

## FELLOWSHIP FORUM

# Mismatch of Classroom Furniture and Student Body Dimensions

## *Empirical Findings and Health Implications*

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**Purpose:** To examine possible mismatch between the individual body dimensions of students and the classroom furniture they use.

**Methods:** A total of 74 (37 male and 37 female) sixth-through eighth-grade students in a Michigan school district participated in the study; their ages ranged from 10 years, 11 months to 14 years, 3 months. Anthropometric measurements (including elbow height, shoulder height, upper arm length, knee height, popliteal height, buttock-popliteal length, and stature) were gathered in several physical education classes, each during a single session. In addition, the furniture dimensions were measured for three styles of chairs and three styles of desks prevalent in the students' classrooms. Based on both the information about student body dimensions and furniture dimensions, measures of fit or mismatch were constructed.

**Results:** The data indicate a substantial degree of mismatch between the students' bodily dimensions and the classroom furniture available to them. Fewer than 20% of students can find acceptable chair/desk combinations. Most students are sitting in chairs with seats that are too high or too deep and at desks that are too high. Even after controlling for body stature, girls are less likely to find fitting chairs.

**Conclusions:** Based on the evidence presented, many sixth through eighth graders must endure seating ar-

rangements in their classrooms that are not conducive to learning. © Society for Adolescent Medicine, 1999

**KEY WORDS:**

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Eighty percent of the U.S. population seeks medical attention for back problems at some time in their lives (1). Contrary to what one might assume, back problems are not confined to the adult population. A surprising number of grade school children and adolescents are reported to have regular bouts of back, neck, and headache pain (2,3). Back and neck pain also have a substantial economic impact. In 1990, direct medical care costs for low back pain exceeded \$24 billion, and total costs increase substantially when the indirect costs of disability are included (4). Given these statistics, the importance of prevention is evident.

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 (5) and Keegan (6), 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

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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 (7). It is for these reasons that 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.

### *Literature Review*

#### **Dynamics of Sitting**

The detrimental effects of improper classroom furniture on the spine have been known for a long time (8). 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<sup>2</sup> (26 cm<sup>2</sup>) 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 (psi) (9). 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 (5). 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 equilibrium (5). 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 (10).

If the major weight is to be placed on the ischial tuberosities and the proximal half of the posterior thighs, seat support should occur under and anterior to the ischial tuberosities (8,11). To maintain the weight bearing over and anterior to the ischial tuberosities, sacral and pelvic support are needed which prevent or reduce backward rotation of the pelvis and subsequent lumbar kyphosis, also known as posterior curve (8). Lumbar lordosis, the normal anterior curve of the lumbar vertebrae, helps to transfer some of the weight (as much as 25%) over the posterior thighs (12,13). Since flattening of the lumbar curve and posterior rotation of the pelvis occurs when hips flex and the trunk–thigh angle narrows, Keegan (6) recommended chairs with a

rearward sloping backrest as a means of achieving a minimum trunk–thigh angle of 105°. For the same reasons, Mandal (14) suggested that when one works at a desk, the seat should slope forward to accommodate a trunk–thigh angle >90° and still maintain the trunk in an erect position. Mandal also proposed that work surfaces be tilted toward the user, because this is more compatible with upright sitting and improved vision. In addition, lessening the need for users to flex neck and trunk for an improved viewing angle should also reduce lumbar flexion.

Studies of sitting posture which evaluate postural accommodations of seats with forward slope angles have found that with increasing forward slope, the spine moves toward lumbar lordosis (15,16). In a study of trunk adaptation to forward inclining seats, Bendix and Biering-Sorensen (17) noted that one third of the body's adaptation takes place in the spine and two thirds in the hip joints. Evaluations based on user comfort indicate a preference for 0° (horizontal) and 5° forward inclinations. While a forward-inclining seat seems to affect the lumbar spine in a positive direction, a sloping desk appears to accomplish the same and, in addition, improves the posture of the other parts of the spine (18).

#### **Classroom Furniture and Postural Alignment**

Classroom furniture from manufacturers is typically not designed to accommodate the dimensions of the individual user. While a few desks offer an overall height adjustment and chairs of different sizes are available, individual adjustments for the seat, arm and back are not offered (personal communication with two school furniture manufacturers, 1996). 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. When the five major school furniture manufacturers in the United States were asked what research they relied on for their furniture designs, the response was that they did not rely on any. Instead, each company based their designs on specifications from the American Furniture Manufacturers Association and the National Standards Board to decide "seat width, belly room, and prohibited combustible materials" (19). Existing designs have basically been unaltered for years.

