

Mismatch of Classroom Chair and Schoolchildren Body Dimensions

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ABSTRACT

The purpose of this study was to examine possible mismatch between the schoolchildren body dimensions and the classroom chair they use. A total of 74 fourth- through sixth-grade students in a single primary school in Riyadh participated in the study. The participants' ages ranged from 9 to 12 years. Anthropometric measurements including popliteal height and buttock-popliteal length were gathered in several physical education classes. In addition, the furniture dimensions were measured for the only one style chair that is used in the classes of the three participated grades. These dimensions included the seat height as well as the seat depth. Based on the information about student body dimensions and the chair dimensions, measures of fit or mismatch were constructed. The data indicate a substantial degree of mismatch between the students' bodily dimensions and the classroom chair available to them. Fewer than 11% of the students can find an acceptable fit chair. Most students are sitting with seats that are too high or too deep. It is concluded that there is a high level of mismatch between the chair dimensions and the anthropometric characteristics of the primary school students. Based on the evidence presented, many fourth through sixth graders must endure seating arrangements in their classroom that are not conducive to learning.

Key words: Posture; Children anthropometric measures; Classroom furniture.

INTRODUCTION

The most widespread work posture in industrialized countries today is sitting. With the increasing use of visual display units such as personal computers, sitting will become even more common in the workplace of the future³. Overtime, workplace deficiencies can cause problems such as physical symptoms of musculoskeletal stress and disorder, emotional stress, low productivity and poor quality of work¹. For this reason, the sitting posture and all it entails should be examined more closely to ensure that ergonomic interventions are made to prevent injury and loss of productivity.

A surprisingly high proportion of school students report suffering from musculoskeletal discomfort and low back pain (MSD/LBP)^{2,13}. This is of great concern because the strongest predictor of having future back pain is often considered to be a previous history of such symptoms⁵. Thus, it is important to determine the risk factors for MSD/LBP amongst school students. A small body of research has implicated the mismatch between school furniture and body size as a causative factor for MSD/LBP among school students^{7,10,12}.

During the past decade, research in ergonomics has led to heightened interest in the technology of work and furniture design based on the biomechanics of the human body. The debate, building on early work in the field by Branton (1969)⁴ has been especially active

concerning the recommendations of new principles for the design of chairs and desks in the workplace. However, little interest has been shown in the largest workplace of all: the school. Schoolchildren are at special risk for suffering negative effects from badly designed and ill fitting furniture owing to the prolonged periods spent seated during school. In addition, it is in the school where students acquire permanent habits of sitting. Therefore, public health concerns over the effects of bad posture need to be focused on the design of classroom furniture. However, studies that provide empirical evidence on the extent and the nature of a possible mismatch between school furniture and schoolchildren's bodily dimensions are rare.

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 inch² (26 cm²) 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, are necessary to produce equilibrium¹⁴. 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 seat⁶.

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 leads to poor 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. Health care providers can be instrumental in focusing attention on environmental influences that impact health. Good posture facilitates lung expansion and reduces organ crowding and strain on soft bones, tendons, and muscles⁶. While schools have implemented health education programs in an effort to introduce young people to health-promoting and health-protecting behaviors, proper seating rarely gets the attention it deserves.

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 schools⁸.

Current research concerning school chair and desk design has predominantly been conducted in the Scandinavian countries. Not surprisingly, observations and measurements of body alignments indicate that furniture designed to accommodate the task and the individual's size is more acceptable to users than standardized styles. Furniture designs that take account of such research are now being produced in Denmark and Sweden. The trend is also spreading in Germany, France, and Switzerland¹⁰. A starting point for research on

the proper dimensions of school furniture is to investigate how the dimensions and styles of chairs and desks actually used in classroom situations reflect the body dimensions and the functional needs of today's student population. A review of the literature reveals that the study with the most extensive anthropometric data on children aged 11–13 years was completed in 1975 by the Highway Safety Research Institute for the Consumer Product Safety Commission¹². However, two key measurements, i.e., popliteal height and buttock to popliteal length, were not included in that study.

These measures of popliteal height and buttock-popliteal length are needed to understand the impact of chair height and depth on posture. 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 thighs¹⁴. 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. A seat depth of 32.5 cm was suggested for an 11 years old^{11,14}.

Given the existing evidence about the importance of popliteal height and buttock-popliteal length for school seating designs, but the lack of current anthropometric data on schoolchildren, this study provided evidence from a school district in Saudi Arabia. Specifically, the purpose of the study was to investigate the percentage of 9–12 year old students who experienced a mismatch between their individual anthropometric dimensions and the classroom chair they use.

