Anthropometric Consideration for Designing Class Room Furniture in Arabic Primary and Preparatory Boys Schools

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ABSTRACT

Background: *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. However, anthropometric dimensions of the body of the students were not considered during designing of this school furniture. Therefore the school furniture becomes ill fitted for the children. It is a known fact that body dimensions of the children varies from age and region. Consequently, the dimensions of furniture should also be different in different cases.* ***Objective:*** *The objective of this study was to determine reliable and accurate structural anthropometrical measurements for male students to use in the product design process.* ***Methods:*** *The present investigation was carried out on 90 Saudi schoolboys having the age range of 6-15 years. Different anthropometric data were collected from these boys.* ***Results and Conclusion:*** *The results revealed that all the anthropometric dimensions of the schoolchildren increase with their age. Regarding the primary schoolboys, there were a large difference between mean values of different anthropometric dimensions between the boys of grade I and grade II (4.94% to 42.94%), between grade III and grade IV (0.57% to 16.10%) and between grade V and grade VI (0.30% to 20.58%). Similarly, for the preparatory schoolboys, there were a large difference between mean values of different anthropometric dimensions between the boys of grade VII and grade VIII (0.02% to 30.64%) and between grade VIII and grade IX (0.43% to 22.18%). Therefore, the design of furniture for the children of grade I will not match the anthropometric dimensions of the children of grade VI. Similarly, the design of furniture for the children of grade VII will not match the anthropometric dimensions of the children of grade IX. This Study also computed the percentile values (5^{th}, 50^{th} and 95^{th}) of anthropometric measures, which will be helpful for designing of the classroom furniture and layout of furniture in the classroom from grade I to Grade IX.*

Key words: *School children, Anthropometric dimensions, Classroom furniture.*

INTRODUCTION

Children, teenagers and college students spend a lot of time sitting at school. Mostly they sit in forward leaning position like during writing and painting. While resting or attending to the teacher, students adopt backward position learning against the back rest (Paulsen and Hansen, 1994). The design of suitable school furniture is complicated not only by the fact that school work involves a variety of tasks and postures, but also by the diversity of student's body dimensions (Parcells et al., 1999).

There are a substantial degree of mismatch between the sizes of the furniture and the anthropometric data of its users. For children between 7 and 14 years old, chair is too high and too deep and the table is too high (Panagiotopulou et al., 2004). On the other hand, in the age group 12 to 18 years, it was found that the smallest students had the best fit. Taller students were more at risk of developing spinal pain (Milanese, 2004).

Anthropometric measurements of human body have been developed for various reasons since early time of history (Bolstad, 2001). The aim is to eliminate harmful postures and to minimize the design imposed stresses on the user.

A school is a home away from home for children, with purpose to participate their learning activity. Children spend a considerable part of their daily life (between 4 and 6 hours per day) in school (Khaspuri, 2007). When in school, children spend about 80% of their school time in the class room performing various activities like reading, writing , drawing and other related activities which requires them to sit continuously for long hours. Children used to spend the major time on the disk during school hours. Hence, it is necessary that the school furniture should suit the requirements of schoolchildren (Savanur et al., 2004). Therefore, the school furniture should be made on the basis of the anthropometric dimensions of the user population (schoolchildren) of different age groups.

The existing school furniture design has been in use in most of classrooms of schools in Egypt for at least few decades. The body anthropometric dimensions measurements were not considered during the designing of this school furniture. Therefore, it becomes ill fitted for students. It has been reflected from many studies that there is a mismatch between the classroom furniture dimensions and anthropometric dimensions of schoolchildren.

Chaudhary et al. (2004) showed that the school furniture did not match up with the schoolchildren's anthropometric measures on an average. Without proper design, sitting will require greater muscular force and control to maintain stability and equilibrium. This in turn, results in greater fatigue and discomfort and is likely to cause postural habits as well as neck or back complaints. Most important for schoolchildren, musculoskeletal stress resulting from efforts to maintain stability and comfort of seating may make for a fidgety individual, a condition not conductive to focused learning. There are numerous medical problems that have resulted because of the use of school furniture that do not match the anthropometry of schoolchildren. Wrongly designed school furniture induces improper posture leading to operational uneasiness and musculoskeletal and some physiological disorders among schoolchildren (Chaudhary, 2004). It well known that the body dimensions of children vary according to age, sex and region. In addition in Arabic countries the schoolchildren anthropometry did not considered for designing classroom furniture.

The main objective of this study was to determine reliable and accurate structural anthropometrical measurements for male's students to use in the product design process.