While manufacturing and inventory costs are important concerns, there are also costs involved in products that do not reflect designs based on properly selected anthropometric data and ergonomics.

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 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 muscles (10). While schools have implemented health education programs (20) in an effort to introduce young people to health-promoting and health-protecting behaviors, proper seating rarely gets the attention it deserves.

Current research in the area of 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 Switzerland (21). 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 Commission (22). 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 thighs (8). 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 (8,23). Too shallow a 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 (23). 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 (26). Diffrient et al. (26) suggested a seat depth of 32.5 cm for an 11-year-old.

Knee and elbow rest height are also important in studying posture. When knee height exceeds the desk/table clearance, the patella or anterior thigh will strike the underside of the desk or table. This may lead the user to extend and position the legs forward. The feet then lack stability. If the elbow rest height is lower than the desk or table surface, the working arm must be raised. To compensate, shoulders must also be raised or abducted placing a stress on the deeper posterior neck musculature to provide stabilization of the head posture. If the elbow rest height exceeds that of the desk or table, it will result in the user bending forward by spinal flexion, with the body weight being supported by the arms. A kyphotic spinal posture with round shoulders will result. When performing desk work, a shoulder flexion angle of  $<25^\circ$  and a shoulder abduction angle of between  $15^\circ$  and  $20^\circ$  is indicated (10).

Given the existing evidence about the importance of popliteal height, buttock-popliteal length, knee height, and elbow rest height for school seating designs, but the lack of current anthropometric data on schoolchildren, our study provides evidence from a school district in Michigan. Specifically, we studied: (a) the percentage of 11–13-year-old students who experience a mismatch between their individual anthropometric dimensions and the classroom furniture they use; and (b) the student characteristics (age, gender, and anthropometric measures) that predict a mismatch.

## Methods

### Sample and Study Design

With a target population of schoolchildren between 11 and 13 years of age, a convenience sample of sixth- through eighth-grade students was drawn from a single school district. The target population in the school district was divided into three strata by grade level (sixth, seventh, and eighth) comprising approximately 900 students. 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. Approximately 250 (125 male and 125 female) students were furnished consent forms to be given to their parents. After parental permission and student assent were obtained, a total of 74 students (37 males and 37 females; 30% participation rate) participated in the study. There are 12 or 13 boys and 12 or 13 girls representing each of the three grades. Students' ages ranged from 10 years, 11 months to 14 years, 3 months, with a median age of 12 years, 5 months and a mean age of 11 years, 2 months. Other than age and gender, no demographic background information was gathered, to minimize intrusion during class time.

All measurements were gathered by the first author with the aid of one data-recording assistant during a single session. For the furniture measurements, three styles of chairs and three styles of desks were identified as the dominant models in the students' classrooms. Further data collected include the anthropometric measures, age (in years and months), grade level, and gender of the subjects.

### Measures

All anthropometric measures were taken with the subject in a relaxed and erect posture. Each student was measured in T-shirt and shorts. Student dimensions (with the exception of height) 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. Height was taken standing erect without shoes. The following human body dimensions, which are essential for seating and work surface design (23), were measured in this study:

*Elbow height.* Taken with 90° elbow flexion, elbow height is measured as the vertical distance from the bottom of the tip of the elbow (olecranon) to the subject's seated surface.

*Shoulder height.* Shoulder height refers to the distance taken vertically from the top of the shoulder at the acromion process to the subject's sitting surface.

*Upper arm length.* The difference between the elbow height and shoulder height.

*Knee height.* Knee height is the vertical distance measured with 90° knee flexion from the foot resting surface to the top of the kneecap just in back and above the patella.

*Popliteal height.* Popliteal height is the distance, 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 from the posterior surface of the buttock to the posterior surface of the knee or popliteal space.

*Stature.* Stature (or height) is the vertical distance from the floor to the top of the head, while the subject stands erect, looking straight ahead. 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 furniture:

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

*Seat depth.* The chair seat depth is the horizontal distance of the sitting surface from the back of the seat, at a point where it is assumed that the buttocks begins, to the front of the seat.

*Seat slope.* The chair seat slope is the direction and angle of pitch of the seat of the chair.