SUBJECTS AND MEASURES

Subjects

With a target population of schoolchildren between 6 and 12 years of age, a convenience sample of fourth- through sixth-grade students was drawn from a single girls' school in Riyadh. Ethical approval was obtained from the concerned school authority. After parental permission, 74 students (26 girls from the fourth grade, 25 girls from the fifth grade and 23 girls from the sixth grade) participated in the study. Students' ages ranged from 9 years to 12 years, 1 month, with a median age of 10 years, 4 months and a mean age of 10 years, 5 months (Table 1).

Table (1): Age Characters in the Study Sample.

School Grades	No.	Mean	Median	SD
Fourth	26	9.4	9.5	0.28
Fifth	25	10.5	10.5	0.37
Sixth	23	11.7	11.7	0.27
Total	74	10.5	10.4	0.99

SD: Standard Deviation.

No.: Number of students.

Measures

For the furniture measurements, one chair style was identified as the dominant model in the students' classrooms. All anthropometric measures were taken with the student in a relaxed and erect 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 following human body dimensions, which are essential for seating, were measured in this study:

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.

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.

These variables were measured using an anthropometer. Other equipment 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.

The following variables represent relevant dimensions of the classroom chair:

Seat height: The chair seat height is the vertical distance in cm from the floor to the highest point on the front of the seat.

Seat depth: The chair seat depth 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.

Chair dimensions were measured with a metal tape. The anthropometric and furniture measures were then combined to operationalize mismatch, which is defined as incompatibility between the dimensions of the classroom chair and the dimensions of the student's body.

Popliteal Height and Seat Height Mismatch: A mismatch of popliteal height and seat height was defined as any seat height that is either >95% or <88% of the popliteal height. This allows for popliteal clearance of between 5% and 12% of popliteal height¹².

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 length¹².

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.

RESULTS

The classroom furniture under the study is one chair style that was used in the classroom of the three studied grades. Seat height is 34 cm while Seat depth is 40 cm.

Summary information on the student body measures is reported in Table (2).

Table (2): Summary of the Students Anthropometric Measures.

Student Measures (cm)	No.	Popliteal Height					Buttock-Popliteal Length				
		Mean	SD	Min.	Med.	Max.	Mean	SD	Min.	Med.	Max.
4 th Grade	26	35.04	2.55	31	35	39	37.39	2.08	43	37	41
5 th Grade	25	35.64	1.82	33	36	39	40.56	2.80	36	41	45
6 th Grade	23	36.57	1.70	43	37	39	43.09	4.02	38	42	50
Total	74	35.72	2.14	31	35.5	39	40.23	3.80	34	39	50

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

As the data show, means and medians for the measures were almost identical, indicating highly symmetrical distributions. Although, there was a consistent increase in means and median by age group.

Tables (3 and 4) as well as figures (1 and 2) reveal the number and percentage of the students who fit or did not fit the chair used in their classroom.

Table (3): Number and Percentage of Students who fit the Classroom Chair Based on Seat Height.

	4 th Grade		5 th Grade		6 th Grade		Total Students	
	No.	%	No.	%	No.	%	No.	%
Too Low	3	11.54	3	12	3	13.04	9	12.16
Fits	5	19.23	11	44	11	47.83	27	36.49
Too High	18	69.23	11	44	9	39.13	38	51.35

No.: Number of students. %: Percentage.

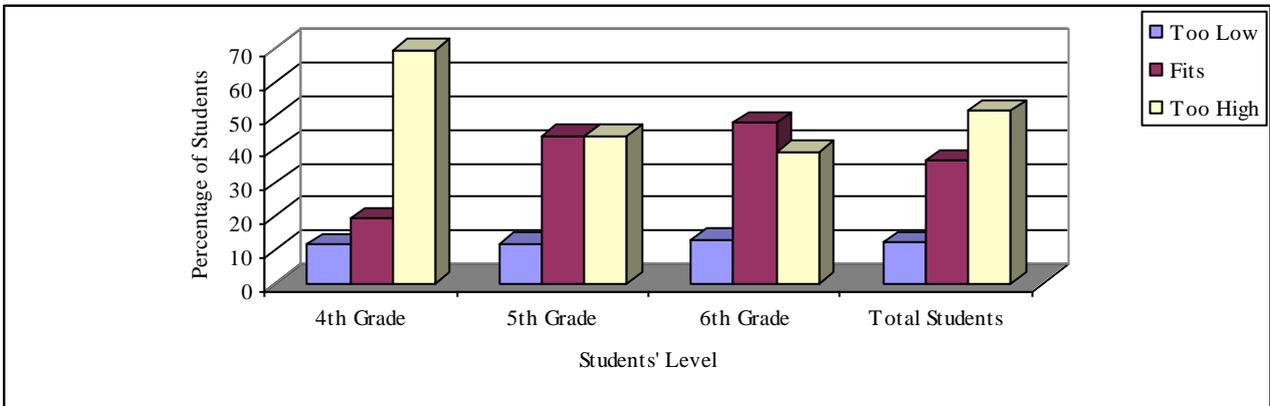


Fig. (1): Percentage of students who fit the classroom chair based on the seat height.

