Journal of Interior Design and Academy

Journal of Interior Design and Academy
INda 2026, 6(1):1-19
e-ISSN: 2791-7436

To Cite This Article: Adu, S. and Adu, G. (2026). Focusing on User-Centered Design. *Journal of Interior Design and Academy*, 6(1), 1-19.

DOI: 10.53463/inda.20260282

Submitted: *26/09/2024* ***Revised:*** *08/12/2025* ***Accepted:*** *06/04/2026*

FOCUSING ON USER-CENTERED DESIGN

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Abstract

This study explores the development of ergonomic lecture hall furniture at Kumasi Technical University, Ghana, using a user-centered approach. By analyzing the anthropometric data of 300 students (176 males; 124 females), researchers identified severe mismatches between current furniture and actual body dimensions. Key findings revealed that existing setups are largely unsuitable: approximately 64% of students used chairs of incorrect height, over 50% used seats with improper depth, and 100% used tables that were too high. Such discrepancies lead to physical discomfort, reduced focus, and potential long-term health issues. To address these gaps, the study utilized percentile-based design equations to calculate dimensions that accommodate a diverse student population. The results underscore the necessity of integrating human body measurements into furniture design. By closing the gap between user needs and classroom infrastructure, institutions can foster a more inclusive, healthy, and productive learning environment.

Keywords: Ergonomics, anthropometry, mismatch, furniture design, user-centred design

1. INTRODUCTION

By applying anthropometric data to furniture design, institutions can replace uncomfortable, "one-size-fits-all" seating with ergonomic, user-centered solutions that improve student health, focus, and academic performance.

While international research highlights classroom ergonomic issues, a significant gap remains in Ghana, where schools rely on standardized or imported furniture that fails to account for the specific body dimensions of the local student population.

This study uses anthropometric data from Kumasi Technical University students to transition from identifying ergonomic problems to creating data-driven, locally relevant furniture designs that improve both physical comfort and academic performance.

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RESEARCH ARTICLE

SEKİZGEN ACADEMY

Journal of Interior Design and Academy
INda 2021, 6(1):1-19
e-ISSN: 2791-7436

By employing a participatory, human-centered approach, this research moves beyond identifying problems to create customized furniture solutions that enhance student comfort, posture, and academic success while reducing long-term health risks.

2. MATERIALS AND METHODS

2.1. Research design and approach

This study uses a quantitative, user-centered design approach to transform students' anthropometric data into objective ergonomic guidelines that help Ghanaian universities create furniture tailored to students' physical needs.

2.2. Population and sampling

To ensure a representative and ethical study, 300 students from various academic departments at Kumasi Technical University were selected through simple random sampling to provide diverse anthropometric data with their informed consent.

2.3. Data collection tools and procedure

To ensure accuracy and realism, trained assistants used standardized tools to measure seated students three times each, averaging the results to reflect typical classroom posture and attire.

2.4. Furniture and anthropometric variables measured

Measurements of the current furniture were conducted in the lecture hall (seat height, seat depth, table height, and others **(**Figure 1**).** The definitions of the design features for the chair-with-table are as follows accordingly (Parvez et al., 2019):

1. Seat Height (SH): The distance between floor surface and topmost front part of seat.
2. Seat Width (SW): The distance between outer left and outer right sides of seat pan.
3. Seat Depth (SD): The horizontal distance between back and seat front.
4. Table Width (TW): This is maximum distance between lateral edges of table.
5. Table Length (TL): This is minimum distance between front and back edges of table.
6. Table Height (TH): Distance from the floor to the upper surface of the table.
7. Upper Edge of Backrest (UEB): Distance from top of the sitting surface to top edge of 1. backrest.

8. Table Clearance (TC): Distance between lowest part of table surface (usually the underside of the tabletop or the bottom of the apron if present) and the floor.
9. Seat-Table Height (STH): This is distance between top surface of chair seat (where one sits) and the bottom of the tabletop (or underside of the apron if present).
10. Backrest Width (BW): This refers to distance between two outermost edges of backrest of a chair, measured at the widest point.
11. Height of Basket (HBa): The vertical distance from the bottom bar to the underside of the tabletop.
12. Tabletop Thickness (TTp): The vertical distance from underneath to the top of the writing surface.

