

Anthropometric Consideration for Designing Class Room Furniture in Arabic Primary and Intermediate Girls Schools

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ABSTRACT

Background: Children spend one-quarter of a day in school. About 60-80% of this time is spent in the classroom. However, the anthropometric dimensions of the body of the students were not considered during designing the existing school furniture. It is well known fact that body dimensions of the children varies from age, region etc. Therefore 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 female students to use in the product design process. **Methods:** The present investigation was carried out on 90 Saudi schoolgirls having the age range of 6-15 years. Different anthropometric data were collected from these girls. **Results and Conclusion:** The results revealed that all the anthropometric dimensions of the schoolchildren increase with their age. Moreover, there were a little difference between mean values of different anthropometric dimensions between the girls of grade I and grade II (0.27% to 14.20%), between grade III and grade IV (0.79% to 5.94%) and between grade VII and grade VIII (0.74% to 10.63%). On the other hand, the mean differences of girls dimension were appreciably large (2.07% to 28.08%) when they were compared between the girls of grade V and grade VI and between the girls of grade VIII and grade IX (1.99% to 22.93%). These differences become much higher (0.69% to 71.06%) when they were compared between the girls of grade I and grade VI and between grade VII and grade IX (0.61% to 20.12%). 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 (5th, 50th and 95th) 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

Anthropometric measurements of human body have been developed for various reasons since early time of history². The aim was 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 school⁸. 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 school children¹⁶. Therefore, the school furniture should be made on the basis of anthropometric dimensions of the user population (schoolchildren) of different age groups.

The existing school furniture (benches and disks) may not be suitable for the children as these are designed without due consideration to the body dimensional requirements of the schoolchildren. 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)⁵ 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 lead to 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 conducive 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 schoolchildren⁵. In addition in Arabic countries the schoolchildren anthropometry do not considered for designing classroom furniture.

The main objective of this study was to determine reliable and accurate structural anthropometrical measurements for female 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 intermediate three grade students was drawn from one girls' school (Riyadh Alsaleheen) in North of Riyadh-Kingdom of Saudi Arabia. The ethical approval was obtained from the concerned school authority. After parental permission, 90 students were participated in the study. A classification of schoolgirls was performed on the basis of their age and grade (Table 1).

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

Level	Grade	Age Range (Years)	Number of Girls
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
Secondary 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^{3,7,17,18}. 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 iliac crest 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. 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, 5th, 50th 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 girls (Tables 2 and 3). Results reflected that most of the anthropometric dimensions of the schoolgirls 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 (Fig. 1).

Table (2): Mean $\pm$ standard deviation and range of different anthropometric dimensions of schoolgirls of the primary level.