Table (4): Number and Percentage of Students who fit the Classroom Chair Based on the Seat Depth.

	4 th Grade		5 th Grade		6 th Grade		Total Students	
	No.	%	No.	%	No.	%	No.	%
Too Shallow	0	0	0	0	0	0	0	0
Fits	0	0	7	28	11	47.83	18	24.32
Too Deep	26	100	18	72	12	52.17	56	75.68

No.: Number of students. %: Percentage.

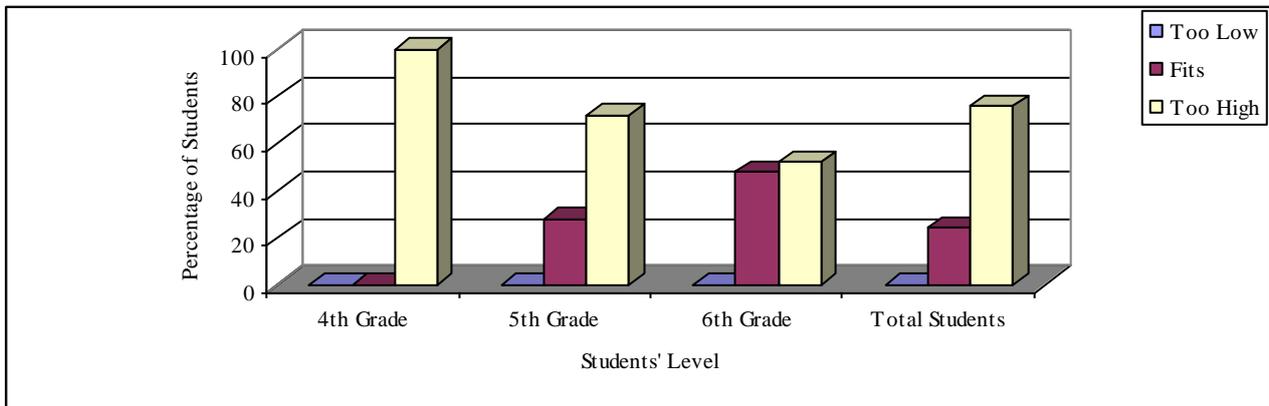


Fig. (2): Percentage of students who fit the classroom chair based on the seat depth.

About 36.49% of students in the sample fit the seat height the classroom chair. The overall level of mismatch was 63.51%. The majority (51.35%) of the students found the seat too high and 12.16% found the seat too low. Only 24.32% of the students fit the seat depth of the classroom chair. All the mismatches were attributable to seats that was too deep (75.68%) (Tables 3 and 4 as well as Figures 1 and 2).

Concerning the combination between the seat height and the seat depth (Table 5), only 10.81% of the all students fit the seat of the

classroom chair in both height and depth. The overall level of mismatch was 89.19%. The majority (40.54%) of the students found the seat to be too high as well as too deep.

The results revealed that mismatch between the students' body dimensions and the classroom chair dimensions decreases with age (Figure 3).

The results also revealed that the higher degree of matching (about 47.83%) was found in the students in the 6th grade which supports the claim that mismatching decreases with aging.

Table (5): Number and Percentage of Students who fit the Classroom Chair Dimensions.

Total Students			
Height	Depth		
	Too Shallow	Fits	Too Deep
Too Low	0 0%	2 2.70%	7 9.46%
Fits	0 0%	8 10.81%	19 25.68%
Too High	0 0%	8 10.81%	30 40.54%

#: Percentage.

