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Relationship between Learning Environment Design and Musculoskeletal Disorders in Learners

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Resumen

Introducción: Los estudiantes pasan la mayor parte del día en la escuela sentados en sus muebles de aula que no son del tamaño adecuado para ellos. Esto puede resultar incómodo e incluso provocar dolor de espalda, calambres en las piernas y otros problemas. Métodos: El tamaño corporal de los estudiantes para una buena postura mientras están sentados incluye la altura poplítea al suelo, la altura del codo al asiento, el grosor del muslo, la altura sentada, la longitud de la nalga al poplítea, la longitud de la nalga a la rodilla, la anchura del codo al codo, el ancho del bitrocánter, la altura subescapular y la altura del hombro sentado, y una estatura de pie. De manera similar, se tomaron las dimensiones de la silla con mesa, como la altura del asiento, el borde superior del respaldo, el ancho del asiento, la profundidad del asiento, la longitud de la mesa, el ancho de la mesa, la altura de la mesa, la altura del respaldo y el reposapiés que se utilizan actualmente en el aula. El estudio comparó los datos antropométricos de los estudiantes con los datos de las dimensiones del mobiliario para obtener una coincidencia o desajuste entre ellos con la ayuda de ecuaciones de desajuste estándar. Resultados: El estudio informó que las medidas corporales medias de los hombres son mayores que las de las mujeres, excepto por el ancho del bitrocánter. El ancho del asiento, la profundidad del asiento, la altura del respaldo y el borde superior del respaldo mostraron altos porcentajes de desajuste entre los estudiantes cuando utilizaban sillas. La longitud de la mesa reportó altos porcentajes de desajuste entre los estudiantes. Conclusión: El uso de las dimensiones corporales de los usuarios para el diseño de muebles reducirá los trastornos musculoesqueléticos y mejorará la posición sentada de los usuarios. Las dimensiones recomendadas en el diseño de muebles se ajustarán ergonómicamente a las medidas antropométricas de los estudiantes.

Palabras Clave: Medidas antropométricas, Ergonomía en el aula, Trastornos musculoesqueléticos, Postura, Estudiantes

Abstract

Introduction: Students spend most of their day at school sitting in their classroom furniture which is not quite the right size for students. This can be uncomfortable and even lead to back pain, leg cramps, and other problems. **Method:** Students' body size for good posture while sitting, include popliteal to floor height, elbow to seat height, thigh thickness, sitting height, buttock to popliteal length, buttock to knee length, elbow to elbow breadth, the width of bitrochanter, subscapular height, and sitting shoulder height, and one standing is stature. Similarly, dimensions of chair-with-table, like seat height, the upper edge of the backrest, seat width, seat depth, table length, table width, table height, backrest height, and footrest currently used in the classroom were taken. The study compared students' anthropometry data with the furniture dimension data to obtain a match or mismatch between them with the help of standard mismatch equations. **Results:** The study reported that the mean body measurements of males are larger than females except for the width of bitrochanter. Seat width, seat depth, backrest height, and the upper edge of the backrest showed high mismatch percentages in students when patronising chairs. Table length reported high mismatch percentages among students. **Conclusion:** Using the users' body sizes for furniture design

will reduce musculoskeletal disorders and improve users' sitting position. The recommended dimensions in furniture design will ergonomically fit students' anthropometric measurements.

Keywords: Anthropometric measurements, Classroom ergonomics, Musculoskeletal disorders, Posture, Students

Introduction

Students dedicate a substantial amount of their day to learning. While educational achievement is paramount, ensuring their physical well-being is equally important. Research suggests a concerning link between poorly designed learning environments and the Musculoskeletal Disorders (MSDs) in students.

Traditional classroom setups often promote static postures for extended periods. This, coupled with furniture that may not be ergonomically designed for different body sizes, can lead to strain on muscles, ligaments, and joints. Studies have shown a rise in MSDs, such as neck and back pain, among students (Modh et al., 2010; Uyal & Umar, 2022). This raises concerns about potential long-term health consequences. The field of ergonomics focuses on designing environments that accommodate the human body's needs. Applying ergonomic principles to learning environments can significantly improve student posture and comfort, potentially reducing the risk of MSDs (Grimes & Legg, 2004).

Studies often show a correlation between poorly designed environments and Musculoskeletal disorders (MSDs), but establishing a direct causal relationship is difficult. Other factors, like pre-existing health conditions or physical activity levels, may also play a role (Bernard & Becker, 1988). Most research is cross-sectional, meaning it captures a snapshot in time. Longitudinal studies, tracking students over time, are needed to definitively determine if specific learning environment designs contribute to the development of MSDs (Linton et al., 1994). Accurately measuring MSDs in young learners can be challenging. Self-reported pain levels may not always be reliable, and objective measures like medical diagnoses are not always practical (Chung et al., 2013). Students have varying body sizes, postures, and pre-existing conditions. This makes it difficult to establish a universally applicable design standard for learning environments. Learning environment design is just one-factor influencing MSDs. Factors like backpack weight, screen time, and physical activity levels also need to be considered (Foster & Tucker, 2018).

Promoting movement and behavioral change are some of the approaches when adopted can address some of the challenges encountered in this study. These may include scheduling regular breaks throughout learning sessions where students can stretch, walk around, or participate in light physical activity (Uyal & Umar, 2022). Also, short posture awareness sessions must be integrated into the curriculum where students will be taught proper ergonomic techniques for sitting, standing, and carrying backpacks. Students come in all shapes and sizes, but schools have furniture that's only one size due to cost. Otherwise, schools should ensure chairs and tables are adjustable to fit various body sizes (Shariati & Naderi, 2016). Invest in chairs with good lumbar support, adjustable armrests, and appropriate seat depth (Grimes & Legg, 2004).