*Desk/table height.* The desk/table height is the vertical distance from the floor to the top of the front edge of the desk or table.

*Desk/table clearance.* The desk/table clearance is the vertical distance from the floor to the bottom of the front edge of the desk or table.

*Desk slope.* The desk slope is the angle of pitch of the top of the desk.

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

**Popliteal Height and Seat Height Mismatch**

Based on existing research (10,23–25), we define a mismatch of popliteal and seat height 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 height. To establish how sensitive results are to changes in the definition of mismatch, we also employed a very strict definition of mismatch: seat height of either >99% or <80% of popliteal height.

**Buttock-Popliteal Length and Seat Depth Mismatch**

Based on available anthropometric evidence (27), in this study a mismatch of buttock-popliteal length to seat depth is defined as a seat that is either <80% or >95% of the buttock-popliteal length. Again, a second, laxer standard of mismatch is adopted of the seat depth that is either <80% or >99% of the buttock-popliteal length.

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

**Knee Height and Desk/Table Clearance Mismatch**

To be comfortable, desk-knee clearance should exceed 2 cm (14). Thus, a mismatch is defined to occur when a desk/table is <2 cm higher than the knee height.

**Elbow Rest Height and Desk/Table Height Mismatch**

Elbow rest height depends not only on vertical elbow height, but also the shoulder flexion and shoulder abduction angles. To determine acceptable elbow rest height with shoulder flexion and abduction (hE), the measurements of shoulder height (hS), vertical

**Table 1.** Chair and Desk Characteristics

Chairs	Seat Height (cm)	Seat Depth (cm)	Seat Angle
1	42.4	44.6	5°back
2	42.4	40.0	5°back
3	44.5	39.0	5°back
Desks	Height (cm)	Clearance (cm)	Surface Angle
1	71.2	69.6	0°
2	71.2	68.0	0°
3	69.3	67.8	5°

elbow height (hEv) upper arm length ( $U = hS - hEv$ ), shoulder flexion ( $\theta$ ), and shoulder abduction ( $\beta$ ) will be used in the following equation:

$$hE = hEv + U[(1 - \cos\theta) + \cos\theta(1 - \cos\beta)]$$

With this formula and the maximum acceptable angles suggested by Chaffin and Anderson (10), it is possible to determine for each student the maximum and minimum desk height appropriate for the student. With minimum and maximum shoulder flexions of 0° and 25°, the corresponding cosines are 1 (0°) and .9063 (25°). For abduction angles of 0° (minimum) and 20° (maximum), the corresponding cosines are 1 and 0.9397. Given that the cosines are monotone functions of the angles, a student's minimum desk height is determined by the vertical elbow height alone ( $hE = hEv + U[(1 - 1) + 1(1 - 1)] = hEv$ ). The maximum desk height is determined by:

$$\begin{aligned} hE &= hEv + U[(1 - 0.9063) + 0.9063(1 - 0.9397)] \\ &= hEv + U(0.1483) \\ &= hEv + 0.1483 hS - 0.1483 hEv \\ &= 0.8517 hEv + 0.1483 hS, \text{ since } U = hS - hEv. \end{aligned}$$

Thus, the maximum desk height acceptable for an individual student was determined by that student's shoulder height and vertical elbow height and can be calculated for each individual on the basis of the collected information.

*Results*

The classroom furniture under study consisted of three chairs and three tables. Two of the three chair types had an attached desk surface. The dimensions of the chairs and desks are given in Table 1. Summary information on the student body measures is reported in Table 2. As the data show, means and medians for most measures were almost identical, indicating highly symmetrical distributions. Al-

**Table 2.** Summary of Anthropometric Measures for 74 Students (Grades 6–8)

Student Measures (cm)	<i>n</i>	Mean	SD	Minimum	Median	Maximum
Stature/height	74	156.8	10.2	138.5	156.3	162.7
Shoulder height (sitting)	74	51.7	4.1	43.0	51.4	66.4
Elbow height (vertical)	74	19.0	3.0	13.2	22.0	29.5
Knee height	74	49.7	3.6	43.4	49.5	57.3
Popliteal height	74	39.5	2.8	33.4	39.0	45.5
Buttock-popliteal length	74	44.8	3.3	38.0	44.8	50.4

though not shown here, there was a consistent increase in means and medians by age group, and with the exception of the buttock-popliteal length measurement, standard deviations also increased with age. The latter is indicative of greater variability with increasing age.