SUBJECTS AND METHODS

Subjects

With a target population of schoolchildren between 6 and 15 years of age, a convenience sample of primary one-through preparatory three grade students was drawn from one primary and one preparatory boys schools (El-Nassr and El-Azhar institute respectively) in Tanta-Egypt. The ethical approval was obtained from the concerned school authority. After parental permission, 90 students were participated in the study. A classification of schoolboys was performed on the basis of their age and grade (Table 1).

Table (1): Classification of the schoolboys on the basis of their age and grades.

Level	Grade	Age Range (Years)	Number of Boys
Primary Level	Grade I	6 : < 7	10
	Grade II	7 : < 8	10
	Grade III	8 : < 9	10
	Grade IV	9 : < 10	10
	Grade V	10 : < 11	10
	Grade VI	11 : < 12	10
Preparatory Level	Grade VII	12 : < 13	10
	Grade VIII	13 : < 14	10
	Grade IX	14 : ≤ 15	10

Measurement of Body Dimensions

Different anthropometric measures of the schoolchildren 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 tape measurement. 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:

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 tape measurement. The beginning of the tape measurement was placed on the acromial end of the right clavicle.

Infrascapulare Height, Sitting: The vertical distance from the seat surface to the most prominent part of the lower portion of the right infrascapulare bone was measured. 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.

Lower Lumbar (5th) Height, Sitting: The most prominent part of the upper portion of the right in nominate bone was extended to the back of the subject to get the 5thlumbar vertebral point. The vertical distance from the seat surface to that point was measured. Sitting position of the subject was the same as during the measurement of the sitting infrascapulare height.

Popliteal Height, Sitting: Subject sat erect on a seat, feet on the adjustable platform, knees flexed 90 degrees, and thighs parallel. With tape measurement, 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.

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.

Hip Breadth, Sitting: The horizontal distance between the maximum bulges on the soft

tissues in the hip area on either side was measured during sitting condition of the subject.

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 during sitting condition of the subject.

Buttock-Popliteal Length, Sitting: Subject was asked to sit erect on an adjustable seat with knees flexed 90 and thighs parallel. With the tape measurement, the horizontal distance from the most posterior aspect of the right buttock to the posterior surface of the right knee was measured.

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 tape measurement. Sitting condition of the subject was the same as during the measurement of popliteal height.

Thigh Clearance Height Sitting: The vertical distance from the seat surface to the maximum bulge on the anterior surface of the thigh was measured. Sitting condition of the subject was the same as during the measurement of the popliteal height.

Buttock-Knee Length, Sitting: Subject was asked to sit erect as stated in case of measuring buttock-popliteal length. With the tape measurement, 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.

Elbow Breadth, Sitting: The horizontal distance between the two most prominent points on the right elbow joint was measured by a tape measurement. 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.

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. The measured value was then added with popliteal height of the same subject to get elbow height from the floor (sitting).

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, 5^{th}, 50^{th} and 95th, for each body dimension were computed with the help of standard statistical packages.

RESULTS

The anthropometric dimensions which are related to the classroom furniture and layout design were calculated for all the participated boys (Tables 2 and 3). Results reflected that most of the anthropometric dimensions of the schoolboys increase as their age increases. Four important body dimensions, which are related to school furniture design, were found to vary as the function of the children' grades (Figure 1).

Table (2): Mean ± standard deviation and range of different anthropometric dimensions of schoolboys of the primary level.