The present study wants to understand how much of a mismatch there is and how it might be affecting students' comfort and health. There are three main principles in product design using body measurements for classroom furniture dimensions to fit the body measurements of students are very important. Firstly, the design of products to accommodate students with large dimensions applies the 95th percentile value of male body measurements. Secondly, the design of products to accommodate students with varying sizes and positional preferences applies to the 5th and 95th percentiles of females' and males' body measurements, respectively. Thirdly, the design of products to accommodate students with the lowest dimensions uses the 5th percentile of female body sizes (Alrashdan et al., 2014; Khaspuri et al., 2007). It is not practicable to design for the average population since 50% of the population is accommodated. Given this, some authors recommend the application of principles of adjustment for furniture design (Al-Saleh et al., 2013; Ziefle, 2003).

University students use classroom furniture as sitting items for studies. In a situation where this furniture mismatches body measurements, the result is a negative impact on their health (Agha, 2010; Castellucci et al., 2010; Chung & Wong, 2007; Parcells et al., 1999; Saarni et al., 2007). Sitting on unfit furniture for a long period causes musculoskeletal disorders (MSDs) and poor well-being (Dianat et al., 2013). Also, poor ergonomic design contributes to the occurrence of MSD (Balague et al., 1999; Trevelyan & Legg, 2011).

Standards in primary and secondary education have been reported. However, few researchers have managed to develop furniture dimensions for tertiary students in their countries, with little or no work in Ghana (Shah et al., 2013; Thariq et al., 2010). Ghanaian universities prefer to import tables and chairs as classroom furniture from other countries which are unsuitable for students.

Many researchers have used different principles to find mismatches between furniture and student size (Altaboli et al., 2015; Castellucci et al., 2015). When classroom furniture sizes were compared to students' anthropometric measurements in Greece, the results were too high tables and too deep chairs (Panagiotopoulou et al., 2004).

Students come in all sizes, but chair-with-tables often come in just one. This mismatch between student body size and furniture dimensions can force students into uncomfortable postures, leading to pain, fatigue, and difficulty concentrating in class.

Materials and Methods

Student size

Lecturers sought permission to recruit volunteers in their classes, explaining that the authors were doing a project to improve classroom furniture. A representative sample of students was recruited from the Faculty of Built and Natural Environment, Kumasi Technical University, Kumasi, Ghana. The student population was 188 (108 males and 80 females). Students' safety and confidentiality of details and data were not compromised. Participants were aged 18 to 32, with an average age of 22.86 years. To compute a sample size (n) of 188, equations (1) and (2) are applied (Cochran, 1977). N is the total population size (368); confidence level Z (1.96); baseline level assuming a probability (p) of 0.5 and a margin of error d (0.05).

$$Y = \frac{Z^2 p(1-p)}{d^2} \tag{1}$$

$$n = \frac{Y}{(1 + \frac{Y}{N})} \tag{2}$$

Anthropometric measurements, equipment, and procedure

A stadiometer (height measuring tool) and a regular tape measure assisted in taking measurements of students' body sizes that are important for ergonomic sitting posture). With the consent of lecturers, ten sitting students' body sizes are important for good postures like popliteal to floor height, elbow to seat height, thigh thickness, sitting height, buttock to popliteal length, buttock to knee length, elbow to elbow breadth, the width of bitrochanter, subscapular height and sitting shoulder height, and one standing measurement like stature with the help of height measuring tool were measured as shown Figure 1.

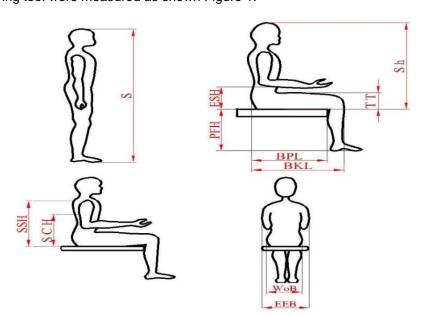


Figure 1. S = Stature, ESH = Elbow-seat height, PFH = Popliteal-floor height, BPL = Buttock-popliteal length, BKL = Buttock knee length, TT = Thigh thickness, Sh = Sitting height, SSH = Sitting shoulder height, SCH = Subscapular height, WoB = Width of bitrochanter, EEB = Elbow-elbow breadth

Two authors helped with data collection. The average value from three separate values of each measurement was considered and recorded to verify data accuracy. Below are the definitions of the dimensions employed (Roebuck, 1997).

- 1. Sitting height: The distance from the sitting surface to the crown of the head.
- 2. Popliteal-floor height: This is the vertical line between the floor and the knee back.
- 3. Elbow seat height: The distance between the seat surface and the underside of the elbow.
- 4. Buttock-popliteal length: This is the distance between the buttock back and the back of the knee.
- 5. Buttock-knee length: The distance between kneecap front and uncompressed buttock back.
- 6. Width of bitrochanter: Is the outermost points of the hips when seated.
- 7. Sitting shoulder height: This is the distance from the seat surface to the topmost of the shoulder.
- 8. Elbow-elbow breadth: This is the lateral distance between the elbow ends.
- 9. Thigh thickness: This is the vertical height between the surface of the seat and the thigh top.
- 10. Subscapular height: This is the height of the scapular's lowest point above the sitting surface.
- 11. Stature: This is the vertical distance from the floor to the top of the head.

Furniture measurement

Nine dimensions of the chair-with-table currently used in the classroom seat height, the upper edge of the backrest, seat width, seat depth, table length, table width, table height, backrest height, and footrest were considered as shown in Figure 2.

