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Incompatibility between Students' Body Measurements and School Chairs

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Abstract: Children spend about five hours per day sitting down while doing their school work. Considering this as well as the potential inadequate use of school furniture, it is likely that some anatomical-functional changes and problems in the learning process may occur. The aim of this study was to examine possible incompatibility between students' body measures and school chairs they use. A total of 60 fourth-through sixth-grade students in a single primary boys' school in Cairo participated in the study. Their ages ranged from 9 to 12 years. Anthropometric measurements including popliteal height and buttock-popliteal length were measured. Seat height and seat depth for the only one style chair that is used in the classes of the three participated grades were measured. Based on the information about students' body dimensions and the chair dimensions, measures of fit or mismatch were constructed. The results revealed a high level of incompatibility between the chair dimensions and the anthropometric characteristics of the primary boy school students as less than 14% of the participated students can find an acceptable fit chair. Most students are sitting with seats that are too low or too deep.

Key words: Body Measurements · Anthropometric Dimensions · School Furniture · Incompatibility

INTRODUCTION

Egyptian school children spend a large part of their day sitting in a classroom environment comprising the normal school hours as well as the almost daily routine of tuition classes. This prolonged sitting posture makes them susceptible to risk of suffering negative effects from badly design and ill-fitting furniture.

Furniture wrongly designed and ill fitted to the characteristics of a child can result in defective posture and the establishment of pathological states which could affect their performance in focusing in class and faster fatigue occurrence [1]. Various studies have shown that the ill fitted design of classroom furniture has contributed to the high incidence of musculoskeletal disorders and low back pain (MSD/LBP) among school children [2-4]. This is of great concern because the strongest predictor of having future back pain is often considered to be a previous history of such symptoms [5]. A small body of research has implicated the mismatch between school furniture and body size among school students [6-13].

The detrimental effects of improper classroom furniture on the spine have been known for a long time. The dynamics of sitting can best be understood by studying the mechanics of both the relevant body parts and the external support system involved. For example, 75% of the total body weight is supported by only 4 inch^2 of surface when sitting. This small area is under the ischial tuberosities of the pelvis. The heavy load concentrated in this area results in high compressive stresses estimated at 85-100 pounds per square inch. Structurally, the tuberosities form a two-point support system, which is inherently unstable, since the center of gravity of a seated person's body above the seat may not be directly over the tuberosities. Therefore, the seat alone is insufficient for stabilization and the use of the legs, feet and back in contact with other surfaces, as well as muscular forces, is necessary to produce equilibrium [14]. Leg support is also critical for distributing and reducing buttock and thigh loads. Feet need to rest firmly on the floor or foot support so that the lower leg weight is not supported by the front part of the thighs resting on the seat [15].

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Measurement of popliteal height and buttock-popliteal length as body dimensions is needed to understand the impact of chair height and depth on posture [14]. If the seating surface is too high, the underside of the thigh becomes compressed causing discomfort and restriction in blood circulation. To compensate for this, a sitting person usually moves his buttocks forward on the chair seat. This can result in a slumped, kyphotic posture due to lack of back support. In addition, the feet do not have proper contact with the floor surface (heels are off the floor) and body stability is weakened. On the other hand, if the seat surface is too low, the knee flexion angle becomes small, the user's weight is transferred to a small area at the ischial tuberosities and there is a lack of pressure distribution over the posterior thighs [14]. When the seat is too deep, the front edge of the seat will press into the area just behind the knees, cutting off circulation to the legs and feet. To alleviate the discomfort, the person in the seat will slide forward but will lose proper lumbar and backrest support. Again, this is likely to result in a slumped, kyphotic posture with excessive pressure over and posterior to the ischial tuberosities. Too shallow seat depth may cause the user to have the sensation of falling off the front of the chair as well as result in a lack of support of the lower thighs. A free area between the back of the lower limb and the seat pan is useful to facilitate the suggested 80° flexion of the knees for rising out of the chair and for leg movements [14,16].