Anthropometric Dimensions	Grades of Primary Level					
	Grade I	Grade II	Grade III	Grade IV	Grade V	Grade VI
Shoulder height	49.26±12.00 35.40-62.50	38.33±3.62 34.00-45.00	57.51±17.04 37.50-79.20	65.32±15.21 44.80-80.30	57.20±17.12 38.80-87.40	68.97±16.01 49.00-91.10
Elbow height from the floor	45.02±5.45 40.30-54.70	54.81±7.48 43.20-64.10	53.56±2.91 49.30-57.70	52.85±4.26 45.20-57.30	57.26±8.71 44.70-75.80	54.60±5.41 45.70-62.30
Infra-scapular height	31.55±2.73 28.50-35.70	33.62±2.95 30.20-38.40	38.73±7.58 33.20-58.50	33.36±2.97 29.10-38.30	36.64±5.51 29.10-45.10	40.12±4.84 33.50-48.50
Lower lumber (5^{th}) height	10.76±2.06 8.00-13.50	12.96±2.43 9.00-16.00	13.88±2.31 11.50-18.90	15.04±2.37 13.00-19.50	14.04±3.92 9.00-22.20	16.51±4.79 10.30-22.40
Elbow breadth	28.95±3.12 23.30-35.10	31.17±4.15 24.10-39.50	32.26±7.88 14.50-43.10	28.88±3.15 23.20-34.50	30.84±3.35 25.10-35.70	35.46±7.46 25.50-47.00
Bi-deltoid breadth	38.87±2.81 35.50-42.10	43.42±3.34 39.40-49.50	42.24±3.71 38.20-48.30	44.47±3.42 39.70-51.30	48.94±7.60 38.30-62.40	48.74±5.66 40.30-60.10
Hip breadth	24.54±3.53 22.20-33.70	25.89±3.76 22.60-33.40	28.12±3.13 24.30-33.00	32.12±4.77 27.10-42.00	34.52±5.62 27.40-43.30	34.15±5.30 27.20-43.50
Popliteal height	33.12±3.68 29.20-42.20	35.15±2.87 32.00-40.50	38.66±3.18 35.40-46.20	38.88±2.89 34.10-43.50	41.89±4.38 36.60-52.70	41.71±3.84 37.50-50.50
Knee height	35.40±4.25 31.20-41.00	37.15±2.96 34.30-42.40	40.51±1.50 37.80-42.70	41.48±3.09 39.20-48.30	47.85±4.53 42.30-53.00	45.20±2.50 41.50-49.40
Buttock-popliteal length	30.02±2.47 25.70-33.00	36.50±3.21 32.50-42.20	39.63±4.47 33.40-43.60	39.96±4.27 35.10-47.50	45.96±6.87 37.40-57.00	43.56±5.37 36.40-52.00
Buttock-knee length	34.61±1.26 32.00-36.20	43.68±4.83 38.20-51.40	45.36±3.38 40.30-49.00	47.82±4.27 41.20-54.00	49.81±7.00 42.60-63.00	49.96±7.13 45.00-64.60
Thigh clearance height	9.22±1.17 7.70-11.10	10.30±1.88 7.20-12.50	11.13±1.81 8.00-14.20	12.54±2.81 9.10-16.80	14.56±4.53 9.50-22.10	14.95±3.71 11.30-23.00
Elbow to elbow length	58.52±2.70 52.30-62.00	40.94±12.04 26.40-53.10	49.34±12.72 32.30-62.40	47.27±16.62 27.30-72.00	50.66±10.97 35.70-67.00	48.94±14.51 30.20-72.00

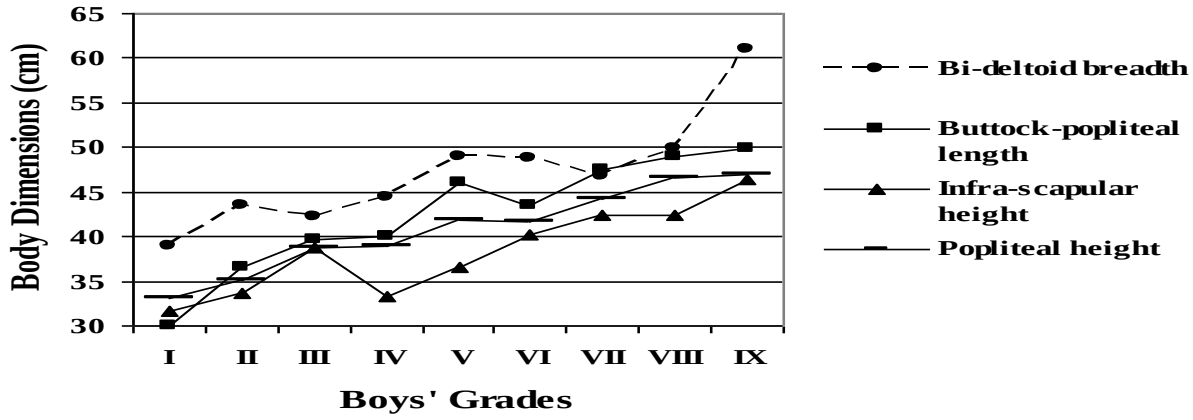

Fig. (1): Different body dimensions of schoolboys as function of grades.

Table (3): Mean ± standard deviation and range of different anthropometric dimensions of schoolboys of the preparatory level.

