differences (%) of different anthropometric dimensions of the boys between 12 and 13 years are very small (1.3% to 9.9%) and the mean differences (%) in case of 14 and 15 years vary from only 1.4% to 5.5%. Those two pairs of neighbouring age groups are also treated as two single groups (12-13 years and 14-15 years) and their percentile values body dimensions were computed which are shown in Table 4 and Table 5 respectively.

On the other hand, the mean differences of body dimension are appreciably large (16.2% to 42.2%) when they are compared between the

boys of 10 years and 15 years. Therefore, design for single group (10-15 years) will not be suitable for matching user body dimension and furniture dimension. So, it is suggested to formulate furniture design for three different small age groups.

Different percentile values of anthropometric dimensions of schoolboys of different age groups (present study) are compared (in Table 6) with the data as obtained from the work of Chakrabarti et al. (2004). For this purpose, different percentile values (5th and 95th) of different anthropometric dimensions of two combined age groups (11-12 years, and 13-14 years) have been computed. It is noted that data obtained from the present study are more or less the same (or a little difference) with the data as obtained from the study of

Chakrabarti et al. (2004). These investigators collected data from the subjects of eastern part of India. The present investigation has also been conducted in the places, which are the parts of eastern India. This may be one of the possible reasons for a little difference (3.2% to 7.7%) between the data as obtained from the present study and the data obtained from the work of Chakrabarti et al. (2004).

During designing of school furniture various aspects of human comfort must be considered to make it suitable for the user. So, consideration of different anthropometric dimensions of the school children is essential during determination of dimensions of classroom furniture. The anthropometric database of the present investigation may be helpful for designing of

Table 3: Percentile values of different anthropometric dimensions of schoolboys between 10 and 11 years of age.

<i>Anthropometric dimensions (cm)</i>	<i>10 years (n=106)</i>	<i>11 years (n=105)</i>	<i>Mean differences (%)</i>	<i>Grand mean and SD (10-11years)</i>	<i>5th%-ile</i>	<i>50th%-ile</i>	<i>95th%-ile</i>
Shoulder height*	42.2±2.7 (38.5-50.5)	44.8±3.4 (37.8-52.9)	6.2	43.5±3.3	38.1	43.5	48.9
Infrascapulare height*	31.9±2.4 (26.0-39.5)	33.7±3.1 (28.2-42.1)	5.6	32.8±2.9	28.0	32.8	37.6
Lower lumber (5 th) height*	17.0±1.7 (15.7-24.2)	18.5±1.6 (16.5-25.1)	8.8	17.7±1.8	14.7	17.7	20.7
Popliteal height*	33.9±2.2 (27.7-39.5)	35.7±2.5 (28.8-41.0)	5.3	34.8±2.5	30.7	34.8	38.9
Buttock-popliteal length*	35.3±2.7 (30.0-43.1)	38.3±2.8 (32.3-45.0)	8.5	36.8±3.1	31.7	36.8	41.9
Buttock-knee length*	42.7±3.1 (35.6-50.2)	46.3±3.5 (39.2-54.4)	8.4	44.5±3.8	38.2	44.5	50.8
Buttock-feet length*	54.1±2.0 (48.5-60.2)	57.9±2.8 (50.2-62.3)	7.0	56.0±3.1	50.9	56.0	61.1
Elbow height from the floor*	55.4±2.2 (35.9-62.1)	57.2±2.4 (37.1-65.1)	3.2	56.3±2.5	52.2	56.3	60.4
Elbow breadth*	5.2±0.4 (4.5-6.7)	5.6±1.1 (4.3-5.7)	7.7	5.4±0.9	3.9	5.4	6.9
Elbow to elbow length (writing position) *	40.5±6.2 (34.5-60.5)	41.9±4.9 (39.5-61.0)	3.5	41.2±5.6	32.0	41.2	50.4
Knee height*	41.3±2.3 (33.2-45.4)	42.5±2.2 (34.4-47.5)	2.9	41.9±2.3	38.1	41.9	45.7
Foot length*	18.6±1.2 (17.0-24.3)	19.2±1.5 (18.5-25.0)	3.2	18.9±1.4	16.6	18.9	21.2
Thigh clearance height from seat*	9.9±0.8 (7.3-11.7)	10.6±1.3 (8.4-12.0)	7.1	10.2±1.1	8.4	10.2	12.0
Hip breadth (cm) *	21.8±1.6 (18.9-27.4)	23.2±1.9 (19.5-28.4)	6.4	22.5±1.9	19.4	22.5	25.6
Bi-deltoid breadth *	31.2±2.3 (25.9-39.3)	33.0±2.6 (23.2-39.7)	5.8	32.1±2.6	27.8	32.1	36.4
Maximum horizontal distance between the calf and the thigh**	11.8±1.7 (10.0-14.5)	12.5±1.2 (11.1-15.3)	5.9	12.1±1.5	9.6	12.1	14.6
Maximum transverse diameter of the body**	33.8±1.9 (30.9-34.3)	35.9±2.6 (31.2-36.7)	6.2	34.8±2.5	30.7	34.8	38.9