While a few chairs of different sizes are available, individual adjustments for the seat are not offered. Instead, a one-size-fits-all philosophy has been adopted in the industry, because such furniture is less costly to manufacture and easier to sell at a lower price and lessens the inventory problems for manufacturers and schools [1].

Many researchers investigated incompatibility between school furniture and anthropometric dimensions of the student and the effects of this incompatibility to the students' health. Parcells *et al.* [8] studied the mismatch between furniture and students' dimensions by measuring anthropometric characteristics of American children aged 11-13 years and the dimensions of their classrooms' desks and chairs, reporting that only 18.9% of students could find an appropriate match. Panagiotopoulou *et al.* [10] reported mismatch between the students' body dimensions and the classroom chair they use and stated that 20% of 4th grade and 45% of 6th grade students reported recurrent or continuous back pain that might be due to this incompatibility. Abdel Rahman [11] also reported 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-Saudi Arabia.

The purpose of this study was to examine the possible mismatches between the individual body dimensions of Egyptian primary school students and the standard classroom chairs made available to them by the school authorities. This study investigated the percentage of 9-12 year old boys' students who experienced a mismatch between their individual anthropometric dimensions and the classroom chairs they use.

MATERIALS AND METHODS

Subjects: With a target population of school children between 9 and 12 years of age, a convenience sample of grade 4 through grade 6 students was drawn from a single school district (one primary boys' school in Cairo-Egypt). The target population in the school district was divided into three strata by grade level (4th, 5th and 6th) comprising 800 students. Approval from Ministry of Education in Cairo city was obtained. Approximately 250 students were furnished consent forms to be given to their parents. After parental permission and student assent were obtained, a total of 60 students (24% participation rate) participated in the study (20 boys from each of the studied grades).

Measures: For the furniture measurements, one chair style was identified as the dominant model in the students' classrooms. Students were contacted during physical education classes, because all students were required to enroll in physical education and this setting offered easy access to data collection. All anthropometric measures were taken with the student in a relaxed and erect sitting posture. Each student was measured in T-shirt and shorts. Student dimensions were taken with the student seated erect on a flat horizontal surface, with knees bent 90° and feet (without shoes) flat on an adjustable horizontal surface. The body dimensions of the students were taken only from the right side of their body. Accuracy and repeatability of measurement was achieved by practice prior to the data collection sessions. The data recorded for a student was the mean of three trials. Popliteal height and buttock-popliteal length as human body dimensions, which are essential for seating, were measured using a tape measurement [17]. Other equipments to facilitate the measuring process included a portable sitting surface and an adjustable foot rest platform. They allowed the subjects to be oriented into position for ease and accuracy of taking measurements.

Body Measurements

Popliteal Height: It is the distance in centimeter (cm), taken vertically with 90° knee flexion, from the foot-resting surface to the posterior surface of the knee or popliteal space [8]. Subject sat erect on an adjustable seat, feet on the adjustable platform, knees flexed 90° 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.

Buttock-popliteal Length: With 90° knee flexion, the buttock-popliteal length is the horizontal distance (in cm) from the posterior surface of the buttock to the posterior surface of the knee or popliteal space [8]. The 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.

Chair Measurements: Seat height and seat depth as a matching school chair dimensions were measured with a metal tape [11].

Seat height: It is the vertical distance (in cm) from the floor to the highest point on the front of the seat.

Seat Depth: It is the horizontal distance (in cm) of the sitting surface from the back of the seat, at a point where it is assumed that the buttocks begin, to the front of the seat.

Anthropometrics Mismatches: The number and percentage of the students where the body match or mismatch with the furniture was calculated based on the rules adapted from Parcells *et al*. [8] and Chaffin and Anderson [15]. The body and furniture measures were then combined to operationalize mismatch, which is defined as incompatibility between the dimensions of the school chair and the dimensions of the student's body. The mismatch rules were followed in order to determine mismatch between certain body dimensions and its corresponding design parameter as listed below.