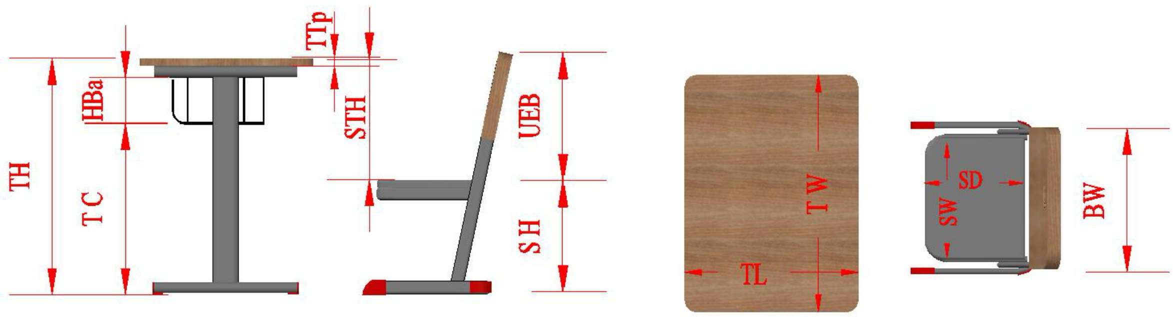

Figure 1. Measures of lecture hall furniture (by the author)

Essential and significant anthropometrical variables recorded for furniture design included popliteal to floor height, buttock to popliteal length, sitting height, and others (Figure 2). Roebuck (1997) defined the following body measurements:

1. Sitting height (Sh): The distance between sitting surface and top point of head, important for determining the overall height of the chair's backrest.
2. Popliteal-Floor Height (PFH): Distance from the underside of the thigh behind the knee to the floor, essential for determining seat height.
3. Elbow-Seat Height (ESH): Vertical distance from the seat surface to the underside of the elbow when the arm is bent at 90°, used for armrest or desk height.
4. Buttock-Popliteal Length (BPL): Distance from the posterior surface of the buttocks to the back of the lower leg, guides seat depth.
5. Buttock-Knee Length (BKL): Horizontal distance from the back of the buttocks to the front of the knee, important for legroom and desk clearance.

6. Width of Bitrochanter (WoB): The horizontal distance across the widest part of the hips, used to determine seat width.
7. Arm Length (AL): Distance from the shoulder to the wrist, relevant for writing surface distance and desk alignment.
8. Elbow-Elbow Breadth (EEB): This is the lateral distance between the elbow ends, important for determining the width of the seat and the spacing of armrests.
9. Thigh Thickness (TT): This is the vertical height between the surface of the seat and the thigh top, which directly influences the seat-to-obstacle clearance, such as that of a desk or table top.
10. Subscapular Height (SCH): Vertical distance from the seat to the inferior angle of the scapula, helps in designing backrests.
11. Stature (S): This is the distance from floor to head top.
12. Elbow-Fingertip Length (EFL): Distance from the elbow to the tip of the middle finger used in determining desk surface reach.

These measurements were chosen based on anthropometric principles that emphasise compatibility between human body dimensions and the functional parameters of furniture to minimise health risks and discomfort.

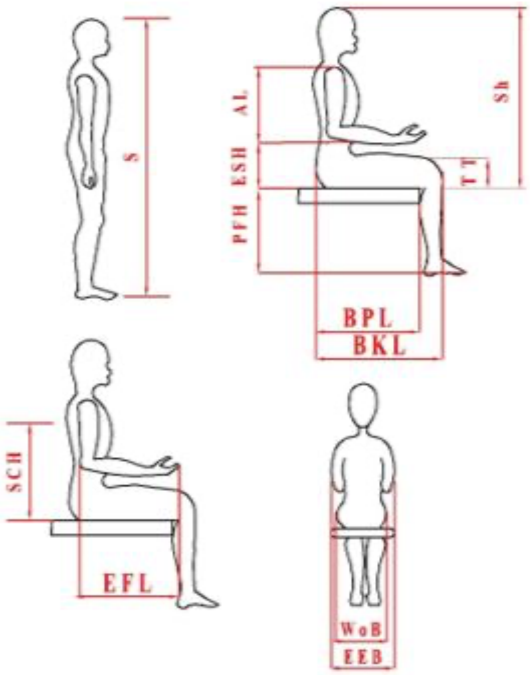

Figure 2. Anthropometric data required in lecture hall furniture design (by the author)

Journal of Interior Design and Academy
INda 2021, 6(1):1-19
e-ISSN: 2791-7436

2.5. Data Analysis

Researchers used IBM SPSS Version 25 to calculate descriptive statistics and key percentiles (5th, 50th, and 95th) for each measurement, providing the foundational body dimension data needed for ergonomic design recommendations.