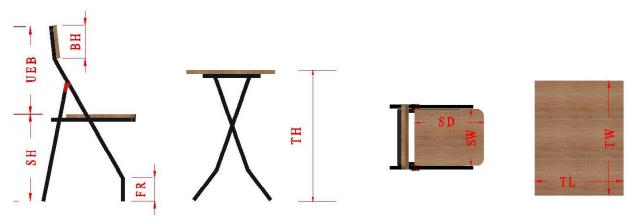


Figure 2. UEB = Upper edge of backrest, SH = Seat height, SDC = Seat-desk clearance, SDH = Seat-desk height, FR = Footrest, BW = Backrest width, SW = Seat width, SD = Seat depth, TL = Table length, TW = Table width, TH = Table height, BH = Backrest height

The definitions of the design features for the chair-with-table are as follows accordingly (Parvez et al., 2019).

- 1. Seat height: The vertical measurement between the floor and the topmost front part of the seat.
- 2. Seat width: The horizontal measurement between the outer left and outer right sides of the seat.
- 3. Seat depth: Distance from the seat front to the backrest.
- 4. Backrest height: The vertical dimension of the backrest.
- 5. Table width: This is the maximum horizontal measurement across the table.
- 6. Table length: This is the minimum longitudinal dimension of the table.
- 7. Backrest height: The vertical measuremet from the seat surface to the top edge of the backrest.
- 8. Table height: The vertical distance from the floor to the upper surface of the table.
- 9. Upper edge of the backrest: The vertical measurement from the top of the sitting surface to the top edge of the backrest.

Comparison of sizes

To establish a mismatch like furniture not fitting students' body sizes, students' measurements are compared to the furniture measurements. In this way, one can see how well the current furniture matches the student's needs and identify areas of improvement.

Popliteal-floor height (PFH) versus seat height (SH)

The correct height of seat should allow the knee to bend to create an angle of 30° between the lower leg and the craniocaudal body axis (JFM et al., 2003). To avoid mismatch, PFH is greater than SH (Moelenbroek & Ramaekers, 1996). Concerning the vertical axis, 5°-30°, and 95°-120° are the angles formed for the lower leg and thigh shin, respectively (Gouvali & Boudolos, 2006). Negative effects of high seat include pressure under the knee pain, nerve damage, and decreased blood flow; while low SH results in pressure on the seat bones. To address the incidence of pressure, 3 cm is taken as shoe height and added to PFH. Equation (3) shows the relationship between PFH and SH:

$$(PFH + 3)Cos\ 30^{\circ} \le SH \le (PFH + 3)Cos\ 5^{\circ}$$
 (3)

Width of bitrochanter (WoB) against seat width (SW)

SW design is dependent on WoB. Multiplying 1.1 by WoB results in minimum SW, while multiplying 1.3 by WoB results in maximum SW. Therefore, the relationship between WoB and SW is shown in equation (4):

$$1.10 \text{ WoB} \le \text{SW} \le 1.30 \text{ WoB} \tag{4}$$

Buttock to popliteal length (BPL) Seat depth (SD) relationship

When SD is lower than BPL, there will be no support for the participant's thigh. Whereas for a longer SD, the user can support his/her lumbar spine with a seat backrest. Therefore, BPL relates with SD in equation (5):

$$0.80 \text{ BPL} \le SD \le 0.95 \text{ BPL}$$
 (5

Sitting shoulder height (SSH) versus backrest height (BH)

To enable arm and upper body mobility, the right BH should be well-thought-out. The backrest should not extend higher than the scapula (Evans et al., 1998). The backrest should extend no higher than the scapula, with an optimal height between 60% and 80% of sitting shoulder height (Castellucci et al., 2015). The relationship that encompasses BH and SSH is available in equation (6):

$$0.6 SSH \le BH \le 0.8 SSH \tag{6}$$

Width of bitrochanter (WoB) against backrest width (BW)

WoB is appropriate for BW design. A number of studies have taken into consideration the dimensions of BW (Thariq et al., 2010). It has come out in recent times that WoB should be considered an important anthropometric measurement for BW design (Taifa & Desai, 2017). It follows that the relationship between WoB and BW has been developed and shown in Equation (7):

$$BW \ge WoB$$
 (7)

Buttock knee length (BKL) versus table length (TL)

Having adequate room helps the user to change the movement of his/her lower body part in a sitting position. TL relates with BKL according to literature of which TL must be greater than or equal to BKL (Pérez-Gosende, 2017). This is represented in equation (8).

$$TL \ge BKL$$
 (8)

Elbow-elbow breadth (EEB) against table width (TW)

Anthropometric measurement of EEB is associated with TW. Sufficient legroom is essential for mounted desktop. Consequently, TW allows elbow abduction at 20° and 2 cm allowance (Afzan et al., 2012). In effect, we can see in Equation (9) that a relationship exists between EEB and TW:

$$TW \ge EEB$$
 (9)

Subscapular height (SCH) versus the Upper edge of backrest (UEB)

In relating SCH to UEB, if SCH becomes less than UEB, the scapula and arm will not move simultaneously (García-Acosta & Lange-Morales, 2023). The relationship that exists between them can be seen in equation (10):

$$UEB \leq SCH$$
 (10)

Levels of consistency

In comparing respondents' measurements with that of furniture, match and mismatch percentages were recorded from one-way limits and two-way limits equations to ascertain compatibility. Two-way limits are defined as high mismatch, low mismatch, and match.