Popliteal Height and Seat Height Mismatch: A mismatch of popliteal height and seat height was defined as any seat height that is either <88% or >95% of the popliteal height [8,15]. This allowed for popliteal clearance of between 5 and 12% of popliteal height.

Buttock-popliteal Length and Seat Depth Mismatch: A mismatch of buttock-popliteal length to seat depth is defined as a seat depth that is either <80% or >95% of the buttock-popliteal length [8,15].

Taken together, a well-fitting chair requires both a seat height between 88 and 95% of a student's popliteal height and a seat depth of between 80 and 95% of the students' buttock-popliteal length.

Statistical Analysis: Statistical analysis was conducted using statistical package for the social sciences (SPSS) version 16 for Windows. Means, standard deviations, median, minimum and maximum of the age and the anthropometric measures of students in each grade as well as for all students were calculated. Students' number and percentage for school chair compatibility based on seat height as well as seat depth were then calculated in each grade and for all students. Finally, the percentage of students who fit the classroom chair based on both seat height and depth was calculated.

RESULTS

Sixty male primary school students from the fourth to the sixth grades participated in the study. Their ages ranged from 9 to 12 year, with a median age of 10.05 years and a mean age of 10.15 ± 0.98 years (Table 1). One chair style was the school chair that was used in the three studied grades with a seat height of 34 cm and a seat depth of 40 cm. Popliteal height and buttock-popliteal length of the students were statistically treated and the summary information of their measures was reported in table (2). As the data show, means and medians for the body measures were almost identical, indicating highly symmetrical distributions. There was a consistent increase in means and median by age increment.

The number and percentage of the students who fit or did not fit the chair used in their schools were presented in tables (3 and 4) as well as figures (1 and 2). About 33.33% of students fit the seat height of the school chair and 46.67% of students fit the seat depth of

Table 1: Age characters in the study sample.

School Grades	Mean ± Standard Deviation	Median	Minimum	Maximum
Grade 4	9.06 ± 0.03	9.07	9.01	9.09
Grade 5	10.05 ± 0.03	10.05	10.00	10.09
Grade 6	11.30 ± 0.42	11.08	11.01	12.00
Total	10.15 ± 0.98	10.05	9.01	12.00

Table 2: Summary of the students' anthropometric measures

		Popliteal Height (cm)				Buttock-Popliteal Length (cm)			
Grade	No.	Mean±SD	Median	Min.	Max.	Mean±SD	Median	Min.	Max.
Grade 4	20	38.88 ± 2.81	38.80	34.10	43.50	39.96 ± 4.15	38.70	35.10	47.50
Grade 5	20	41.71 ± 3.73	41.10	37.50	50.50	43.56 ± 5.23	42.85	36.40	52.00
Grade 6	20	41.89 ± 4.26	41.70	36.60	52.70	45.96 ± 6.68	48.15	37.40	57.00
Total	60	40.83 ± 3.85	40.50	34.10	52.70	43.16 ± 5.91	41.00	35.10	57.00

No.: Number of the students. Min.: Minimum. SD: Standard deviation. Max.: Maximum.

Table 3: Students' number and percentage for school chair compatibility based on seat height

	Grade 4		Grade 5		Grade 6		Total Students	
Compatibility	No.	%	No.	%	No.	%	No.	%
Too Low	6	30	16	80	16	80	38	63.33
Fits	12	60	4	20	4	20	20	33.33
Too High	2	10	0	0	0	0	2	3.33

No.: Number of students. %: Percentage.

Table 4: Students' number and percentage for school chair compatibility based on the seat depth

	Grade 4		Grade 5		Grade 6		Total Students	
Compatibility	No.	%	No.	%	No.	%	No.	%
Too Shallow	0	0	2	10	4	20	6	10
Fits	12	60	8	40	8	40	28	46.67
Too Deep	8	40	10	50	8	40	26	43.33

No.: Number of students. %: Percentage.