2.6. Match or mismatch criteria for furniture and student measures

The match and mismatch between students' anthropometric data and chair and table dimensions will be made possible using relationship equations that compare measures of anthropometry and furniture to come up with appropriate furniture sizes to design an ergonomic modeled chair and table to address sitting problems associated with the use of furniture.

2.6.1. Popliteal-Floor Height (PFH) verses Seat Height (SH)

SH is related to PFH. PFH ought to be greater than SH (Lee & Yun, 2019). Concerning the vertical axis, the angle that is generated between the lower leg and shin thigh falls between the angle range of 5°- 30° and 95°-120°, respectively (Lu and Lu, 2017). High SH leads to pressure behind the knee and loss of circulation of blood. Notably, a 3cm allowance is added to PFH to take care of shoe height. Therefore, a relationship is constructed between PFH and SH in Equation (1):

$$(PFH + 3)\, Cos30^o \leq \mathrm{SH} \leq (PFH + 3)\, Cos5^o \quad (1)$$

2.6.2. Width of Bitrochanter (WoB) versus Seat Width (SW)

SW has a direct bearing on WoB. There should be enough room in the seat to accommodate the WoB of users. In this case, there should be free movement of participants in the furniture (Mukhopadhyay, 2019, Fidelis & Ogunlade, 2022). Thus, SW has to be greater than WoB for seats to receive those who will patronise them. Equation (2) relates WoB and SW:

$$1.10\ WoB \leq SW \leq 1.30\ WoB \quad (2)$$

2.6.3. Buttock to Popliteal Length (BPL) against Seat Depth (SD)

SD is directly related to BPL. BPL is used in chair design for evaluating SD. If SD is short, users' thighs will not be supported (Obinna et al., 2021). However, large SD will deprive the support of the users' lumbar spine by seat backrest (Parvez et al., 2019). According to (Satır & Erdoğan, 2021, Sejdiu et al., 2023), the equation (3) relates SD and BPL:

$$0.80\ BPL \leq SD \leq 0.95\ BPL \quad (3)$$

2.6.4. Elbow-Seat Height (ESH) verses Seat-Table Height (STH)

ESH is the measure to find STH according to some researchers (Stack & Ostrom, 2023, Parvez et al., 2019). Shoulder mechanics include shoulder flexion and shoulder abduction in range angles of 0°-25° and 0°-20°, respectively. The angles cannot be overlooked when it comes to the design of the right STH (Lu & Lu, 2017, Sejdiu et al., 2023). When the arms are kept at the right surface level of the table, the spine load is decreased considerably. The work zone of STH is above ESH by 3 – 5cm (Pereira et al., 2019, Eldar & Fisher-Gewirtzman, 2019). The relationship between STH and ESH is shown in Equation (4):

$$ESH \leq STH \leq ESH + 5 \tag{4}$$

2.6.5. Popliteal-Floor Height (PFH) and Thigh Thickness (TT) versus Table Clearance (TC)

The essence of TC is to help the user enter the seat, move the leg and exit from the seat. SH, TT and 2cm allowance add up to the lowest value of TC (Mokarami et al., 2022). According to (Lu & Lu, 2017), the highest value of TC is below the maximum value of Table Height (TH) minus basket height (HBa). So, the equation involving SH, TT, TC, elbow-seat height (ESH), PFH, arm length (AL) and HBa is shown in Equation (5):

$$SH + TT + 2 \leq TC \leq ESH + [(PFH + 3)\, Cos5^{o}] + 0.1483AL - HBa \tag{5}$$