Anthropometric Dimensions	Grades of Primary Level					
	Grade I	Grade II	Grade III	Grade IV	Grade V	Grade VI
Shoulder height	36.67 $\pm$ 5.32 27.00-44.20	36.57 $\pm$ 2.38 34.00-40.70	43.16 $\pm$ 2.54 40.00-47.00	43.50 $\pm$ 3.53 35.30-47.30	47.01 $\pm$ 4.81 39.10-54.40	51.76 $\pm$ 5.00 44.50-61.20
Elbow height from the floor	53.63 $\pm$ 3.76 48.00-58.60	57.61 $\pm$ 2.37 55.00-63.00	53.12 $\pm$ 2.81 50.10-58.10	55.01 $\pm$ 3.10 50.00-59.80	58.51 $\pm$ 9.90 45.20-83.20	54.00 $\pm$ 4.70 45.50-59.00
Infra-scapular height	30.66 $\pm$ 4.97 17.80-35.90	32.70 $\pm$ 3.42 27.00-38.00	36.73 $\pm$ 3.63 32.00-44.30	36.51 $\pm$ 2.45 31.30-39.80	37.27 $\pm$ 5.61 27.00-44.30	42.65 $\pm$ 4.55 36.00-49.40
Lower lumber (5 th) height	13.95 $\pm$ 2.72 9.70-18.60	14.49 $\pm$ 3.29 11.60-21.00	16.89 $\pm$ 2.99 13.00-21.50	17.25 $\pm$ 3.01 12.10-22.0	17.00 $\pm$ 3.38 13.00-24.00	20.27 $\pm$ 2.77 16.00-25.00
Elbow breadth	31.36 $\pm$ 2.78 27.40-36.50	30.61 $\pm$ 5.31 23.00-38.10	30.57 $\pm$ 4.25 24.70-35.50	30.06 $\pm$ 5.42 23.70-42.10	33.13 $\pm$ 7.42 24.40-47.30	41.08 $\pm$ 12.45 29.00-74.00
Bi-deltoid breadth	39.77 $\pm$ 4.25 35.00-46.20	40.74 $\pm$ 6.08 28.80-49.00	39.84 $\pm$ 1.80 37.50-42.50	40.32 $\pm$ 3.74 36.50-46.40	44.09 $\pm$ 7.47 37.50-62.20	47.08 $\pm$ 5.29 39.30-55.00
Hip breadth	26.08 $\pm$ 4.32 21.10-35.00	28.26 $\pm$ 4.51 22.00-35.00	28.92 $\pm$ 2.76 25.60-33.00	30.09 $\pm$ 4.63 25.60-39.30	31.34 $\pm$ 4.58 25.70-40.20	35.15 $\pm$ 4.59 28.00-43.30
Popliteal height	38.32 $\pm$ 4.44 31.00-44.00	43.76 $\pm$ 2.54 41.00-48.00	41.84 $\pm$ 3.25 37.80-47.90	40.98 $\pm$ 1.88 37.40-44.50	42.27 $\pm$ 2.37 39.20-45.00	40.82 $\pm$ 2.10 37.30-45.10
Knee height	41.20 $\pm$ 3.26 36.00-47.00	45.47 $\pm$ 3.24 40.00-49.50	44.21 $\pm$ 2.28 40.80-48.50	44.78 $\pm$ 1.71 42.70-48.50	47.70 $\pm$ 4.30 43.40-57.70	45.42 $\pm$ 2.30 42.00-49.00
Buttock-popliteal length	36.38 $\pm$ 2.59 32.30-39.50	39.50 $\pm$ 1.81 36.00-41.90	41.93 $\pm$ 3.02 37.00-47.50	42.84 $\pm$ 2.74 39.00-47.20	46.77 $\pm$ 3.91 42.40-55.70	47.74 $\pm$ 2.67 44.20-52.00
Buttock-knee length	41.85 $\pm$ 5.51 33.80-52.00	46.47 $\pm$ 3.60 40.00-50.00	47.32 $\pm$ 1.35 45.30-49.80	50.13 $\pm$ 3.59 44.50-55.30	50.98 $\pm$ 6.50 39.00-63.00	55.44 $\pm$ 5.11 50.10-64.30
Thigh clearance height	10.40 $\pm$ 2.37 7.00-15.00	9.95 $\pm$ 1.14 8.00-12.00	13.22 $\pm$ 1.67 11.00-16.70	12.86 $\pm$ 2.49 8.30-16.00	13.89 $\pm$ 3.44 9.50-21.30	17.79 $\pm$ 5.56 10.20-26.00
Elbow to elbow length	58.65 $\pm$ 2.80 55.00-64.00	56.91 $\pm$ 5.50 51.00-65.00	61.58 $\pm$ 6.91 51.40-73.50	61.81 $\pm$ 5.25 55.30-71.50	57.92 $\pm$ 9.88 41.10-73.00	63.13 $\pm$ 10.91 47.00-85.10

Table (3): Mean $\pm$ standard deviation and range of different anthropometric dimensions of schoolgirls of the intermediate level.