Data Analysis

Anthropometric dimensions of respondents

Different anthropometric dimensions were measured in different sex groups. Summary information on minimum (min), maximum (max), mean, standard deviation (SD), and percentile values (5th, 50th, and 95th) were carried out in centimetres.

Results

Table 1. Anthropometric dimensions for male (M) and female (F) respondents

Dimension	Sex	Min	Max	SD	Mean	5 th	50 th	95 th
Sitting height	М	74.00	92.50	4.06	83.27	76.45	83.00	91.00
Sitting height	F	52.00	87.00	6.57	79.21	63.25	80.00	86.95
Popliteal-floor height	М	39.00	46.00	1.52	41.45	39.00	41.50	43.78
T opinodi nooi noight	F	38.80	45.00	1.50	41.08	39.00	41.00	43.48
Elbow-seat height	М	15.00	33.20	3.73	17.40	16.00	16.00	27.10
Libow coat noight	F	14.00	23.00	1.82	15.89	14.50	15.40	21.95
Buttock-popliteal length	М	41.00	54.00	2.41	47.76	43.00	48.55	50.00
Buttook popilitoai iongin	F	40.00	50.00	2.66	46.31	40.05	46.75	50.00
Buttock knee length	М	45.00	89.00	5.30	58.28	51.23	58.00	65.55
Buttook knoo longth	F	43.00	69.00	5.28	57.35	46.15	58.00	64.48
Width of bitrochanter	М	29.50	39.50	1.97	34.68	31.00	34.55	38.00
Width of billoonanto	F	29.50	45.00	2.90	35.76	32.05	35.00	42.00
Sitting shoulder height	М	45.00	64.00	3.38	54.28	49.23	54.00	61.00
Ontaing chodidor hoight	F	44.50	59.00	2.94	53.04	48.50	53.50	57.48
Elbow-elbow breadth	М	40.00	56.00	3.12	45.94	41.00	46.00	52.00
List older broadin	F	36.00	59.00	4.50	44.07	37.05	44.00	51.48
Thigh thickness	М	10.00	24.00	2.63	15.26	11.00	15.00	20.00
Triigit triottiooo	F	9.50	22.50	3.20	15.10	10.00	15.00	21.00

Subscapular height	М	28.00	49.00	3.95	36.54	30.23	36.00	43.28
Subscapular neight	F	26.00	45.00	3.64	35.39	29.00	35.00	42.95
Stature	М	155.50	185.00	7.01	173.81	162.00	174.00	184.00
Cididio	F	148.00	183.00	6.95	164.04	154.00	164.00	177.00

Table 2. Match and mismatch percentages of chair and table

Dimension	Sex	Match	Low mismatch	High mismatch	Total
Seat height	М	72.22	0	27.78	27.78
ood: noight	F	65.00	0	35.00	35.00
Seat width	М	4.63	95.37	0	95.37
ocat width	F	3.75	96.25	0	96.25
Seat depth	М	0	100.00	0	100.00
ocat acptii	F	1.25	98.75	0	98.75
Table height	М	6.48	0.93	92.59	93.52
Table Height	F	0	0	100.00	100.00
Backrest height	М	0	100.00	0	100.00
Buomoor noight	F	0	100.00	0	100.00
Table length	М	3.70			96.30
rabio iong	F	7.50			92.50
Table width	М	100.00			0
Table Width	F	100.00			0
Upper edge backrest	М	8.33			91.67
appor ougo buomout	F	5.00			95.00

Table 3. Recommended measurements for furniture types in centimetres

Туре	Dimension	Recommended measurement	Sex	Low	High	Total
	Seat height	42.00	М	0.93	5.56	6.49
		12.00	F	0	17.50	17.50
	Seat width	42.00	М	3.70	5.56	9.26
	Coat main	12.00	F	11.25	6.25	17.50
Chair	Seat depth	40.05	М	0	0.93	0.93
			F	0	10.00	10.00
	Backrest height	48.50	М	0	3.70	3.70
			F	0	8.75	8.75
	Upper edge backrest	26.00	M	0	0	0
			F	0	0	0
Table	Table length	64.48	М	5.56	0	5.56
	and a resigni		F	5.00	0	5.00

Ta	able width	52.00	М	0	0	0
	Table Watti	02.00	F	0	0	0

Data was collected separately for males and females. This suggests that there might be significant differences in body measurements between the sexes. Several body measurements were taken for each individual. Statistical summaries such as minimum (min), maximum (max), mean, standard deviation (SD), and percentiles (5th, 50th, 95th) were calculated for each sex group are shown in Table 1. All measurements were recorded in centimetres.

Potential percentages of match and mismatch for the classroom chair and table combination furniture concerning students' body sizes are displayed in Table 2. Table 3 reports recommended furniture measurements in centimeters for the furniture for males and females.

Discussion

Concerning Table 1, the mean stature of males and females are 173.81 ± 7.01 cm and 164.04 ± 6.95 cm, respectively; while the sitting height of males and females are 83.27 ± 4.06 cm and 79.21 ± 6.57 cm, respectively. The 5th, 50^{th} , and 95^{th} percentile values of stature are males (162 cm, 174 cm, and 184 cm) and females (154 cm, 164 cm, 177 cm). Also, the mean of popliteal to floor height showed males (41.45 \pm 1.52) and females (41.08 \pm 1.50).

Seat height

A high match between seat height and student stature is significant for several reasons related to ergonomics and student well-being. This match improves posture and reduces musculoskeletal disorders (MSDs). When a student's feet are flat on the floor with their knees bent at a 90-degree angle, it promotes proper spinal alignment (Pierce et al., 2023). This reduces strain on the back and neck, preventing discomfort and potential pain in the long run. A well-matched seat height allows for a relaxed and comfortable sitting position, promoting better concentration. By minimizing physical discomfort, students can dedicate more energy to active learning and participation in class (Salvendy & Karwowski, 2021). This can lead to a more positive and productive learning experience.