Anthropometric Dimensions	Grades of Preparatory Level		
	Grade VII	Grade VIII	Grade IX
Shoulder height	59.73±19.28 49.20-100.00	55.78±14.83 47.50-97.50	62.58±20.39 46.30-102.00
Elbow height from the floor	46.83±15.41 28.50-65.60	61.18±6.21 46.50-67.60	60.92±5.26 51.50-68.30
Infra-scapular height	42.47±1.16 40.20-44.40	42.46±1.83 40.30-46.50	46.32±6.80 35.50-62.30
Lower lumber (5^{th}) height	19.47±4.98 13.50-24.90	19.95±3.38 12.40-23.20	19.61±4.30 13.40-26.40
Elbow breadth	34.97±4.43 28.50-39.30	34.80±2.68 28.50-37.40	38.49±5.22 33.70-51.50
Bi-deltoid breadth	46.77±2.65 43.50-50.30	49.94±2.94 44.30-52.50	61.02±8.87 46.00-71.00
Hip breadth	31.78±1.00 30.50-33.20	36.85±4.61 29.90-43.60	37.78±4.35 30.30-46.50
Popliteal height	44.14±2.05 42.40-48.50	46.52±1.70 42.30-48.30	46.90±2.17 43.50-51.20
Knee height	48.09±2.19 45.50-50.70	48.49±3.68 42.50-52.50	46.96±6.08 37.90-54.70
Buttock-popliteal length	47.48±1.77 44.90-50.00	48.88±4.13 42.50-53.60	49.80±2.72 44.40-54.00
Buttock-knee length	52.58±3.34 46.60-56.40	54.34±4.06 49.50-61.30	57.19±4.20 50.30-62.80
Thigh clearance height	14.23±1.61 11.60-16.50	14.18±2.11 9.80-17.50	17.04±3.47 13.00-22.70
Elbow to elbow length	59.54±6.54 48.50-65.70	55.83±6.98 44.90-65.50	58.98±10.02 46.50-81.60

Various percentile values (5^{th}, 50^{th} and 95^{th}) of different anthropometric dimensions of the schoolboys of different grades were computed for the purpose of designing school furniture and layout of the classroom. These are presented in different tables. Table 4 shows mean differences (%) of anthropometric dimensions between the schoolboys of grade I and grade II. It was observed from this table that differences between mean values of various anthropometric dimensions of schoolboys grade I and grade II were very large (4.94% to 42.94%). The percentile values of the anthropometric dimensions of the merged grade group (I-II grades) are shown in Table 4. The mean differences (%) of different anthropometric dimensions of the boys between grade III and grade IV were appreciably large (0.57% to 16.10%) (Table 5). The percentile values of the anthropometric dimensions of the merged grade group (III-IV grades) are shown in Table 5. Similarly, the mean differences of boys dimension were appreciably large (0.30% to 20.58%) when they were compared between the boys of grade V and grade VI (Table 6). The percentile values of the anthropometric dimensions of the merged grade group (V-VI grades) are shown in Table 6. However, the mean differences of girls dimension were very large (19.57% to 62.15%) when they were compared between the boys of grade I and grade VI.

Table (4): Percentile values of different anthropometric dimensions of schoolboys between grade I and grade II.

Anthropometric Dimensions	Grade I	Grade II	Mean differences (%)	Grand mean and SD	5^{th} %-ile	50^{th} %-ile	95^{th} %-ile
Shoulder height	49.26±12.00 35.40-62.50	38.33±3.62 34.00-45.00	28.52	43.80±10.29	34.05	39.55	62.48
Elbow height from the floor	45.02±5.45 40.30-54.70	54.81±7.48 43.20-64.10	21.75	49.92±8.12	40.31	48.35	64.10
Infra-scapular height	31.55±2.73 28.50-35.70	33.62±2.95 30.20-38.40	6.56	32.59±2.97	28.54	32.15	38.34
Lower lumber (5^{th}) height	10.76±2.06 8.00-13.50	12.96±2.43 9.00-16.00	20.45	11.86±2.47	8.00	11.80	16.00
Elbow breadth	28.95±3.12 23.30-35.10	31.17±4.15 24.10-39.50	7.67	30.06±3.75	23.34	29.55	39.28
Bi-deltoid breadth	38.87±2.81 35.50-42.10	43.42±3.34 39.40-49.50	11.71	41.15±3.81	35.52	41.00	49.44
Hip breadth	24.54±3.53 22.20-33.70	25.89±3.76 22.60-33.40	5.50	25.22±3.62	22.21	23.40	33.69
Popliteal height	33.12±3.68 29.20-42.20	35.15±2.87 32.00-40.50	6.13	34.14±3.38	29.25	33.50	42.12
Knee height	35.40±4.25 31.20-41.00	37.15±2.96 34.30-42.40	4.94	36.28±3.67	31.22	34.90	42.33
Buttock-popliteal length	30.02±2.47 25.70-33.00	36.50±3.21 32.50-42.20	21.59	33.26±4.34	25.73	32.75	42.11
Buttock-knee length	34.61±1.26 32.00-36.20	43.68±4.83 38.20-51.40	26.21	39.15±5.78	32.09	37.20	51.36
Thigh clearance height	9.22±1.17 7.70-11.10	10.30±1.88 7.20-12.50	11.71	9.76±1.62	7.23	9.45	12.49
Elbow to elbow length	58.52±2.70 52.30-62.00	40.94±12.04 26.40-53.10	42.94	49.73±12.39	26.46	53.10	61.95