2.6.6. Width of Bitrochanter (WoB) against Backrest Width (BW)

The design of BW is dependent on the measurement of WoB (Kibria & Rafiquzzaman, 2019). It follows that a relationship between WoB and BW has been developed and shown in Equation (6):

$$BW \geq WoB \tag{6}$$

2.6.7. Buttock Knee Length (BKL) verses Table Length (TL)

TL is considered a requirement dependent on BKL so that adequate room is created for lower part of user’s body to change sitting position. According to (Mokarami et al., 2022), TL must be larger than BKL. Thus, equation (7) relates TL to BKL:

$$TL \geq BKL \tag{7}$$

2.6.8. Elbow to Elbow Breadth (EEB) versus Table Width (TW)

EEB is the measure that is used to determine TW. The minimum dimension of TW includes EEB according to (Pérez-Gosende, 2017). TW allows elbow abduction of 20° plus an allowance of 2 cm

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e-ISSN: 2791-7436

(Satır & Erdoğan, 2021, Sejdiu et al., 2023). We can see in Equation (8) that a relationship exists between EEB, arm length (AL), elbow fingertip length (EFL), and TW.

$$0.5\,EEB + (0.342AL) + 2 \leq TW \leq EFL \qquad (8)$$

2.6.9. Subscapular Height (SCH) versus Upper Edge of Backrest (UEB)

According to (Kahya, 2019), SCH is used to determine UEB in equation (9). Many researchers were of the view that, when SCH is lower than UEB, there is no simultaneous movement for the scapula and arm (Sejdiu et al., 2023).

$$UEB \leq SCH \qquad (9)$$

2.7. Levels of compatibility

Compatibility equations were used to compare anthropometric data with existing furniture dimensions, identifying specific mismatches to provide quantifiable, evidence-based guidelines for improving lecture hall seating and tables.

3. RESULTS AND DISCUSSION

3.1. Anthropometric profile of participants

The data analysis revealed noticeable differences between male and female students.

Table 1

Anthropometric Dimensions Among Male (M) and Female (F) Participants in Centimetres

Variable	Sex	Min	Max	SD	Mean	5^{th}	50^{th}	95^{th}
Sitting height	M	65.00	89.60	5.45	80.07	69.43	81.00	87.00
	F	50.00	87.00	6.80	77.71	60.75	79.00	86.00
Popliteal-floor height	M	33.50	50.00	4.58	42.78	35.17	44.00	49.00
	F	33.00	49.00	3.66	41.50	35.00	42.00	47.00
Elbow-seat height	M	14.00	24.00	1.92	18.31	15.50	18.00	22.00
	F	14.00	23.00	1.94	18.00	15.50	18.00	21.88
Arm length	M	26.00	48.00	3.10	36.40	32.00	36.00	42.58
	F	20.00	56.00	4.13	35.67	30.30	36.00	41.88
Buttock-popliteal length	M	35.00	55.00	4.63	45.83	38.00	45.95	53.58
	F	34.70	58.50	5.15	45.38	36.05	45.25	54.00
Buttock knee length	M	40.00	66.00	5.52	55.40	45.00	55.75	64.00
	F	41.00	67.00	5.61	55.01	45.00	54.50	64.00

Width of bitrochanter	M	26.00	40.00	2.84	33.35	28.39	33.00	38.15
	F	26.50	44.00	3.52	34.15	28.50	34.00	40.00
Elbow-elbow breadth	M	34.00	50.00	3.10	44.49	39.85	45.00	48.50
	F	36.00	49.50	3.44	43.51	38.00	44.00	48.08
Thigh thickness	M	14.00	24.00	1.60	16.88	15.00	16.70	20.00
	F	14.00	22.50	1.74	16.62	14.33	16.00	20.00
Subscapular height	M	28.00	47.00	3.72	36.34	30.00	36.00	43.00
	F	25.00	45.00	3.70	35.58	29.00	35.00	43.00
Elbow fingertip length	M	40.00	57.00	3.45	49.29	42.43	49.00	55.00
	F	39.50	65.00	4.07	48.10	42.25	48.00	54.75
Stature	M	160.00	182.00	5.13	170.71	162.00	171.00	179.00
	F	148.00	180.00	5.19	165.68	160.00	164.25	177.00

The anthropometric data in Table 1 details the specific body dimensions of male and female students necessary for designing ergonomic furniture that ensures proper posture and comfort.

Mean sitting heights of 80.07 cm for males and 77.71 cm for females highlight gender-based upper-body variability that must be reflected in backrest design to prevent spinal discomfort and fatigue.