Seat width

A low mismatch between seat width and student hip width is significant for promoting comfort and focus in the classroom, with potential benefits for posture and health. A seat that closely matches a student's hip width allows for proper leg positioning and blood circulation in the legs. This minimises pressure points and discomfort, especially during extended periods of sitting (Meeusen et al., 2013). A substantial percentage of students, ranging from 95.37 % to 96.25 %, are using chairs that are too narrow for their hips. When a seat is too narrow, it can force students to adopt awkward postures to fit, potentially leading to slouching or twisting. A well-matched seat width allows for a more natural hip and leg position, indirectly supporting better spinal alignment (Eguiguren & Ackerman, 2018).

Seat depth

For almost 100 % of students using seat depths that are too shallow for their lower body parts suggests a significant mismatch between the chair design and the students' leg length. A low mismatch between seat depth and student thigh length is significant for comfort, posture, and focus in the classroom. When a seat depth closely matches a student's thigh length, it allows for proper back support against the backrest and prevents pressure on the backs of the knees. This minimizes discomfort, especially during long periods of sitting (Pierce et al., 2023). A seat that is too deep can force students to slouch forward to reach the backrest, straining the lower back. Conversely, a too-shallow seat can cause them to perch on the edge, putting excessive pressure on the thighs and disrupting proper spinal alignment (Arezes et al., 2015). A well-matched seat depth allows for a natural back and leg position, promoting better posture.

Discomfort caused by a seat that is too deep or too shallow can be distracting, hindering a student's ability to focus on learning (Shernoff et al., 2017). A comfortable seat depth allows for a relaxed and stable sitting position, promoting better concentration. By preventing pressure on the backs of the knees, a well-matched seat

depth can aid in proper blood circulation in the legs (Lee, 2019). This can help students feel more alert and energized during class.

Table height

Concerning 92.59 % to 100 % of students using tables that are too high, the data suggests a significant mismatch between the table height and the student's body size. A high mismatch between table height and student height can have several negative consequences for students, impacting their comfort, posture, and ultimately, their ability to focus and learn.

When a table is too high or too low for a student's height, it forces them to adopt awkward postures to reach the surface comfortably. This can lead to hunching, slouching, or excessive arm reaching, causing strain on the back, neck, and shoulders (Pierce et al., 2023). A mismatch in table height can disrupt the natural alignment of the spine, leading to discomfort and potentially causing pain in the back, neck, and shoulders over time (Castellucci et al., 2017). Discomfort caused by poor posture can be distracting, hindering a student's ability to focus on tasks like writing or reading at the table (Pheasant & Haslegrave, 2018). A comfortable and supportive posture allows for better concentration and learning. Prolonged periods in awkward postures due to a table height mismatch can lead to fatigue and decreased productivity. Students may struggle to maintain focus and complete tasks efficiently (Koirala & Nepal, 2022).

Backrest height

A high mismatch between backrest height and student stature can significantly impact a student's comfort, posture, and ultimately, their ability to focus and learn. A backrest that is too high can dig into the student's shoulder blades, causing discomfort and restricting movement. Conversely, a backrest that is too low fails to provide proper upper back support, leading to slouching and potential strain on the neck and lower back (Pierce et al., 2023). When the backrest height is mismatched, it disrupts the natural alignment of the spine. This can lead to slouching, hunching, or excessive arching in the back, causing discomfort and potentially leading to pain in the neck, shoulders, and lower back over time (Equiguren & Ackerman, 2018).

Discomfort caused by poor posture due to a backrest mismatch can be distracting, hindering a student's ability to focus on tasks like listening to lectures or taking notes (Assiri et al, 2019). A comfortable and supportive posture allows for better concentration and learning. Prolonged periods in awkward postures due to a high backrest mismatch can lead to fatigue and decreased productivity. Students may struggle to maintain focus and complete tasks efficiently (Schmoker, 2018). Long-term use of a backrest with a high mismatch may contribute to the development of musculoskeletal problems like muscle strain, neck pain, and even kyphosis (a hunchbacked posture) (Castellucci et al., 2017).

Furthermore, the interpretation and implication of 100 % of students using chair backrests that are too low for their backs, can lead to straining the muscles in the neck and upper back, causing pain and discomfort.

The upper edge of the backrest

Finally, an inappropriate upper edge of the backrest on a chair can lead to several issues with one's posture and comfort, potentially causing pain and fatigue. When the upper edge of the backrest is too high, it can cause strain on the neck and shoulders as students crane their heads forward or hunch their backs to find support (Pierce et al., 2023). This can lead to discomfort and tension in the upper body. A mismatch between backrest height and shoulders disrupts the natural alignment of the spine. To compensate for the lack of support at the upper back, students may slouch or hunch, leading to poor posture and potential pain in the neck, shoulders, and lower back over time (Castellucci et al., 2017).

Discomfort caused by poor posture due to a high backrest mismatch can be distracting, hindering a student's ability to focus on tasks like listening to lectures or taking notes (Pheasant & Haslegrave, 2018). A comfortable and supportive posture allows for better concentration and learning. Long-term use of a backrest with a high mismatch can contribute to the development of musculoskeletal problems like muscle strain, neck pain, and even kyphosis (a hunchbacked posture) (Castellucci et al., 2017).