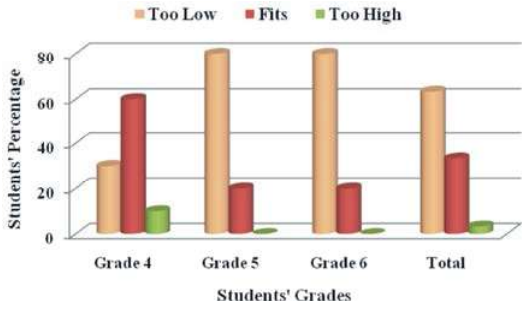

Fig. 1: Students' percentage for school chair compatibility based on seat height.

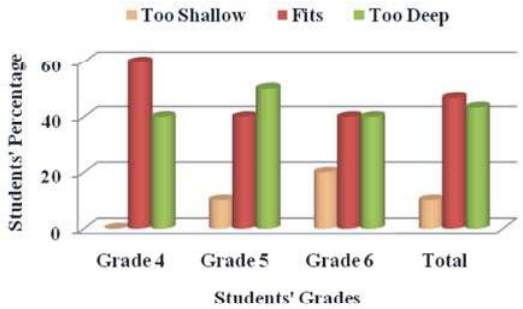

Fig. 2: Students' percentage for school chair compatibility based on seat depth.

the school chair. The overall level of mismatch was 66.66% due to incompatible seat height and 53.33% due to incompatible seat depth. Most of the mismatches were attributable to seats that was either too low (63.33%) or too deep (43.33%).

Concerning the combination between the seat height and the seat depth (Table 5), only 13.33% of the students fit the seat of the classroom chair in both height and depth. The overall level of mismatch was 86.67%. The majority (23.33%) of the students found the seat to be too low as well as too deep.

The results revealed that mismatch between the students' body dimensions and the classroom chair dimensions increases with age increment (Figure 3). The results also revealed that the higher degree of matching (about 60%) is found in the students in the 4th grade which supports the claim that mismatching increases with aging.

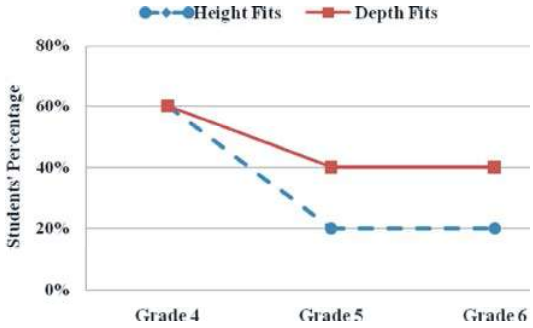

Fig. 3: Percentage of students who fit the height and depth of their school chair.

Table 5: Percentage of students who fit the classroom chair, based on seat height and seat depth

	Seat Depth		
Seat Height	*Too Shallow*	*Fits*	*Too Deep*
Too Low	6.66%	33.33%	23.33%
Fits	3.33%	13.33%	16.67%
Too High	0	0	3.33%

%: Percentage.

Table 6: Accepted limit of chair's dimensions that could match with students' body dimensions [25]

Grade	Chair Dimension	Minimum Accepted Limit*	Maximum Accepted Limit*
4	Seat Height	27.71	35.46
	Seat Depth	26.00	36.63
5	Seat Height	28.75	38.21
	Seat Depth	26.40	40.59
6	Seat Height	30.92	41.63
	Seat Depth	28.32	43.36

*: Measured in cm.

DISCUSSION

The data in this study indicate a substantial degree of mismatch between the bodily dimensions of these fourth through sixth graders and the classroom chairs available to them. A well-fitting chair requires both a seat height between 88 and 95% of a student's popliteal height and a seat depth of between 80 and 95% of the student's buttock-popliteal length [15]. Most students were sitting in chairs with seats that are too low or too deep.

Seat height, which is the starting point for the design of classroom furniture and also the measure used for prescription of a set size [18,19], was appropriate for popliteal height in only 13.33% of the students. However, seat depth was appropriate for buttock-popliteal length in 46.67% of the students.