Regarding the preparatory level, the percentile values of the anthropometric dimensions of the merged grade groups (VII-VIII grades and VIII-IX grades) are shown in Table 7 and 8. The mean differences of boys dimension were large when they were compared between the girls of grade VII and grade VIII and between grade VIII and grade IX (0.02% to 30.64% and 0.43% to 22.18% respectively) (Table 7 and 8). Similarly the mean differences (%) of different anthropometric dimensions of the boys between grade VII and grade IX were appreciably large (0.72% to 33.18%). The important dimensions of the furniture and the relevant user dimensions are shown Table 9.

DISCUSSION

There are many variations in body size among children. The body dimensions should match with the furniture used in schools. On the other hand, any mismatch in the school environment leads to users' discomfort, low productivity, work hazards and accidents. The body dimensions of children are important for the design of schools furniture. This possesses problems because children of different body sizes may be combined in the same classroom. Therefore, desks and benches of 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 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. Many countries 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.

Table (5): Percentile values of different anthropometric dimensions of schoolboys between grade III and grade IV.

Anthropometric Dimensions	Grade III	Grade IV	Mean differences (%)	Grand mean and SD	5^{th} %-ile	50^{th} %-ile	95^{th} %-ile
Shoulder height	57.51±17.04 37.50-79.20	65.32±15.21 44.80-80.30	13.58	59.92±16.23	37.75	62.15	80.29
Elbow height from the floor	53.56±2.91 49.30-57.70	52.85±4.26 45.20-57.30	1.34	53.21±3.57	45.35	53.35	57.68
Infra-scapular height	38.73±7.58 33.20-58.50	33.36±2.97 29.10-38.30	16.10	36.05±6.24	29.20	35.50	57.78
Lower lumber (5^{th}) height	13.88±2.31 11.50-18.90	15.04±2.37 13.00-19.50	8.36	14.46±2.35	11.50	13.70	19.47
Elbow breadth	32.26±7.88 14.50-43.10	28.88±3.15 23.20-34.50	11.70	30.57±6.09	14.94	29.45	42.87
Bi-deltoid breadth	42.24±3.71 38.20-48.30	44.47±3.42 39.70-51.30	5.28	43.36±3.65	38.20	43.30	51.15
Hip breadth	28.12±3.13 24.30-33.00	32.12±4.77 27.10-42.00	14.22	30.12±4.43	24.31	29.75	41.79
Popliteal height	38.66±3.18 35.40-46.20	38.88±2.89 34.10-43.50	0.57	38.77±2.96	34.14	38.25	46.07
Knee height	40.51±1.50 37.80-42.70	41.48±3.09 39.20-48.30	2.39	41.00±2.42	37.87	40.25	48.19
Buttock-popliteal length	39.63±4.47 33.40-43.60	39.96±4.27 35.10-47.50	0.83	39.80±4.26	33.43	40.95	47.41
Buttock-knee length	45.36±3.38 40.30-49.00	47.82±4.27 41.20-54.00	5.42	46.59±3.96	40.34	46.85	53.96
Thigh clearance height	11.13±1.81 8.00-14.20	12.54±2.81 9.10-16.80	12.67	11.84±2.41	8.06	11.35	16.76
Elbow to elbow length	49.34±12.72 32.30-62.40	47.27±16.62 27.30-72.00	4.38	48.31±14.44	27.40	47.85	71.71

Optimal furniture design recommendations are often based on the relationship of the furniture dimensions with the anthropometrics of the seated person. Given the range of anthropometric dimensions of the children population, it is often recommended that optimal furniture design should allow for adjustability to suit the user. Despite the wide range of anthropometric dimensions that exist in the children student population, students are often exposed to fixed-dimension furniture throughout their school life, with little opportunity for adjustability to suit their own changing

anthropometry. If prolonged sitting at school furniture is a risk factor for the development of musculoskeletal symptoms, and there exists an optimal relationship between the anthropometric dimensions of the student population and the dimensions of the fixed furniture, then this should be demonstrated in higher reports of symptoms amongst individuals, who reflect a mismatch in this relationship (Milanese and Grimmer, 2004).