### Mismatch Between Student Body Dimensions and Classroom Furniture

Table 3 reveals the number and percentage of students who fit or did not fit the two relevant dimensions of the three chairs in the classroom. Only 14.9% of the students in the sample fit Chair 1 in both height and depth, 17.6% fit Chair 2, and a mere 4.1% fit Chair 3 (Table 3). As is apparent, all three chairs tended to be too high for the students and were also too deep for many students. In fact, cross-classification of the tables for the three separate chairs (not shown here) revealed that only 14 (or 18.9%) of all students could find at least one chair which adequately fit their body dimensions of popliteal height and buttock-popliteal length. [Using the alternative, stricter definition of mismatch (seat height/depth of either >99% or <80% of popliteal height/buttock-popliteal length) and thus, looser definition of fit, 24.3% of the students fit Chair 1 in both height and depth, 33.8% fit Chair 2, and only 9.5% fit Chair 3. Even under this scenario, 65% of the students could not find any chair that fit their body dimensions.]

To examine fit or mismatch of students' body dimensions with the desks in the classroom, it was first established that none of the students experienced knee clearance problem: for the lowest desk, a clearance of 67.8 cm still exceeded the tallest knee height (57.3 cm) by 10.5 cm (see Tables 1 and 2). Substituting the maximum angle values in the formula used to calculate functional elbow height from the vertical elbow height measurements ( $hE = hEv + U[(1 - \cos\theta) + \cos\theta(1 - \cos\beta)]$ ) yields:  $hE = 0.8517 hEv + 0.1483hS$ , where  $hE$  is the maximum functional elbow height,  $hEv$  is the vertical elbow height, and  $hS$  is the shoulder height. Each student's functional elbow height is then added to each of the chair seat heights to result in three maximum acceptable desk heights, depending on which chair the student sits in. (Owing to the 5° backward slope of the chairs under study, the back of the seat, where the elbow is aligned, is lower than the front edge. This height can easily be calculated as: seat height – seat depth ·  $\sin 5^\circ$ .) These maximum acceptable heights are then compared to the two desk heights (71.2 and 69.3 cm) available in the school district. As the data in Table 4 show, for a large majority of the students, all of the desk chair combinations available in the classroom yielded desk heights that exceed acceptable functional elbow heights. Depending on the desk/chair combination, an excess desk height of >5 cm (approximately 2 inches) was experienced by 40% of students for the most favorable combination and

**Table 3.** Number of Percentage of Students Who Fit Three Classroom Chairs, Based on Seat Height and Seat Depth

Height	Chair 1 (Height: 42.4 cm, Depth: 44.6 cm)			Chair 2 (Height: 42.4 cm, Depth: 40.0 cm)			Chair 3 (Height: 44.5 cm, Depth: 39 cm)		
	Depth			Depth			Depth		
	Too shallow	Fits	Too deep	Too shallow	Fits	Too deep	Too shallow	Fits	Too deep
Too low	0 0.0%	1 1.4%	0 0.0%	1 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
Fits	0 0.0%	11 14.9%	2 2.7%	0 0.0%	13 17.6%	0 0.0%	4 5.4%	3 4.1%	0 0.0%
Too high	0 0.0%	10 13.5%	50 67.6%	1 1.4%	42 56.8%	17 23.0%	8 10.8%	48 64.9%	11 14.9%

**Table 4.** Number and Percentage of Students ( $n = 74$ ) Whose Body Dimensions Fit the Desk Heights Among Six Desk–Chair Combinations

Excess of Desk Height Over Acceptable Functional Elbow Height of Student	Desk (71.2 cm), Chair (38.5 cm)		Desk (71.2 cm), Chair (38.9 cm)		Desk (71.2 cm), Chair (41.1 cm)		Desk (69.3 cm), Chair (38.5 cm)		Desk (69.3 cm), Chair (38.9 cm)		Desk (69.3 cm), Chair (41.1 cm)	
	N	%	N	%	N	%	N	%	N	%	N	%
≤0cm	1	1.4	1	1.4	3	4.1	2	2.7	3	4.1	5	6.8
0–2cm	1	1.4	2	2.7	2	2.7	1	1.4	1	1.4	10	13.5
2–5cm	4	5.4	3	4.1	22	29.7	15	20.3	20	27.0	25	33.8
5–8cm	22	29.7	25	33.8	25	33.8	26	35.1	26	35.1	25	33.8
>8cm	46	62.2	43	58.1	22	29.7	30	40.5	24	32.4	9	12.2

91.9% for the least favorable combination. Even with the most favorable combination of highest seat height (41.1 cm) and lowest desk height (69.3 cm), 12.2% of the students were required to raise their elbow (most likely through increased shoulder abduction or shoulder elevation) above 8 cm (more than 3 inches) to achieve forearm placement on the desk work surface. As with the chairs alone, desk chair combinations are definitely inadequate for these students and are certain to cause a lot of discomfort.