Anthropometric Dimensions	Grades of Intermediate Level		
	Grade VII	Grade VIII	Grade IX
Shoulder height	51.77 $\pm$ 3.42 44.60-55.40	53.88 $\pm$ 3.51 48.50-58.30	54.95 $\pm$ 3.19 48.30-58.60
Elbow height from the floor	59.03 $\pm$ 3.73 51.60-63.50	65.27 $\pm$ 2.01 61.30-68.40	59.45 $\pm$ 5.73 44.50-64.40
Infra-scapular height	43.45 $\pm$ 2.80 40.60-48.20	43.13 $\pm$ 3.66 37.20-48.40	44.86 $\pm$ 2.95 40.50-49.40
Lower lumber (5 th) height	19.06 $\pm$ 2.40 14.20-22.30	20.43 $\pm$ 1.79 18.20-24.20	19.32 $\pm$ 3.98 14.40-26.40
Elbow breadth	35.83 $\pm$ 3.77 29.30-42.70	35.78 $\pm$ 5.44 30.40-46.30	37.11 $\pm$ 5.15 28.40-45.40
Bi-deltoid breadth	49.34 $\pm$ 4.22 44.80-57.00	52.23 $\pm$ 6.04 46.20-64.30	50.17 $\pm$ 3.57 45.30-56.30
Hip breadth	35.93 $\pm$ 3.35 31.30-41.30	36.38 $\pm$ 5.40 23.40-44.40	35.65 $\pm$ 2.83 32.30-39.60
Popliteal height	42.15 $\pm$ 3.16 36.60-48.30	45.74 $\pm$ 1.78 43.40-49.30	42.41 $\pm$ 2.47 38.00-46.50
Knee height	45.83 $\pm$ 3.11 40.50-51.20	43.97 $\pm$ 2.19 40.20-46.40	48.01 $\pm$ 2.16 44.30-51.50
Buttock-popliteal length	49.81 $\pm$ 2.91 47.00-57.00	50.42 $\pm$ 2.93 46.40-55.30	51.51 $\pm$ 2.36 47.30-54.90
Buttock-knee length	57.27 $\pm$ 2.68 53.20-60.20	56.17 $\pm$ 3.86 51.60-63.90	60.65 $\pm$ 2.21 56.40-62.60
Thigh clearance height	13.57 $\pm$ 2.78 9.20-18.30	13.26 $\pm$ 2.51 10.30-18.20	16.30 $\pm$ 3.33 11.50-22.00
Elbow to elbow length	62.38 $\pm$ 6.56 53.10-70.50	69.01 $\pm$ 7.43 53.30-76.40	61.10 $\pm$ 12.13 42.40-81.70

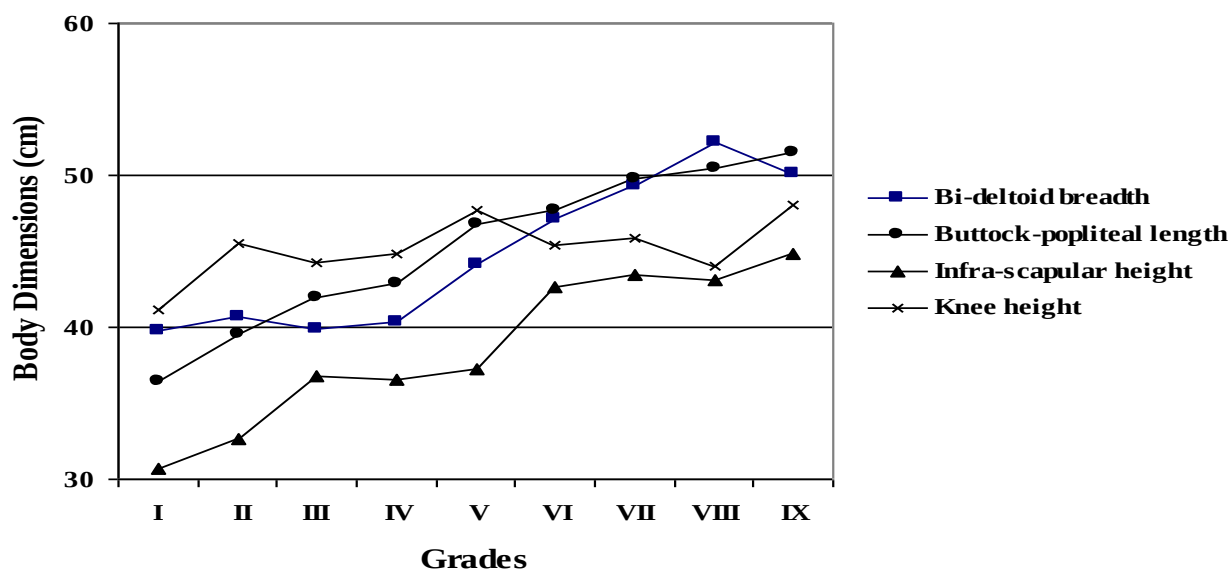


Fig. (1): Different body dimensions of school girls as function of grades.