Table (6): Percentile values of different anthropometric dimensions of schoolboys between grade V and grade VI.

Anthropometric Dimensions	Grade V	Grade VI	Mean differences (%)	Grand mean and SD	5^{th} %-ile	50^{th} %-ile	95^{th} %-ile
Shoulder height	57.20±17.12 38.80-87.40	68.97±16.01 49.00-91.10	20.58	63.09±17.22	39.01	54.75	90.95
Elbow height from the floor	57.26±8.71 44.70-75.80	54.60±5.41 45.70-62.30	4.87	55.93±7.19	44.75	56.30	75.18
Infra-scapular height	36.64±5.51 29.10-45.10	40.12±4.84 33.50-48.50	9.50	38.38±5.36	29.20	38.40	48.39
Lower lumber (5^{th}) height	14.04±3.92 9.00-22.20	16.51±4.79 10.30-22.40	17.59	15.28±4.45	9.00	14.15	22.39
Elbow breadth	30.84±3.35 25.10-35.70	35.46±7.46 25.50-47.00	14.98	33.15±6.10	25.12	31.95	46.91
Bi-deltoid breadth	48.94±7.60 38.30-62.40	48.74±5.66 40.30-60.10	0.41	48.84±6.52	38.35	48.50	62.29
Hip breadth	34.52±5.62 27.40-43.30	34.15±5.30 27.20-43.50	1.08	34.34±5.32	27.21	33.80	43.49
Popliteal height	41.89±4.38 36.60-52.70	41.71±3.84 37.50-50.50	0.43	41.80±4.01	36.65	41.30	52.59
Knee height	47.85±4.53 42.30-53.00	45.20±2.50 41.50-49.40	5.86	46.53±3.81	41.54	45.85	53.00
Buttock-popliteal length	45.96±6.87 37.40-57.00	43.56±5.37 36.40-52.00	5.51	44.76±6.13	36.45	46.20	56.85
Buttock-knee length	49.81±7.00 42.60-63.00	49.96±7.13 45.00-64.60	0.30	49.89±6.60	42.60	46.30	64.60
Thigh clearance height	14.56±4.53 9.50-22.10	14.95±3.71 11.30-23.00	2.68	14.76±4.15	9.50	14.00	23.00
Elbow to elbow length	50.66±10.97 35.70-67.00	48.94±14.51 30.20-72.00	3.51	49.80±11.72	30.20	47.90	69.70

Results of this study reflected that all anthropometric dimensions of the school children increase as their age increases. 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. Therefore, 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 indicated the need for separate design of furniture for different age groups.

Table (7): Percentile values of different anthropometric dimensions of schoolboys between grade VII and grade VIII.

Anthropometric Dimensions	Grade VII	Grade VIII	Mean differences (%)	Grand mean and SD	5^{th} %-ile	50^{th} %-ile	95^{th} %-ile
Shoulder height	59.73±19.28 49.20-100.00	55.78±14.83 47.50-97.50	7.08	57.76±16.86	47.55	51.65	99.88
Elbow height from the floor	46.83±15.41 28.50-65.60	61.18±6.21 46.50-67.60	30.64	54.01±13.59	28.53	59.75	67.55
Infra-scapular height	42.47±1.16 40.20-44.40	42.46±1.83 40.30-46.50	0.02	42.47±1.49	40.21	42.20	46.40
Lower lumber (5^{th}) height	19.47±4.98 13.50-24.90	19.95±3.38 12.40-23.20	2.47	19.71±4.15	12.46	20.50	24.88
Elbow breadth	34.97±4.43 28.50-39.30	34.80±2.68 28.50-37.40	0.49	34.89±3.57	28.50	35.50	39.28
Bi-deltoid breadth	46.77±2.65 43.50-50.30	49.94±2.94 44.30-52.50	6.78	48.36±3.17	43.52	48.75	52.50
Hip breadth	31.78±1.00 30.50-33.20	36.85±4.61 29.90-43.60	15.95	34.32±4.16	29.93	32.45	43.41
Popliteal height	44.14±2.05 42.40-48.50	46.52±1.70 42.30-48.30	5.39	45.33±2.20	42.31	45.85	48.49
Knee height	48.09±2.19 45.50-50.70	48.49±3.68 42.50-52.50	0.83	48.29±2.95	42.50	49.50	52.46
Buttock-popliteal length	47.48±1.77 44.90-50.00	48.88±4.13 42.50-53.60	2.95	53.46±3.17	42.50	48.10	53.60
Buttock-knee length	52.58±3.34 46.60-56.40	54.34±4.06 49.50-61.30	3.35	53.46±3.73	46.68	53.35	61.16
Thigh clearance height	14.23±1.61 11.60-16.50	14.18±2.11 9.80-17.50	0.35	14.21±1.83	9.89	14.30	17.45
Elbow to elbow length	59.54±6.54 48.50-65.70	55.83±6.98 44.90-65.50	6.65	57.69±6.85	44.94	59.35	65.69

Table (8): Percentile values of different anthropometric dimensions of schoolboys between grade VIII and grade IX.