Recommended furniture dimensions

The recommended size of seat height design uses the 5th percentile of female popliteal to floor height plus 3cm shoe clearance (Parvez et al., 2018; Oyewole et al., 2010). The seat width size is obtained by using the 95th

percentile of the female width of bitrochanter. Seat depth size is obtained by the 5th percentile buttock to the popliteal length of female measurement (Gouvali & Boudolos, 2006). Backrest height size is obtained by using 5th percentile female sitting shoulder height. The size of the upper edge of the backrest is attained by using the minimum value of the scapular height of the female body dimension (Kahya, 2018). Also, the size of table length uses the 95th percentile of female buttock knee length, while table width is obtained by using the 95th percentile male elbow-elbow breadth (Castellucci et al., 2015). According to the recommended measurements of furniture dimensions in Table 3, the mismatch percentages are far lower than the mismatch percentages displayed in Table 2 (chair and table combination).

Conclusion

Too narrow seats for students' hips can have negative impacts like discomfort that can be distracting and hinder focus, fatigue, poor posture, circulation issues, and health problems for students who sit for long hours during lectures.

Shallow seat depth can significantly reduce comfort and lead to back pain or leg fatigue, especially for taller individuals. The institution must opt for furniture with a seat depth that allows users' knees to bend comfortably at a 90-degree angle for optimal support.

Tables that are too high can cause discomfort and strain. Fortunately, there are several solutions available, such as adjusting chair height, using a footrest, or modifying the table itself (if possible). By creating an ergonomic setup, one can ensure comfortable and productive work. Just like chairs, tables come in various heights. To avoid discomfort, it's crucial to choose a table that complements one's chair height and allows for proper posture. It is necessary to consider standard height ranges for different table types to guide one's selection. Tables that are too high can lead to health problems like neck and back pain over time. Investing in furniture that fits one's body dimensions promotes good posture and helps to prevent long-term health issues.

Backrests that fall short of adequately supporting one's upper back can lead to discomfort, fatigue, and even potential for pain in one's back and shoulders. Choosing a chair with a backrest that reaches at least shoulder height is crucial for maintaining proper posture and promoting long-term comfort. Low backrests offer minimal support for one's upper spine, which can strain muscles and lead to back pain, especially during prolonged sitting. It is up to institutions to opt for a backrest that provides proper lumbar support and reaches one's shoulder blades for optimal ergonomic positioning. If one is stuck with a chair that has a low backrest, one must consider adding a lumbar pillow for additional support. However, this is not a long-term solution, and ideally, a chair with an adjustable or higher backrest is recommended for optimal comfort and posture.

References

- Afzan, Z.Z., Hadi, S.A., Shamsul, B.T., Zailina, H., Nada, I., & Rahmah, A.S. (2012). Mismatch between school furniture and anthropometric measures among primary school children in Mersing, Johor, Malaysia. In 2012 Southeast Asian Network of Ergonomics Societies Conference (SEANES), IEEE, Malaysia. https://doi.org/10.1109/SEANES.2012.6299557
- Agha, S.R. (2010). School furniture matches students' anthropometry in the Gaza Strip. *Ergonomics*, 53(3): 344-354. https://doi.org/10.1080/00140130903398366
- Alrashdan, A., Alsudairi, L., & Alqaddoumi, A. (2014). Anthropometry of Saudi Arabian female college students. In *Proceedings of the 2014 industrial and systems engineering research conference*, 4075-4083.
- Al-Saleh, K.S., Ramadan, M.Z., Al-Ashaikh, R.A. (2013). Ergonomically adjustable school furniture for male students. *Educational Research and Reviews*, 8 (13): 943. https://doi.org/10.5897/ERR11.141
- Altaboli A., Belkhear M., Bosenina A., Elfsei N. (2015). Anthropometric evaluation of the design of the classroom desk for the fourth and fifth grades of Benghazi primary schools. *Procedia Manufacturing*, 3:5655 5662. https://doi.org/10.1016/j.promfg.2015.07.778
- Arezes, P.M., Baptista, J.S., Barroso, M.P., Carneiro, P., Cordeiro, P., Costa, N., Melo, R.B., Miguel, A.S., Perestrelo, G. (2015). Occupational safety and hygiene, *CRC Press*, London, UK.
- Assiri, A., Mahfouz, A.A., Awadalla, N.J., Abouelyazid, A.Y., Shalaby, M., Abogamal, A., Alsabaani, A., Riaz, F. (2019). Classroom furniture mismatch and back pain among adolescent school-children in Abha City, Southwestern Saudi Arabia. *International Journal of Environmental Research and Public Health*, 16(8): 1395. https://doi.org/10.3390/ijerph16081395