Popliteal-floor height (PFH) is another fundamental measurement that determines appropriate seat height. A seat that is too high or too low relative to this measurement can impair circulation and cause leg fatigue. The mean PFH was 42.78 cm for males and 41.50 cm for females. For inclusive design, the 5th percentile value is usually the benchmark to accommodate shorter users. In this case, the female 5th percentile was 35.00 cm, meaning that the seat height should not be lower than this, with an additional 3 cm allowance to account for shoe thickness. Providing such ergonomic consideration helps ensure users' feet rest flat on the floor, enhancing stability and comfort.

The elbow-seat height, which influences seat-to-table height and table clearance, showed minimal variation between males and females. Males had a mean of 18.31 cm, while females recorded 18.00 cm. This close alignment suggests that a uniform standard may be applied for determining table height relative to the seating surface. Proper alignment here is critical to reducing upper arm fatigue and shoulder strain during writing or computer use.

In terms of arm length, males had a slightly longer mean (36.40 cm) than females (35.67 cm), although females exhibited a broader maximum range (56.00 – 20.00 cm). Arm length is key to determining writing reach and table depth. A surface that is too short may limit arm movement, whereas an overly deep surface can encourage slouching, thereby affecting posture. The use of percentile data can guide the provision of tables that allow a comfortable range of motion for various tasks.

Buttock-popliteal length (BPL) and buttock-knee length (BKL) both influence seat depth. Males had slightly longer averages than females in both measures. For BPL, the mean values were 45.83 cm for males and 45.38 cm for females, while BKL averaged 55.40 cm and 55.01 cm, respectively. These similarities suggest that while standard seat depths could work, variations might still be needed to cater to outliers at both ends of the percentile spectrum. If the seat depth is too short, it may fail to support the thighs; too deep, and it may prevent users from engaging the backrest effectively, leading to poor posture and discomfort.

The width of the bitrochanter (hip width) showed that females generally had wider hips (mean of 34.15 cm) than males (33.35 cm), with females also having a greater range (up to 44.00 cm). This variable is important for determining seat width. Seats that are too narrow may apply pressure to the hips and thighs, while excessively wide seats may limit arm support and spatial efficiency. A practical recommendation is to design seat widths at 110 – 130% of the 95th percentile value to ensure comfort and inclusiveness.

Elbow-elbow breadth, which helps define the necessary table width to accommodate arm movement without overcrowding, had a slightly higher average in males (44.49 cm) than in females (43.51 cm). The 95th percentile values of both sexes exceeded 48 cm, indicating that table surfaces should be wide enough, ideally over 50 cm per user, to support natural elbow placement during writing and reading.

Thigh thickness is a less commonly referenced metric, but it is essential in determining table clearance under desks. Both male and female students had similar mean thigh thicknesses (16.88 cm and 16.62 cm, respectively). However, ignoring this measurement can lead to poor leg clearance, resulting in cramped postures or restricted circulation, especially during long study sessions.

Subscapular height informs the backrest height needed to provide adequate support to the lower shoulder blades and spine. Males had a slightly higher mean (36.34 cm) compared to females (35.58 cm), but both sexes had the same 95th percentile (43.00 cm). Backrests that fall below this threshold may fail to provide proper lumbar and thoracic support, leading to slouching or back fatigue over time.

Elbow-fingertip length is critical for determining table depth and writing surface reach. Males had a mean of 49.29 cm and females 48.10 cm, with maximum values reaching up to 57.00 cm and 65.00

cm, respectively. The high maximum in females highlights the necessity for adaptable or modular surfaces to cater for users with longer reach. A writing surface that accommodates at least the 95th percentile ensures that users can write or type without excessive stretching or leaning.

Finally, overall stature followed the expected trend, with males being taller on average (170.71 cm) than females (165.68 cm). While stature influences general spatial needs such as vertical clearance, it also affects seat-to-desk proportions. A proper match between seating and table height ensures visual and physical comfort during learning activities.

In conclusion, the anthropometric differences between male and female students, although sometimes minor, are significant enough to influence design decisions. Using a design approach based on 5th to 95th percentile values rather than simple averages ensures that the needs of the majority are met. This reinforces the essence of user-centred design in educational furniture, advocating for tailored, ergonomic, and inclusive learning environments that can accommodate a wide range of body types.