Anthropometric Dimensions	Grade VIII	Grade IX	Mean differences (%)	Grand mean and SD	5^{th} %-ile	50^{th} %-ile	95^{th} %-ile
Shoulder height	55.78±14.83 47.50-97.50	62.58±20.39 46.30-102.00	12.19	59.18±17.70	46.36	52.80	101.87
Elbow height from the floor	61.18±6.21 46.50-67.60	60.92±5.26 51.50-68.30	0.43	61.05±5.60	46.75	61.55	68.27
Infra-scapular height	42.46±1.83 40.30-46.50	46.32±6.80 35.50-62.30	9.09	44.39±5.24	35.74	43.50	61.64
Lower lumber (5^{th}) height	19.95±3.38 12.40-23.20	19.61±4.30 13.40-26.40	1.73	19.78±3.77	12.45	20.40	26.38
Elbow breadth	34.80±2.68 28.50-37.40	38.49±5.22 33.70-51.50	10.60	36.65±4.46	28.68	35.55	51.03
Bi-deltoid breadth	49.94±2.94 44.30-52.50	61.02±8.87 46.00-71.00	22.18	55.48±8.58	44.39	52.40	70.96
Hip breadth	36.85±4.61 29.90-43.60	37.78±4.35 30.30-46.50	2.52	37.32±4.39	29.92	38.75	46.36
Popliteal height	46.52±1.70 42.30-48.30	46.90±2.17 43.50-51.20	5.83	46.71±1.91	42.36	46.85	51.07
Knee height	48.49±3.68 42.50-52.50	46.96±6.08 37.90-54.70	3.26	47.73±4.96	37.98	49.50	54.60
Buttock-popliteal length	48.88±4.13 42.50-53.60	49.80±2.72 44.40-54.00	1.88	49.34±3.43	42.50	49.80	53.98
Buttock-knee length	54.34±4.06 49.50-61.30	57.19±4.20 50.30-62.80	5.24	55.77±4.28	49.50	55.65	62.74
Thigh clearance height	14.18±2.11 9.80-17.50	17.04±3.47 13.00-22.70	20.17	15.61±3.15	9.94	15.50	22.68
Elbow to elbow length	55.83±6.98 44.90-65.50	58.98±10.02 46.50-81.60	5.64	57.41±8.56	44.94	58.00	80.85

In designing for a specific individual, one's own body dimensions may be measured and used. For mass application, the percentile values of a study population are usually required. A 95^{th} 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 50^{th} 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 95^{th} or 50^{th} or 5^{th} 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 (5^{th}, 50^{th} and 95^{th}) of different anthropometric dimensions of the schoolboys of different grades were computed for the purpose of designing school furniture and layout of the classroom.

Table (9): The relevant dimensions in anthropometric design of school furniture.

User-dimensions	Product-dimensions
A. Popliteal height	1. Upper surface height of the bench
B. Bi-deltoid breadth	2. Length of the bench (in case of multiple user)
C. Buttock-popliteal length	3. Depth of the bench
D. Elbow height from the floor	4. Height of the desk
E. Knee height	5. Free knee room under the desk
F. Thigh clearance height	6. Vertical span for the accommodation of thighs between the bench top and underside of the desk
G. Elbow to elbow length	7. Length of the desk
H. Infra-scapular height	8. Upper edge height of the backrest from the bench surface
I. Lower lumber (5^{th}) height	9. Lower edge height of the backrest from the bench surface

The results indicated that regarding the primary level grades, the mean differences of body dimensions were appreciably large when they were compared between the boys of grade I and grade II, between grade III and grade IV and between grade V and grade IV. Therefore, it is suggested to formulate furniture design for six different grades.

The results indicated that there was massive change in body growth of the schoolchildren of the primary level in the all tested age groups (grade I and II, grade III and IV and grade V and VI). The changes were large for all body measures. Therefore, the boys of these grades could not be merged together and could not be considered as a single grade while selecting design dimensions for the school furniture. Therefore, design for single group will not be suitable for matching user body dimension and furniture dimension. It is suggested to formulate furniture design for six different grades.