- Balague, F., Troussier, B., Salminen, J.J. (1999). Non-specific low back pain in children and adolescents: risk factors. *European Spine Journal*, 8: 429–438. https://doi.org/10.1007/s005860050201
- Bernard, B.P., Becker, C.E. (1988). Environmental lead exposure and the kidney. *Journal of Toxicology: Clinical Toxicology*, 26(1-2): 1 34. https://doi.org/10.3109/15563658808995395
- Castellucci, H.I., Arezes, P.M., Molenbroek, J.F. (2015). Analysis of the most relevant anthropometric dimensions for school furniture selection based on a study with students from one Chilean region. *Applied Ergonomics*, 46: 201 211. https://doi.org/10.1016/j.apergo.2014.08.005
- Castellucci, H.I., Arezes, P.M., Molenbroek, J.F., de Bruin, R., Viviani, C. (2017). The influence of school furniture on students' performance and physical responses: results of a systematic review. *Ergonomics*, 60(1): 93-110. https://doi.org/10.1080/00140139.2016.1170889
- Castellucci, H.I., Arezes, P.M., Viviani, C.A. (2010). A mismatch between classroom furniture and anthropometric measures in Chilean schools. *Applied Ergonomics*, 41(4): 563-568. https://doi.org/10.1016/j.apergo.2009.12.001
- Chung, J.W., Wong, T.K. (2007). Anthropometric evaluation for primary school furniture design. *Ergonomics*, 50(3): 323–334. https://doi.org/10.1080/00140130600842328
- Chung, Y.C., Hung, C.T., Li, S.F., Lee, H.M., Wang, S.G., Chang, S.C., Pai, L.W., Huang, C.N., Yang, J.H. (2013). Risk of musculoskeletal disorder among Taiwanese nurses cohort: a nationwide population-based study. *BMC Musculoskeletal Disorders*, 14: 1 6. http://www.biomedcentral.com/1471-2474/14/144
- Cochran, W.G. (1977). Sampling techniques. John Wiley & Sons.
- Dianat, I., Karimi, M.A., Hashemi, A.A., Bahrampour, S. (2013). Classroom furniture and anthropometric characteristics of Iranian high school students: proposed dimensions based on anthropometric data. *Applied Ergonomics*, 2013 44(1): 101 108. https://doi.org/10.1016/j.apergo.2012.05.004
- Eguiguren, M.L., Ackerman, K.E. (2018). The Female Athlete Triad. In The Young Female Athlete. *Cham: Springer International Publishing*, 57–71. https://doi.org/10.1007/978-3-319-21632-4_5
- Evans, W.A., Courtney, A.J., Fok, K.F. (1988). The design of school furniture for Hong Kong school children: An anthropometric case study. *Applied Ergonomics*, 19(2): 122-134. https://doi.org/10.1016/0003-6870(88)90005-1
- Foster, H., Tucker, L. (2018). Musculoskeletal disorders in children and adolescents. *ABC of Rheumatology*, 14:103.
- Garcia-Acosta G., Lange-Morales K. (2007). Definition of sizes for the design of school furniture for Bogotá schools based on anthropometric criteria. *Ergonomics*, 50(10): 1626-1642. https://doi.org/10.1080/00140130701587541
- Gouvali, M.K., Boudolos, K. (2006). Match between school furniture dimensions and children's anthropometry. *Applied Ergonomics*, 37(6): 765–773. https://doi.org/10.1016/j.apergo.2005.11.009
- Grimes, P., Legg, S. (2004). Musculoskeletal disorders (MSD) in school students as a risk factor for adult MSD: a review of the multiple factors affecting posture, comfort, and health in classroom environments. *Journal of the Human-Environment System*, 7(1): 1-9. https://doi.org/10.1618/jhes.7.1
- Jfm, M., Ymt, K.R., Cj, S. (2003). Revision of the design of a standard for the dimensions of school furniture. *Ergonomics*, 46(7): 681 – 694. https://doi.org/10.1080/0014013031000085635
- Kahya, E. (2018). Evaluation of the classroom furniture for university students. Eskisehir Osmangazi University *Journal of Engineering and Architecture*, 26(1): 20-29. https://doi.org/10.31796/ogummf.330136
- Khaspuri, G.C., Sau, S.K., Dhara, P.C. (2007). Anthropometric consideration for designing classroom furniture in rural schools. *Journal of Human Ecology*, 22(3): 235-244. https://doi.org/10.31901/24566608.2007/22.03.09
- Koirala, R., Nepal, A. (2022). A literature review on ergonomics, ergonomics practices, and employee performance. *Management*, 4(2). https://doi.org/10.3126/qjmss.v4i2.50322
- Lee, Y. (2019). Anthropometric Design and Ergonomic Posture Assessment based on Intelligent Algorithms for Seated Work (Unpublished doctoral dissertation). *National University Graduate School*, Seoul.