3.2. Furniture and anthropometric mismatch analysis

Table 2 presents the match and mismatch percentages between existing lecture hall furniture dimensions and the anthropometric data of students at Kumasi Technical University. The results reveal significant ergonomic inconsistencies across several key furniture variables, indicating that the majority of students are using furniture that does not align with their physical measurements. This mismatch can contribute to postural discomfort, decreased concentration, and long-term musculoskeletal health concerns.

The most concerning mismatch was observed in seat height, where only 35.67% of students were matched appropriately. A staggering 46.00% experienced a low seat height, while 18.33% used seats that were too high. In total, 64.33% of students were mismatched in terms of seat height, highlighting a systemic flaw in the sizing of existing lecture hall chairs. When seats are too low, students may experience hip and lower back discomfort due to knee elevation. Conversely, high seats may prevent the feet from resting flat on the floor, leading to reduced circulation and increased pressure under the thighs. The implications of this are critical, as improper seat height not only affects comfort but also influences writing posture and spinal alignment during lectures.

For seat width, the analysis showed a relatively better outcome, with 61.00% of students appropriately matched. However, 32.00% experienced low mismatch (narrow seats), and 7.00% experienced high mismatch (seats too wide). While this is a more acceptable level of compliance

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INda 2021, 6(1):1-19
e-ISSN: 2791-7436

compared to other variables, the 39.00% total mismatch is still substantial. Narrow seats restrict lateral movement, compress the hips and thighs, and can lead to discomfort when entering or exiting the chair. Oversized seats, although less common, can compromise arm and upper body support, especially if tables are fixed and not proportionally aligned.

Seat depth mismatch was another major concern. Only 49.33% of students used seats with appropriate depth, while 40.00% were exposed to shallow seats and 10.67% to excessively deep ones. A total mismatch of 50.67% suggests that half the student population sits in a position that does not adequately support the thighs or lumbar spine. Shallow seats fail to support the full length of the thighs, leading to muscle fatigue and forward-leaning posture. On the other hand, deep seats hinder the use of backrests, cause pressure behind the knees, and may encourage slouched sitting positions, all of which are ergonomically detrimental.

One of the most critical issues identified was the seat-to-table height, where 100.00% of students were mismatched. This means that not a single student had a proper alignment between seat height and table surface. This variable is essential in ensuring that students can comfortably write or use a laptop without straining their arms, shoulders, or neck. A mismatch in this domain can cause significant upper-body discomfort and adversely affect learning performance over time. The result indicates an urgent need for a redesign of either the chairs, the tables, or both.

For backrest width, 68.00% of students had appropriate matches, while 32.00% were mismatched. A well-matched backrest width ensures that users receive adequate support along the shoulder blades and lower back without restricting movement. A narrower backrest might cause instability or discomfort, especially during long lectures, while an excessively wide one may not conform to the natural shoulder curvature of smaller users, diminishing effective support.

Regarding table clearance, the vertical space under the table, 81.33% of students were adequately accommodated, while 3.67% experienced low mismatch and 15.00% experienced high mismatch. The 18.67% total mismatch indicates that for nearly one-fifth of the students, there may be insufficient legroom or excessive space that disrupts writing posture. Adequate clearance is crucial for smooth entry and exit from the seating and for avoiding contact between the knees/thighs and the underside of the table.

The findings on table length were especially troubling, with only 20.00% of students having a match and 80.00% experiencing a mismatch. A table that is too short limits the space available for students to rest their arms, write, or use materials such as laptops and textbooks. This can cause

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e-ISSN: 2791-7436

forward leaning, shoulder rounding, and elbow extension, all of which promote poor posture and discomfort. These findings suggest that current tables are either too compact or poorly aligned with students' reach measurements, making it difficult to maintain ergonomic working positions.

On a more positive note, table width was a standout success, with 100.00% of students matched appropriately. This suggests that horizontal working space is adequate for individual users, allowing for natural arm spread and elbow movement. However, it's worth noting that table width alone cannot compensate for other mismatches, such as height and length, and its effectiveness is diminished if the seating posture is already compromised.

Finally, the upper edge of the backrest showed severe inadequacy, with only 6.00% matched and a massive 94.00% of students mismatched. This mismatch indicates that the backrests of most chairs are either too low or too high to provide proper support to the upper torso. Poor alignment in this area can lead to mid- and upper-back strain, particularly during extended periods of sitting. It also diminishes the effectiveness of lumbar support and may lead to slouched or twisted postures.