Various percentile values (5th, 50th and 95th) of different anthropometric dimensions of the schoolgirls 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 schoolgirls of grade I and grade II. It was observed from this table that differences between mean values of various anthropometric dimensions of schoolgirls grade I and grade II were small (0.27% to 14.20%). The percentile values of the anthropometric dimensions of the merged grade group (I-II grades) are shown in Table 4. Similarly the mean differences (%) of different

anthropometric dimensions of the girls between grade III and grade IV were very small (0.79% to 5.94%) (Table 5). The percentile values of the anthropometric dimensions of the merged grade group (III-IV grades) are shown in Table 5. On the other hand, the mean differences of girls dimension were appreciably large (2.07% to 28.08%) when they were compared between the girls 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 (0.69% to 71.06%) when they were compared between the girls of grade I and grade VI.

Table (4): Percentile values of different anthropometric dimensions of schoolgirls 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	36.67±5.32 27.00-44.20	36.57±2.38 34.00-40.70	0.27	36.62±4.01	27.19	36.20	44.1
Elbow height from the floor	53.63±3.76 48.00-58.60	57.61±2.37 55.00-63.00	7.42	55.62±3.68	48.08	56.00	62.85
Infra-scapular height	30.66±4.97 17.80-35.90	32.70±3.42 27.00-38.00	6.65	31.68±4.28	18.26	31.98	37.95
Lower lumbar (5 th) height	13.95±2.72 9.70-18.60	14.49±3.29 11.60-21.00	3.87	14.22±2.95	9.76	13.50	20.90
Elbow breadth	31.36±2.78 27.40-36.50	30.61±5.31 23.00-38.10	2.45	30.98±4.14	23.05	32.00	38.10
Bi-deltoid breadth	39.77±4.25 35.00-46.20	40.74±6.08 28.80-49.00	2.44	40.25±5.13	29.10	40.85	48.95
Hip breadth	26.08±4.32 21.10-35.00	28.26±4.51 22.00-35.00	8.36	27.17±4.44	21.13	26.80	35.00
Popliteal height	38.32±4.44 31.00-44.00	43.76±2.54 41.00-48.00	14.20	41.04±4.49	31.09	41.50	47.93
Knee height	41.20±3.26 36.00-47.00	45.47±3.24 40.00-49.50	10.36	43.33±3.85	36.10	44.20	49.49
Buttock-popliteal length	36.38±2.59 32.30-39.50	39.50±1.81 36.00-41.90	5.83	37.94±2.70	32.35	38.30	41.86
Buttock-knee length	41.85±5.51 33.80-52.00	46.47±3.60 40.00-50.00	11.04	44.16±5.11	33.91	44.50	51.90
Thigh clearance height	10.40±2.37 7.00-15.00	9.95±1.14 8.00-12.00	4.52	10.17±1.82	7.05	9.85	14.90
Elbow to elbow length	58.65±2.80 55.00-64.00	56.91±5.50 51.00-65.00	3.06	57.78±4.34	51.05	57.40	64.95

Table (5): Percentile values of different anthropometric dimensions of schoolgirls 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	43.16±2.54 40.00-47.00	43.50±3.53 35.30-47.30	0.79	43.33±3.00	35.53	43.85	47.30
Elbow height from the floor	53.12±2.81 50.10-58.10	55.01±3.10 50.00-59.80	3.56	54.07±3.04	50.01	54.10	59.73
Infra-scapular height	36.73±3.63 32.00-44.30	36.51±2.45 31.30-39.80	0.60	36.62±3.02	31.34	37.45	44.08
Lower lumber (5 th) height	16.89±2.99 13.00-21.50	17.25±3.01 12.10-22.0	2.13	17.07±2.93	12.15	16.85	21.98
Elbow breadth	30.57±4.25 24.70-35.50	30.06±5.42 23.70-42.10	1.70	30.32±4.75	23.75	29.90	41.77
Bi-deltoid breadth	39.84±1.80 37.50-42.50	40.32±3.74 36.50-46.40	1.20	40.08±2.87	36.51	39.45	46.33
Hip breadth	28.92±2.76 25.60-33.00	30.09±4.63 25.60-39.30	4.05	29.51±3.76	25.60	28.40	39.11
Popliteal height	41.84±3.25 37.80-47.90	40.98±1.88 37.40-44.50	2.10	41.41±2.62	37.42	40.60	47.83
Knee height	44.21±2.28 40.80-48.50	44.78±1.71 42.70-48.50	1.29	44.50±1.98	40.86	44.05	48.50
Buttock-popliteal length	41.93±3.02 37.00-47.50	42.84±2.74 39.00-47.20	2.17	42.39±2.85	37.08	42.00	47.49
Buttock-knee length	47.32±1.35 45.30-49.80	50.13±3.59 44.50-55.30	5.94	48.73±3.01	44.54	47.95	55.21
Thigh clearance height	13.22±1.67 11.00-16.70	12.86±2.49 8.30-16.00	2.80	13.04±2.07	8.38	13.10	16.67
Elbow to elbow length	61.58±6.91 51.40-73.50	61.81±5.25 55.30-71.50	0.37	61.70±5.98	51.44	60.85	73.40