*Sitting condition

** Standing condition

school furniture for the boys' schools in rural areas of the state of West Bengal. The important dimensions of the furniture and the relevant user-dimensions are shown Table 7. The upper surface height of the seat (bench) corresponds to the popliteal height of the population is under consideration (Sane et al., 2004). Other investigators (Molenbroek et al., 2003; Chakrabarti and Das, 2004), also hold the same opinion. On the other hand, the width of the seat may be determined from the hip width of the user during sitting condition (Molenbroek et al., 2003 and Sane et al., 2004). So, data of sitting hip breadth obtained from the present investigation may be used for the determination of width of a single user seat. But it

should be more comfortable for the user if the length of the seat (bench) is determined by considering their sitting bi-deltoid breadth, in case of multiple users' seat. The data of the same collected from the present investigation will serve the purpose. Buttock-popliteal length (sitting) is helpful for the determination of depth of the seat (Chakrabarti and Das, 2004). For the determination of table height investigators (Molenbroek et al., 2003) used the data of sitting elbow height of the user. So, data of sitting elbow height from the floor collected from the present investigation may be used for the determination of height of the working surface (desk) for seated children. Kroemer and Grandjean (2001) express that if we consider the

Table 4: Percentile values of different anthropometric dimensions of schoolboys between 12 to 13 years of age.

<i>Anthropometric dimensions (cm)</i>	<i>12 years (n=104)</i>	<i>13 years (n=103)</i>	<i>Mean differences (%)</i>	<i>Grand mean and S.D. (12-13 years)</i>	<i>5th %-ile</i>	<i>50th %-ile</i>	<i>95th %-ile</i>
Shoulder height*	47.0±3.4 (39.5-56.8)	49.9±3.9 (40.5-56.0)	6.2	48.4±3.9	42.0	48.4	54.8
Infrascapulare height*	35.0±2.8 (29.5-43.5)	38.3±4.0 (30.5-45.5)	9.4	36.6±3.8	30.3	36.6	42.9
Lower lumbar (5 th) height*	19.2±1.8 (18.5-25.9)	21.1±2.4 (18.7-26.8)	9.9	20.1±2.3	16.3	20.1	23.9
Popliteal height*	37.6±2.3 (30.7-45.5)	40.6±3.7 (34.2-48.2)	8.0	39.1±3.4	33.5	39.1	44.7
Buttock-popliteal length*	40.6±2.8 (33.5-46.5)	44.0±4.5 (35.3-53.2)	8.4	42.3±4.1	35.6	42.3	49.0
Buttock-knee length*	49.5±3.5 (40.5-58.1)	52.8±4.4 (43.8-63.0)	6.7	51.1±4.3	44.0	51.1	58.2
Buttock-feet length*	61.8±3.3 (58.1-63.8)	62.6±3.9 (60.7-67.1)	1.3	62.2±3.6	56.3	62.2	68.1
Elbow height from the floor*	59.5±2.3 (39.7-66.9)	61.1±2.3 (40.5-70.1)	2.7	60.3±2.4	56.4	60.3	64.2
Elbow breadth*	5.8±0.6 (5.0-8.0)	6.3±0.7 (5.0-7.9)	8.6	6.0±0.7	4.8	6.0	7.2
Elbow to elbow length (writing position) *	43.4±7.2 (40.9-62.0)	45.7±6.5 (42.0-63.1)	5.3	44.5±7.0	33.0	44.5	56.0
Knee height*	45.0±2.7 (36.1-48.4)	46.2±2.4 (37.2-50.2)	2.7	45.6±2.6	41.3	45.6	49.9
Foot length*	20.2±2.0 (20.0-24.0)	21.0±1.5 (20.6-25.0)	4.0	20.6±1.8	17.6	20.6	23.6
Thigh clearance height from seat*	11.2±1.3 (9.1-12.9)	12.3±0.7 (10.0-13.2)	9.8	11.7±1.2	9.7	11.7	13.7
Hip breadth (cm) *	24.7±2.2 (20.5-30.0)	27.0±3.2 (21.4-32.6)	9.3	25.8±2.9	21.0	25.8	30.6
Bi-deltoid breadth *	34.7±3.0 (29.6-43.0)	37.8±4.3 (29.3-45.9)	8.9	36.2±4.0	29.6	36.2	42.8
Maximum horizontal distance between the calf and the thigh**	14.0±1.1 (12.2-16.0)	14.3±1.7 (12.8-16.8)	2.1	14.1±1.4	11.8	14.1	16.4
Maximum transverse diameter of the body**	37.7±2.8 (32.6-38.9)	40.5±2.1 (34.3-41.2)	7.4	39.1±2.8	34.5	39.1	43.7

*Sitting condition

** Standing condition

Table 5: Percentile values of different anthropometric dimensions of schoolboys between 14 to 15 years of age.