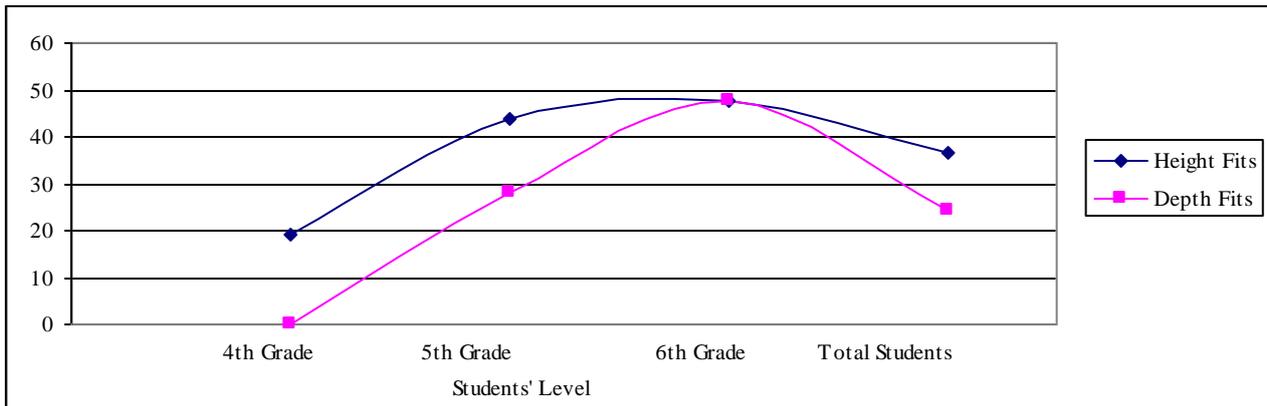


Fig. (3): The percentage of the students who match the height and depth of their classroom chair.

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 chair 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 length⁶.

The present study has clearly shown that the seat was too high for about 51.35% of the all students and was too deep for about 75.68% of the all students. The majority of the cases of mismatch was observed in the 4th grade students, where there was 80.77% of mismatch between the seat height and the popliteal height and 100% of mismatch between the seat depth and the buttock-popliteal length (i.e. the seat was too deep for the students in the 4th grade). None of the all students had found that the chair was too shallow.

The lower level of mismatch between the seat height and the popliteal height was observed in the 6th grade students (52.17%) comparing to 56% for the 5th grade students and 80.77% for the 4th grade students.

Similarly, the lower level of mismatch between the seat depth and the buttock-popliteal length was observed in the 6th grade students (52.17%) comparing to 72% for the 5th grade students and 100% for the 4th grade students.

Parcells et al. (1999)¹² examined the relationship between the secondary school students' anthropometric characteristics and the school furniture dimensions. They showed that there were 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. (2004)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).

The present study was the only study that examined the relationship between the classroom chair dimensions and the primary schoolchildren anthropometric characteristics. In this study, the mismatch between the mean of the students' popliteal height and the seat height was 63.51% while the mismatch between the mean of the students' buttock-popliteal length and the seat depth was 75.68%. when the mismatch data for both seat height and depth was combined, the level of mismatch was 89.19%.

The present study despite being performed on the primary school students supports the findings of both Parcells et al. (1999)¹² and Legg et al. (2004)⁹. 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.

This study was limited by being based only on data from a convenience sample in a single school district. Finally, the definition of mismatch was focused on only a few furniture dimensions (seat height and depth) disregarding the contributions that surface tilt and slop of the backrest may make to the fit to body dimensions.

If manufactures 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. It is also important that health professionals working in schools be aware that full accommodation of students' needs would require ergonomically redesigned classroom furniture.

In conclusion, this study has shown that there is 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 this study may well indicate a significant problem nationwide.

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الملخص العربي

عدم التوافق بين القياسات الخاصة بالكرسي المدرسي والقياسات الجسدية لأطفال المدارس

يهدف البحث إلى دراسة عدم التوافق المحتمل بين القياسات الجسدية لأطفال المدارس و الكرسي المستخدم في المدرسة. شارك في البحث 74 طفل من الصف الرابع (26 طفل) ، الصف الخامس (25 طفل) و الصف السادس الابتدائي (23 طفل) و ذلك من مدرسة للطالبات بمدينة الرياض بالمملكة العربية السعودية . تراوحت أعمار الطالبات بين 9 و 12 سنة . اشتملت القياسات الجسدية للطالبات على طول الساق (المسافة بالسهم من خلف الركبة حتى آخر الكعب عندما تكون الطالبة في وضع الجلوس مع ثني الركبة 90 درجة) و طول الفخذ (المسافة بالسهم من خلف الركبة حتى آخر المقعدة عندما تكون الطالبة في وضع الجلوس مع ثني الركبة 90 درجة) . اشتملت قياسات الكرسي المدرسي على ارتفاع المقعد (المسافة العمودية بالسهم من الأرض حتى أعلى نقطة من مقدمة المقعد) وعمق المقعد (المسافة الأفقية بالسهم من المسند الخلفي للمقعد حتى مقدمة المقعد) . أظهرت النتائج أن أكثر من 89% من الطالبات لم تتوافق قياساتهم مع قياسات الكرسي المدرسي و أن أكبر نسبة من عدم التوافق كانت بين طالبات الصف الرابع . أظهرت النتائج أيضا أن أقل نسبة من عدم التوافق كانت بين طالبات الصف السادس . بناء على نتائج هذه الدراسة ، تم التوصية على ضرورة توافر مقاسات مختلفة للكرسي المدرسي حيث أن عدم التوافق بين القياسات الجسدية للطالبات و قياسات الكرسي المدرسي قد تؤدي إلى تشوهات عديدة بالعمود الفقري للطالبات .