In a final analysis, we employ logit models (28) to address the question of which student characteristics (gender, age, or stature/height) predict whether the student fits any of the chairs at all or any of the desk–chair combinations. Table 5 displays the (ad-

justed) odds ratios, their 95% confidence intervals, and several fit indicators for the two equations. Whether a student could find any chair in the classroom that fit his or her body dimensions was predicted by two characteristics: student height and (to a lesser extent) student age. Not surprisingly, the odds of finding a fitting chair increase by more than 2 for each additional centimeter in height (or what amounts to the same: the odds of a mismatch increase by more than 2 for a student who is 1 cm shorter than another). With student height and student age fairly strongly correlated ( $r = 0.55$ ), age had no independent effect on the odds of fit or mismatch. Finally, even after accounting for body height, girls had substantially lower odds (by a factor of 15.9 or  $1/0.063$ ) of finding a chair that fit their body dimen-

**Table 5.** Student Characteristics that Predict Fit/Mismatch Between Student Body Dimensions Classroom Chairs as Well as Desk/Chair Combinations

	Adjusted Odds Ratios for Predicting Student Fit/Mismatch		
	Odds Ratio	95% CI	p Value
<b>Any classroom chair</b>			
Student gender (1 = female; 0 = male)	0.063	0.007–0.623	0.018
Student age (yr)	0.108	0.009–1.242	0.074
Student height (cm)	2.166	1.305–3.593	0.003
No. of observations	74		
Model $\chi^2$	44.28 ( $p < .000$ )		
Pseudo $R^2$	0.644		
Correctly classified cases	93.2%		
Positive predictive value	83.3%		
Negative predictive value	95.2%		
<b>Any classroom desk</b>			
Student gender (1 = female; 0 = male)	1.252	0.353–4.449	.727
Student age (yr)	1.899	0.866–4.165	.110
Student height (cm)	1.057	0.982–1.137	.138
No. of observations	74		
Model $\chi^2$	10.51 ( $p < .015$ )		
Pseudo $R^2$	0.141		
Correctly classified cases	82.4%		
Positive predictive value	75.0%		
Negative predictive value	82.9%		

sions. A student's height, gender, or age did not, however, predict whether he or she would fit in any of the available desk-chair combinations. In part, this result reflects the fact that body height was only moderately correlated with vertical elbow height ( $r = 0.40$ ); in part, it is owing to the small number of students whose body dimensions fit any desk-chair combination ( $n = 5$ , or 6.8%).

### Discussion

The data in this study indicate a substantial degree of mismatch between the bodily dimensions of these sixth through eighth graders and the classroom furniture available to them. Despite the fact that this school district provides up to six chair-desk combinations for the students, the vast majority of them cannot find any appropriate combination for an acceptable seating arrangement. Most students are sitting in chairs with seats that are too high or too deep and at desks that are too high. The only positive finding is that knee height/desk clearance was not a problem for any student. Consistent with available evidence (23), the data also show substantial variability in students' bodily dimensions, an expected finding for this age group. Thus, it is unlikely that any furniture with fixed dimensions is going to accommodate a majority of students.

Stature or body height is shown to be a good predictor of whether a student fits into a chair. It is not quite clear why gender shows an additional, statistically significant effect on fit or mismatch. The fact that girls are less likely to fit into the chairs, even after the effects of height have been accounted for, points to more subtle differences in body dimensions not captured by body height alone. At an age when many more girls than boys have already entered puberty, developmental differences may explain this independent gender effect.

While the findings of this study are suggestive, they are based only on data from a convenience sample in a single school district. There may also be systematic variations in body dimensions, based on ethnic/racial characteristics of the students, that were not captured in this study. Finally, our definition of mismatch focused on only a few furniture dimensions, such as 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 furniture simply turned out to be too large for many sixth, seventh, and eighth 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 height. 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 (29).

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