Results of this study also reflected that there was massive change in body growth of the schoolchildren in the age groups of the preparatory level (grade VII and VIII and grade VIII and IX). The changes were large for all body measures. Therefore, the boys of these grades could not be merged together to be considered as a single grade while selecting design dimensions for the school furniture. Therefore, design for single group will not be suitable for matching user body dimension and furniture dimension. It is suggested to formulate furniture design for three different grades.

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 schoolchildren is essential during determination of dimensions of classroom furniture. The anthropometric database of the present investigation might be helpful for designing of school furniture for the boys' schools in rural areas of Egypt. The important dimensions of the furniture and the relevant user dimensions were shown Table 9. The upper surface height of the bench (seat) corresponds to the popliteal height of the population, the width of the seat may be determined from the hip width of the user during sitting condition and buttock-popliteal length is helpful for the determination of depth of the seat (Molenbroek et al., 2003; Chakrabarti and Das, 2004; Sane et al., 2004). The data of sitting hip breadth obtained from the present study might 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 is determined by considering their sitting bi-deltoid breadth, in case of multiple users' seat. For the determination of table height, Molenbroek et al., (2003) used the data of elbow height of the user. Therefore, data of sitting elbow height from the floor collected from this study might be used for the determination of height of the working surface (desk) for seated children.

Kroemer and Grandjean (2001) stated that if we consider the 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. Therefore, the dimension of sitting knee height of the present investigation will be helpful for the determination of free knee room under the desk. It may be mentioned that the thigh clearance height from seat should be used for the determination of vertical span for the accommodation of thighs between the bench top and underside of the desk.

The infrascapulare height was measured in this study which will be helpful for the determination of the upper edge height of the backrest from the bench surface. The sitting lower lumber (5^{th}) height collected from the present investigation may be used for determining the lower edge height of the backrest from the bench surface. This was also suggested by Chakroboti and Das (2004). Buttock-knee length (sitting) may be helpful for the assessment of horizontal space below the desk for accommodating the knees of the users. 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 9.

Khaspuri et al. (2007) investigated the anthropometric dimensions of schoolboys of 20 rural schools of different districts in the state of West Bengal (India) and 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.

Savanur et al. (2007) measured the dimensions of 104 items of furniture (chairs and desks) and 42 anthropometric dimensions of 225 students from grade six to grade nine (age: 10-14 years) in five schools at Mumbai, India. They reported that the seat and desk heights were higher than the comparable students' anthropometric dimensions. The depth of the seats and the desks were less than comparable students' anthropometric dimensions. Moreover, the students reported discomfort in shoulder, wrist, knee and ankle regions. This study was limited by being applied only on boys in only two schools in Egypt.

Conclusion

From the present study it may suggested that the design criteria should be selected for six grade groups in the primary school and for three grade groups in a preparatory school. Otherwise there are chances for misfit between the school furniture and the students. Due to the use of ill designed furniture, the school boys may face many problems such as 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 study may be helpful for designing

school furniture and layout design of the classroom for the boys' schools in Egypt.

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الملخص العربي

أهمية القياسات البدنية في تصميم الأثاث المدرسي لطلاب المدارس العربية الابتدائية والإعدادية

يهدف البحث إلى دراسة القياسات البدنية لطلاب المرحلة الابتدائية والإعدادية وذلك لاستخدامها في تصميم الأثاث المدرسي الذي يتناسب مع هذه القياسات البدنية. شارك في البحث ٩٠ طالب من الصف الأول الابتدائي حتى الصف الثالث الإعدادي (10 طلاب من كل مرحلة دراسية) وذلك من معهد ناصر للمرحلة الابتدائية ومعهد الأزهر للمرحلة الإعدادية بمدينة طنطا بجمهورية مصر العربية. تراوحت أعمار الطلاب بين 6 و15 سنة . أظهرت النتائج أن القياسات البدنية تزداد مع زيادة أعمار الطلاب. كما أظهرت النتائج أنه لابد من عمل تصميم الأثاث المدرسي لكل مرحلة دراسية على حدا ، حيث وجدت فروق كبيرة في القياسات البدنية بين كل مرحلتين دراسيتين متتاليتين. تم أيضا حساب النسبة المئوية (5%، 50%، 95%) للقياسات البدنية وذلك لكي يتم استخدامها في تصميم الأثاث المدرسي المناسب لجميع المراحل محل الدراسة .