- Linton, S.J., Hellsing, A.L., Halme, T., Akerstedt, K. (1994). The effects of ergonomically designed school furniture on pupils' attitudes, symptoms and behaviour. *Applied Ergonomics*, 25 (5): 299 304. https://doi.org/10.1016/0003-6870(94)90044-2
- Meeusen, R., Duclos M., Foster C., Fry A., Gleeson M., Nieman D., Raglin J., Rietjens G., Steinacker, J., Urhausen, A. (2013). Prevention, diagnosis and treatment of the overtraining syndrome: Joint consensus statement of the European College of Sport Science (ECSS) and the American College of Sports Medicine (ACSM). *European Journal of Sport Science*, 13(1): 1 –24. https://doi.org/10.1080/17461391.2012.730061
- Moelenbroek, J., Ramaekers, Y. (1996). Anthropometric design of a size system for school furniture. *Contemporary Ergonomics*, 130-135.
- Mohd Azuan K., Zailina H., Shamsul BM., Nurul Asyiqin MA., Mohd Azhar MN., Syazwan Aizat I. (2010). Neck, upper back and lower back pain and associated risk factors among primary school children. *Journal of Appled Science*, 10 (5): 431 435. https://doi.org/10.3923/jas.2010.431.435
- Oyewole, S.A., Haight, J.M., Freivalds, A. (2010). The ergonomic design of classroom furniture/computer workstation for first graders in the elementary school. *International Journal of Industrial Ergonomics*, 40(4): 437-447. https://doi.org/10.1016/j.ergon.2010.02.002
- Panagiotopoulou, G., Christoulas, K., Papanckolaou, A., Mandroukas, K. (2004). Classroom furniture dimensions and anthropometric measures in primary school. *Applied Ergonomics*, 35 (2): 121-128. https://doi.org/10.1016/j.apergo.2003.11.002
- Parcells, C., Stommel, M., Hubbard, R.P. (1999). Mismatch of classroom furniture and student body dimensions: empirical findings and health implications. *Journal of Adolescent Health*, 24 (4): 265-273. https://doi.org/10.1016/S1054-139X(98)00113-X
- Parvez, M.S., Parvin, F., Shahriar, M.M., Kibria, G. (2018). Design of ergonomically fit classroom furniture for primary schools of Bangladesh. *Journal of Engineering*, 1-9. https://doi.org/10.1155/2018/3543610
- Parvez, M.S., Rahman, A., Tasnim, N. (2019). Ergonomic mismatch between students anthropometry and university classroom furniture. *Theoretical Issues in Ergonomics Science*, 20 (5): 603-631. https://doi.org/10.1080/1463922X.2019.1617909
- Pérez-Gosende P. (2017). Anthropometry-based approach for side-mounted desktop chair design
- evaluation for university students in Ecuador. *In 2017 IEEE Second Ecuador Technical Chapters Meeting (ETCM), IEEE*, Ecuador. https://doi.org/10.1109/ETCM.2017.8247516
- Pheasant, S., Haslegrave, C.M. (2018). Bodyspace: Anthropometry, ergonomics and the design of work. *Boca Raton: CRC Press*, 352. https://doi.org/10.1201/9781315375212
- Pierce, S.M., Heiman, A.J., Ricci, J.A. (2023). Evaluating the current state of ergonomics education offered to students in US medical students. *The American Surgeon*, 89(5): 1798-806. https://doi.org/10.1177/00031348211063555
- Roebuck Jr JA. (1997). Indian Anthropometric Dimensions for Ergonomic Design Practice By
- Debkumar Chakrabarti 1997, 161 pages, Rs 1500.00 (approx. US \$35.34) Paldi, Ahmedabad, India: National Institute of Design ISBN 81-86199-15-0. *Ergonomics in Design*, 7(2): 37. https://doi.org/10.1177/106480469900700210
- Saarni L., Nygard CH., Kaukiainen A., Rimpelä A. (2007). Are the desks and chairs at school appropriate? *Ergonomics*, 50(10): 1561 – 1570. https://doi.org/10.1080/00140130701587368
- Salvendy, G., Karwowski W. (2021). Handbook of human factors and ergonomics. John Wiley & Sons.
- Schmoker, M. (2018). Focus: Elevating the essentials to radically improve student learning. *Alexandria, Virginia, ASCD*, USA.
- Shah, R.M., Bhuiyan, M.A., Debnath, R., Iqbal, M., Shamsuzzoha, A. (2013). Ergonomics issues in furniture design: a case of a tabloid chair. *InProc. of the 23rd International Conference on Flexible Automation and Intelligent Manufacturing (FAIM 2013)*, 91-104. https://doi.org/10.1007/978-3-319-00557-7_8
- Shariati, M.A., Naderi, A. (2016). The relationship between chair dimensions and musculoskeletal disorders among female students in one academic branch. *Journal of Occupational Health and Epidemiology*, 5(2): 63-71. https://doi.org/10.18869/acadpub.johe.5.2.63

- Shernoff, D.J., Sannella, A.J., Schorr, R.Y., Sanchez-Wall, L., Ruzek, E.A., Sinha, S., Bressler, D.M. (2017). Separate worlds: The influence of seating location on student engagement, classroom experience, and performance in the large university lecture hall. *Journal of Environmental Psychology*, 49: 55-64. https://doi.org/10.1016/j.jenvp.2016.12.002
- Taifa, I.W., Desai, D.A. (2017). Anthropometric measurements for ergonomic design of students' furniture in India. *Engineering Science and Technology, an International Journal*, 20 (1): 232-239. https://doi.org/10.1016/j.jestch.2016.08.004
- Thariq, M.M., Munasinghe, H.P., Abeysekara JD. (2010). Designing chairs with mounted desktops for university students: Ergonomics and comfort. *International Journal of Industrial Ergonomics*, 40(1): 8-18. https://doi.org/10.1016/j.ergon.2009.10.003
- Trevelyan, F.C., Legg, S.J. (2011). Risk factors associated with back pain in New Zealand school children. *Ergonomics*, 54(3): 257-262. https://doi.org/10.1080/00140139.2010.547608
- Uyal, B.N., Umar, M.U. (2022). The effect of classroom environment on students' academic performance and musculoskeletal discomfort. *Industrial Engineering*, 33(2): 385-401. https://doi.org/10.46465/endustrimuhendisligi.1067573
- Ziefle, M. (2003). Sitting posture, postural discomfort, and visual performance: a critical view on the interdependence of cognitive and anthropometric factors in the VDU workplace. *International Journal of Occupational Safety and Ergonomics*, 9(4): 503-514. https://doi.org/10.1080/10803548.2003.11076586

Authors Contribution

SA is the Lead Researcher (Author 1): 40-50%. The role was to typically take on the most significant responsibilities, including conceptualization, methodology, data analysis, and manuscript writing. GA is an Ergonomist (Author 2): 15-20%. As the second author, GA Provided specialized expertise, contributed to data analysis and interpretation, and contributed to manuscript drafting. AAB; Epidemiologist (Author 3): 15-20%. The contribution was to study design, data analysis, and interpretation and assist in manuscript drafting. KA; the fourth author- Educational Psychologist (Author 4): 10-15%. The contribution was to provide a theoretical framework, contribute to data interpretation, and assist in manuscript drafting.

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Full access to data on request.

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Conflicts of Interest

The authors have no conflicts of interest to declare that they are relevant to the content of this article.

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