The seat was too low for 63.33% of the students for which their thighs would not be supported enough and would generate discomfort [20]. Only 3.33% of the students used a seat that was too high (High mismatch). In the case of the high mismatch most of the students will not be able to support their feet in the floor, generating increase tissue pressure on the posterior surface of the knee [21].

The seat was too deep for 43.33% of the students. In this case and to avoid the compression on the posterior surface of the knee, the students will place their buttocks forward on the edge of the seat [10], causing kyphotic postures due the wrong use of the backrest [22-24].

Parcells *et al.* [8] examined the relationship between the secondary school students' anthropometric characteristics and the school furniture dimensions. They showed that there are generally high levels of mismatch for the three standard sizes of chairs. In their study, the mismatch between the students and both seat height and depth for the three chairs were 82.4, 85.1 and 95.9% (i.e. only 17.6, 14.9 and 4.1% of the students fitting each chair respectively). Legg *et al.* [9] 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). Panagiotopoulou *et al.* [10] studied classroom furniture dimensions and student's anthropometric measures (age 7-12 year) in three primary schools in Thessaloniki, Greece, reporting that none of students of 2nd grade matched with seat depth and only 5% matched with seat height. The study also reported that for 4th grade students, the chair is too deep for 70% of the students while only 53.3% match with seat height. A number of 18.3% students of 2nd grade, 20% of 4th grade and 45% of 6th grade were reported having suffered from recurrent or continuous back pain. Abdel Rahman [11] stated that the mismatch between the mean of the students' popliteal height and the seat height is 63.51% while the mismatch between the mean of the students' buttock-popliteal length and the seat depth is 75.68%. When the mismatch data for both seat height and depth

was combined, the level of mismatch was 89.19%. Brewer [12] reported that 22.3% of the 5th and 6th grade students find their school chair too high and 29.1% find it too shallow. Castellucci *et al.* [13] compared furniture sizes within three different schools with the anthropometric characteristics of Chilean students in the Valparai´so region and reported that seat height was appropriate for students' popliteal height in only 14% of the 2 out of the 3 schools and 28% in the third.

The present study despite being performed on the primary school students supports the findings of Parcells *et al.* [8], Legg *et al.* [9], Panagiotopoulou *et al.* [10], Abdel Rahman [11], Brewer [12] and Castellucci *et al.* [13]. It is therefore reasonable to infer that there is a generally high level and probably widespread mismatch between the chair used by the school students and their anthropometric characteristics.

According to the obtained data, the classroom's chair was, in almost all the analyzed cases and subjects, not adequate for the student population. Seat height was the furniture dimension with a higher level of mismatch, which may result in pain on the posterior surface of the knee.

Situmorang *et al.* [25] reported accepted measures for schools seat height and seat depth in order to achieve high level of compatibility (Table 6). Based on their data, it is clear that the main cause of mismatching is using one-sized chair for all fourth thought sixth students in addition to non-considering of the students dimensions during furniture manufacturing.

While the findings of this study are suggestive, they were based only on data from a convenience sample in a single school district. Finally, our definition of mismatch was focused on only a few furniture dimensions, such as seat height and seat length, disregarding the contributions that surface tilt, slope of back rest and moldings may make to the fit to body dimensions.

If manufacturers are going to continue to produce and sell traditionally designed furniture, schools need to be encouraged to at least provide as much variety in furniture sizes as possible to accommodate the variety of student sizes. In this particular study, school chair simply turned out to be too incompatible for many fourth, fifth and sixth graders. Given the low priority generally assigned to the comfort and functional needs of students, it would not be surprising if school furniture in other school districts show a similar mismatch with students' overall body dimensions. However, it is also important that health professionals working in schools be aware that full accommodation of students' needs would require ergonomically redesigned classroom furniture.

CONCLUSION

According to the obtained data it can be concluded that classroom's chair was not adequate for the student population. The results of this study highlight the fact that classroom chair is typically acquired and selected without any previous ergonomics concern, which will, most likely, result in its inadequacy.

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