<i>Anthropometric dimensions (cm)</i>	<i>14 years (n=102)</i>	<i>15 years (n=101)</i>	<i>Mean differences (%)</i>	<i>Grand mean and S.D. (14-15 years)</i>	<i>5th %ile</i>	<i>50th %ile</i>	<i>95th %ile</i>
Shoulder height*	50.9±3.1 (44.0-60.2)	53.7±3.7 (45.0-61.0)	5.5	52.3±3.7	46.2	52.3	58.4
Infrascapulare height*	38.9±3.3 (32.0-45.0)	40.8±3.2 (33.2-47.2)	4.9	39.8±3.4	34.2	39.8	45.4
Lower lumbar (5 th) height*	22.6±2.2 (19.2-28.7)	23.8±1.5 (21.0-30.0)	5.3	23.2±2.0	19.9	23.2	26.5
Popliteal height*	42.7±3.5 (36.5-51.5)	44.0±3.1 (40.0-50.0)	3.0	43.3±3.4	37.7	43.3	48.9
Buttock-popliteal length*	45.9±3.8 (40.0-54.0)	46.7±2.8 (41.8-53.0)	1.7	46.3±3.4	40.7	46.3	51.9
Buttock-knee length*	53.8±5.7 (44.0-68.9)	54.6±3.2 (45.5-62.8)	1.5	54.2±4.6	46.6	54.2	61.8
Buttock-feet length*	65.2±3.5 (63.1-70.5)	68.0±4.2 (65.1-72.2)	4.3	66.6±4.1	59.9	66.6	73.3
Elbow height from the floor*	63.6±2.1 (42.2-71.1)	64.4±2.2 (43.9-72.8)	1.4	64.0±2.2	60.4	64.0	67.6
Elbow breadth*	6.8±0.7 (5.2-8.6)	7.0±0.7 (6.0-8.9)	2.9	6.9±0.7	5.7	6.9	8.1
Elbow to elbow length (writing position)*	46.4±5.4 (45.0-63.9)	47.9±7.5 (45.8-64.5)	3.2	47.1±6.6	36.2	47.1	58.0
Knee height*	48.9±2.3 (38.8-52.3)	50.7±2.4 (40.5-54.4)	3.7	49.8±2.5	45.7	49.8	53.9
Foot length*	22.5±1.5 (21.0-26.8)	23.1±1.0 (20.6-27.2)	2.7	22.8±1.3	20.7	22.8	24.9
Thigh clearance height from seat*	13.5±0.9 (12.2-15.6)	14.1±1.1 (13.5-15.7)	4.4	13.8±1.0	12.2	13.8	15.4
Hip breadth (cm) *	28.9±2.1 (23.8-35.5)	29.5±1.9 (26.3-36.1)	2.1	29.2±2.1	25.7	29.2	32.7
Bi-deltoid breadth *	38.3±3.0 (30.1-46.9)	40.3±3.1 (32.8-48.0)	5.2	39.3±3.2	34.0	39.3	44.6
Maximum horizontal distance between the calf and the thigh**	15.1±1.3 (13.0-17.2)	15.8±1.8 (14.2-18.1)	4.6	15.4±1.6	12.8	15.4	18.0
Maximum transverse diameter of the body**	41.3±1.9 (36.1-42.6)	42.9±2.2 (39.8-44.0)	3.9	42.1±2.2	38.5	42.1	45.7

* Sitting condition

** Standing condition

Table 6: Comparison of percentile values of different anthropometric dimensions (sitting) of schoolboys between the present study and other study.