Regarding the intermediate 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 girls dimension were small (0.74% to 10.63%)

when they were compared between the girls of grade VII and grade VIII (Table 7). On the other hand, the mean differences of girls dimension were appreciably large (1.99% to 22.93%) when they were compared between the girls of grade VIII and grade IX (Table 8).

Similarly the mean differences (%) of different anthropometric dimensions of the girls between grade VII and grade IX were appreciably large (0.61% to 20.12%). The important dimensions of the furniture and the relevant user dimensions are shown Table 9.

DISCUSSION

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. 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. 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 might appear a suitable solution, but especially young children might have great difficulties in adjusting that furniture to their size and liking⁶. 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 schoolchildren.

Table (6): Percentile values of different anthropometric dimensions of schoolgirls 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	47.01±4.81 39.10-54.40	51.76±5.00 44.50-61.20	10.10	49.39±5.36	39.31	48.25	60.10
Elbow height from the floor	58.51±9.90 45.20-83.20	54.00±4.70 45.50-59.00	8.35	56.26±7.89	45.22	55.80	82.14
Infra-scapular height	37.27±5.61 27.00-44.30	42.65±4.55 36.00-49.40	14.44	39.96±5.68	27.16	39.35	49.34
Lower lumbar (5 th) height	17.00±3.38 13.00-24.00	20.27±2.77 16.00-25.00	19.24	18.64±3.44	13.04	18.00	24.95
Elbow breadth	33.13±7.42 24.40-47.30	41.08±12.45 29.00-74.00	24.00	37.11±10.78	24.56	34.65	72.67
Bi-deltoid breadth	44.09±7.47 37.50-62.20	47.08±5.29 39.30-55.00	6.78	45.59±6.48	37.57	44.50	61.84
Hip breadth	31.34±4.58 25.70-40.20	35.15±4.59 28.00-43.30	12.16	33.25±4.87	25.78	32.90	43.16
Popliteal height	42.27±2.37 39.20-45.00	40.82±2.10 37.30-45.10	3.55	41.55±2.30	37.40	40.75	45.10
Knee height	47.70±4.30 43.40-57.70	45.42±2.30 42.00-49.00	5.02	46.56±3.56	42.07	45.45	57.30
Buttock-popliteal length	46.77±3.91 42.40-55.70	47.74±2.67 44.20-52.00	2.07	47.26±3.30	42.44	47.35	55.52
Buttock-knee length	50.98±6.50 39.00-63.00	55.44±5.11 50.10-64.30	8.75	53.21±6.13	39.30	52.45	64.24
Thigh clearance height	13.89±3.44 9.50-21.30	17.79±5.56 10.20-26.00	28.08	15.84±4.92	9.54	15.20	25.95
Elbow to elbow length	57.92±9.88 41.10-73.00	63.13±10.91 47.00-85.10	9.00	60.53±10.48	41.30	60.45	84.50