<i>Anthropometric dimensions(cm)</i>	<i>%-iles</i>	<i>Age groups</i>					
		<i>11-12 years</i>			<i>13-14 years</i>		
		<i>Present study</i>	<i>Other study**</i>	<i>Difference (%)</i>	<i>Present study</i>	<i>Other study**</i>	<i>Difference (%)</i>
Lower lumbar (5 th) height*	05	16.0	15.9	0.6	17.8	16.5	7.3
Buttock-popliteal length*	05	34.8	33.7	3.2	37.8	39.0	3.2
Thigh clearance height from seat*	95	13.0	14.2	9.2	14.2	15.3	7.7
Buttock-knee length*	95	53.6	52.3	2.4	61.7	57.7	6.5

* Sitting condition,

**Chakrabarti et al. (2004)

measurement 'ground-to-upper surface of knee' and make certain additions to allow for heels and for a minimum amount of movement, we will get

the space for free knee room. So, it can be said that the dimension of sitting knee height of the present investigation will be helpful for the

Table 7: The relevant dimensions in anthropometric design of school furniture.

<i>User-dimensions</i>		<i>Product-dimensions</i>	
A)	Popliteal height, sitting	1)	Upper surface height of the bench
B)	Bi-deltoid breadth, sitting	2)	Length of the bench (in case of multiple user)
C)	Buttock-popliteal length, sitting	3)	Depth of the bench
D)	Elbow height from the floor, sitting	4)	Height of the desk
E)	Knee height, sitting	5)	Free knee room under the desk
F)	Thigh clearance height from seat, sitting	6)	Vertical span for the accommodation of thighs between the bench top and underside of the desk
G)	Buttock-feet length, sitting	7)	Horizontal clearance below the desk
H)	Elbow to elbow length (writing position), sitting	8)	Length of the desk
I)	Infrascapulare height, sitting	9)	Upper edge height of the backrest from the bench surface
J)	Lower lumbar (5 th) height, sitting	10)	Lower edge height of the backrest from the bench surface
K)	Maximum horizontal distance between the calf and the thigh, standing	11)	Horizontal clearance for standing between the desk and the bench (in case of joined bench and desk unit)

determination of free knee room under the desk. It may be mentioned that the thigh clearance height from seat (sitting) should be used for the determination of vertical span for the accommodation of thighs between the bench top and underside of the desk. Molenbroek et al. (2003) also used thigh clearance sitting for the determination of vertical span below table. Buttock-feet length, sitting may be used for the determination of horizontal clearance below the desk. To determine tabletop length shoulder width of the user have been used by some workers (Sane et al., 2004). The said length determined from shoulder width may be suitable for a single user table. But in case of multiple user-desk, the length calculated from the elbow-to-elbow length in writing position may be more suitable. Height for the upper point of the back support was also determined from the height of the lowest point of scapula (Molenbroek et al., 2003). In the present investigation sitting infrascapulare height was measured which will be helpful for the determination of the upper edge height of the backrest from the bench surface. Also the backrest must be capable of supporting the entire width of the back as well as to provide support for the lower back, i.e., lumbar vertebrae (Sane et al., 2004). Chakrabarti and Das (2004) considered lower lumbar height from seat for determining the lowest point height of the back support. The sitting lower lumbar (5th) height collected from the present investigation may be used for determining the lower edge height of the backrest from the bench surface. This is also suggested by Chakroboti and Das (2004). Maximum horizontal distance between the calf and the thigh (standing position) may be used for determining

horizontal clearance for standing between the bench and the desk (in case of joined furniture unit). Foot length may be used for the determination of horizontal distance between the two front legs of a bench and two hind legs of a desk (in case of joined wooden furniture containing a four legged desk and a four legged bench). Buttock-knee length (sitting) may be helpful for the assessment of horizontal space below the desk for accommodating the knees of the users. Width of upper surfaces of armrests (in case of single seated chair/bench) may be determined from the sitting elbow breadth. Maximum transverse diameter of the body may be helpful for the determination of minimal dimension required for passageways in the classroom, which may be helpful for designing classroom layout.

While making school furniture the anthropometric dimension of the user should be used. The physical dimension should be settled from the suitable users body dimension. Some important anthropometric dimensions and their applications are summarized in table 7.

4. CONCLUSION

From the present study it may suggested that the design criteria should be selected for three age groups (10-11 years, 12-13 years and 14-15 years) in a secondary school. Otherwise there are chances for misfit between the school furniture and the students. Due to use of ill-designed furniture the school children may face many problems like, fatigue, muscular stress, and pain/discomfort in their different body parts. Further, improper design of classroom layout also causes various problems of the children and

their free movement in the classroom may be obstructed. Therefore, while designing the school furniture and classroom layout, the anthropometric dimensions of the children should be taken into account. The anthropometric database of the present investigation may be helpful for designing school furniture and layout design of the classroom for the boys' schools in rural areas. For co-education schools (for both boys and girls) separate database should be constructed because anthropometric measures of boys and girls differ. Further study is needed in this direction.

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