Table (7): Percentile values of different anthropometric dimensions of schoolgirls 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	51.77±3.42 44.60-55.40	53.88±3.51 48.50-58.30	4.08	52.83±3.54	44.80	52.70	58.26
Elbow height from the floor	59.03±3.73 51.60-63.50	65.27±2.01 61.30-68.40	5.49	60.65±4.33	51.75	62.85	68.35
Infra-scapular height	43.45±2.80 40.60-48.20	43.13±3.66 37.20-48.40	0.74	43.29±3.18	37.36	42.80	48.39
Lower lumber (5 th) height	19.06±2.40 14.20-22.30	20.43±1.79 18.20-24.20	7.19	19.75±2.18	14.36	19.85	24.11
Elbow breadth	35.83±3.77 29.30-42.70	35.78±5.44 30.40-46.30	0.14	35.81±4.56	29.36	35.70	46.12
Bi-deltoid breadth	49.34±4.22 44.80-57.00	52.23±6.04 46.20-64.30	5.86	50.79±5.28	44.84	49.85	64.16
Hip breadth	35.93±3.35 31.30-41.30	36.38±5.40 23.40-44.40	1.25	36.16±4.38	23.80	37.25	44.25
Popliteal height	42.15±3.16 36.60-48.30	45.74±1.78 43.40-49.30	8.52	43.95±3.10	36.73	44.25	49.25
Knee height	45.83±3.11 40.50-51.20	43.97±2.19 40.20-46.40	4.23	44.90±2.79	40.22	44.45	51.05
Buttock-popliteal length	49.81±2.91 47.00-57.00	50.42±2.93 46.40-55.30	1.22	50.12±2.86	46.43	49.70	56.92
Buttock-knee length	57.27±2.68 53.20-60.20	56.17±3.86 51.60-63.90	1.96	56.72±3.28	51.61	57.25	63.72
Thigh clearance height	13.57±2.78 9.20-18.30	13.26±2.51 10.30-18.20	2.34	13.42±2.59	9.26	13.05	18.30
Elbow to elbow length	62.38±6.56 53.10-70.50	69.01±7.43 53.30-76.40	10.63	65.70±7.62	53.11	68.00	76.30

Table (8): Percentile values of different anthropometric dimensions of schoolgirls 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	53.88±3.51 48.50-58.30	54.95±3.19 48.30-58.60	1.99	54.42±3.31	48.31	55.30	58.59
Elbow height from the floor	65.27±2.01 61.30-68.40	59.45±5.73 44.50-64.40	9.79	62.36±5.14	45.10	63.40	68.35
Infra-scapular height	43.13±3.66 37.20-48.40	44.86±2.95 40.50-49.40	4.01	44.00±3.36	37.36	44.50	49.35
Lower lumber (5 th) height	20.43±1.79 18.20-24.20	19.32±3.98 14.40-26.40	5.75	19.88±3.06	14.45	19.40	26.38
Elbow breadth	35.78±5.44 30.40-46.30	37.11±5.15 28.40-45.40	3.72	36.45±5.20	28.50	34.90	46.26
Bi-deltoid breadth	52.23±6.04 46.20-64.30	50.17±3.57 45.30-56.30	4.11	51.20±4.94	45.3	50.80	64.16
Hip breadth	36.38±5.40 23.40-44.40	35.65±2.83 32.30-39.60	2.05	36.02±4.21	23.85	35.60	44.20
Popliteal height	45.74±1.78 43.40-49.30	42.41±2.47 38.00-46.50	7.85	44.08±2.71	38.12	44.35	49.21
Knee height	43.97±2.19 40.20-46.40	48.01±2.16 44.30-51.50	9.19	45.99±2.96	40.26	46.35	51.45
Buttock-popliteal length	50.42±2.93 46.40-55.30	51.51±2.36 47.30-54.90	2.16	50.97±2.65	46.45	50.35	55.28
Buttock-knee length	56.17±3.86 51.60-63.90	60.65±2.21 56.40-62.60	7.98	58.41±3.83	51.62	58.45	63.84
Thigh clearance height	13.26±2.51 10.30-18.20	16.30±3.33 11.50-22.00	22.93	14.78±3.27	10.31	14.45	21.89
Elbow to elbow length	69.01±7.43 53.30-76.40	61.10±12.13 42.40-81.70	12.95	65.06±10.60	42.90	67.10	81.61

Results of this study reflected that all anthropometric dimensions of the schoolchildren 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. 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 indicated the need for separate design of furniture for different age groups.

In designing for a specific individual, one's own body dimensions may be measured and used. However, 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 schoolgirls of different grades were computed for the purpose of designing school furniture and layout of the

classroom. The results indicated that there was no massive change in body growth of the schoolchildren in the small age group (grade I and II). The changes are little for all body measures. Therefore, the girls of these grades were merged together and may be considered as a single grade while selecting design dimensions for the school furniture. Similarly, the girls of grades III and IV could be merged and considered as a single grade while selecting design dimensions for the school furniture. However, the mean differences of body dimension were appreciably large when they were compared between the girls of grade III and grade IV. Therefore, design for single group (III and IV grades) will not be suitable for matching user body dimension and furniture dimension. So, it is suggested to formulate furniture design for four different grades.

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 lumbar (5 th) height	9. Lower edge height of the backrest from the bench surface

Results of this study also reflected that there was no massive change in body growth of the schoolchildren in the small age group of the intermediate level (grade VII and VIII). The changes were little for all body measures. Therefore, the girls of these grades were merged together and may be considered as a single grade while selecting design dimensions

for the school furniture. However, the mean differences of body dimension were appreciably large when they were compared between the girls of grade VIII and grade IX. Therefore, design for single group (VIII and IX grades) will not be suitable for matching user body dimension and furniture dimension.

So, it is suggested to formulate furniture design for two 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 may be helpful for designing of school furniture for the girls' schools in rural areas of Riyadh. The important dimensions of the furniture and the relevant user dimensions are 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^{4,11,14}. The data of sitting hip breadth obtained from the present study 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 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)¹¹ used the data of elbow height of the user. Therefore, data of sitting elbow height from the floor collected from this study may be used for the determination of height of the working surface (desk) for seated children.

Kroemer and Grandjean (2001)⁹ 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 infrascapular 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 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 Chakrabarti and Das (2004)⁴. 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.

Legg et al. (2004)¹⁰ has examined the relationship between the classroom chair dimensions and the students' anthropometric characteristics in three New Zealand secondary schools. In their study, the mismatch between the mean of the students' popliteal height and the seat height was 95.8% while the mismatch between the mean of the students' buttock-popliteal length and the seat depth was 54.4%. When the authors combined the mismatch data for both seat height and depth, they found that the level of mismatch was 100% (no student had access to a chair that was a suitable fit for the body dimensions).

Murphy et al. (2004)¹² highlighted the predominant postures assumed by students while working at their desks. They interpreted this finding by the fixed position of the

classroom chair that meet less than 30% of the postural support requirements of the students.

Abdel Rahman (2006)¹ examined the possible mismatch between the schoolchildren body dimensions and the classroom chair they use. The author stated that there was a high level of mismatch between the size of the school chair and the anthropometric characteristics of the primary school students in one school in Riyadh. Given that the chair measured in the study enjoys widespread use in Riyadh primary school, and with no reason to believe that the schoolchildren measured were a typical in size, the findings of the study may well indicate a significant problem nationwide. This study was limited by being applied only on girls in only one school in Riyadh.

Conclusion

From the present study it may suggested that the design criteria should be selected for four grade groups (grades I-II, grades III-IV, grade V and grade VI) in the primary school and for two grade groups (grades VII-VIII and grade IX) in the intermediate school. Otherwise there were chances for misfit between the school furniture and the students. Due to the use of ill designed furniture, the school girls 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 girls' schools in Riyadh.

Further study is recommended to measure the anthropometric dimensions of girls' schools.

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الملخص العربي

أهمية القياسات البدنية في تصميم الأثاث المدرسي لطالبات المدارس العربية الابتدائية والمتوسطة

يهدف البحث إلى دراسة القياسات البدنية لطالبات المرحلة الابتدائية والمتوسطة وذلك لاستخدامها في تصميم الأثاث المدرسي الذي يتناسب مع هذه القياسات البدنية. شارك في البحث ٩٠ طالبة من الصف الأول الابتدائي حتى الصف الثالث المتوسط (10 طالبات من كل مرحلة دراسية) وذلك من مدرسة رياض الصالحين بمدينة الرياض بالمملكة العربية السعودية. تراوحت أعمار الطالبات بين 6 و15 سنة. أظهرت النتائج أن القياسات البدنية تزداد مع زيادة أعمار الطالبات. كما أظهرت النتائج أنه بالنسبة للمرحلة الابتدائية يمكن عمل تصميم للأثاث المدرسي لكل مرحلتين متتاليتين (الأولى والثانية، الثالثة والرابعة، الخامسة والسادسة). كما يمكن عمل تصميم للأثاث المدرسي للمرحلة الأولى المتوسطة وتصميم آخر للمرحلتين الثانية والثالثة المتوسطة معاً. تم أيضاً حساب النسبة المئوية (5%، 50%، 95%) للقياسات البدنية وذلك لكي يتم استخدامها في تصميم الأثاث المدرسي المناسب لجميع المراحل محل الدراسة.