Overall, the data from Table 2 paint a clear picture: the majority of lecture hall furniture currently in use at the study location is not ergonomically suitable for the student population. High mismatch rates in seat-to-table height, seat height, seat depth, and backrest edge underscore the urgent need for redesign. These mismatches, if unaddressed, can negatively affect students' posture, focus, physical health, and learning outcomes. The results reinforce the critical role of user-centred design, where anthropometric data directly informs furniture specifications to enhance inclusivity, comfort, and efficiency in academic environments.

Table 2

Match and Mismatch Percentages of Lecture Hall Furniture Variables in Centimetres

Variable	Match	Low Mismatch	High Mismatch	Total Mismatch
Seat height	35.67	46.00	18.33	64.33
Seat width	61.00	32.00	7.00	39.00
Seat depth	49.33	40.00	10.67	50.67
Seat-to-table height	0			100.00
Backrest width	68.00			32.00
Table clearance	81.33	3.67	15.00	18.67
Table length	20.00			80.00
Table width	100.00	0	0	0
Upper edge of backrest	6.00			94.00

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e-ISSN: 2791-7436

3.3. Design specification

Table 3 reports on variables of lecture hall furniture together with their respective different anthropometric measures, with the help of their criteria to obtain their ergonomic design values. According to (Mahantesh et al., 2023), the angle between the backrest and the seat pan (BA), should be 102 degrees. Thus, modeled furniture encompasses the right furniture sizes so that users' comfort, product safety and satisfaction can be achieved.

Table 3

Lecture Hall Furniture Variables, Including Wire-Mesh Height of Basket (HBa) and Tabletop Thickness (TTp), with Students' Measures and Design Values

Variable	Measure	Value	Criteria
SH	PFH	38.17 cm	5^{th} % female PFH plus 3cm shoe clearance
SW	WoB	40.00 cm	95^{th} % of female WoB
SD	BPL	36.05 cm	5^{th} % of female BPL
BW	WoB	48.50cm	95^{th} % male EEB
STH	ESH	29.00 cm	5^{th} % male ESH plus HBa and TTp
UEB	SCH	25.00 cm	minimum value of female SCH
TC	ESH	53.67cm	SH plus 5^{th} % of female ESH
TL	BKL	64.00 cm	95^{th} % of female BKL
TW	EEB and EFL	66.75 cm	95^{th} % male EEB + $\frac{1}{2}$ (95^{th} % female EFL)
BA		102^{0}	Literature review suggestion (Mahantesh et al., 2023)

Table 3 outlines the proposed ergonomic dimensions for lecture hall furniture based on anthropometric data from students and scientifically validated criteria. Each variable, such as seat height, width, and depth, was carefully matched with the appropriate body measurement to ensure optimal comfort, functionality, and posture support. The design values reflect inclusive planning, primarily targeting the 5^{th} and 95^{th} percentile range, to accommodate the majority of the student population while minimising ergonomic strain.

Seat height (SH) was derived from the popliteal-floor height (PFH), which is the vertical distance from the underside of the thigh to the floor when seated. The value of 38.17 cm corresponds to the 5^{th} percentile of female PFH plus a 3 cm shoe allowance. This conservative approach ensures that even the shortest students can place their feet flat on the ground, maintaining stability, reducing leg pressure, and encouraging upright posture. A properly calibrated seat height is essential in preventing both lower limb discomfort and forward slouching.

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Seat width (SW) was established using the width of the bitrochanter (WoB), the maximum distance across the hips when seated. The chosen value of 40.00 cm aligns with the 95th percentile of female WoB, ensuring the seat can accommodate wider hip widths without causing lateral compression. This width promotes user comfort by allowing sufficient space for side-to-side movements while maintaining proximity to the table or writing surface. A seat that is too narrow restricts movement and circulation, while an overly wide seat compromises upper body support and chair compactness.

Seat depth (SD), which impacts thigh support and backrest use, was determined using the buttock-popliteal length (BPL). The selected value of 36.05 cm reflects the 5th percentile of female BPL, ensuring that the seat is not too deep for shorter students. This depth avoids knee pressure while still providing enough support under the thighs, which is essential for reducing fatigue during prolonged sitting. A deeper seat could cause slouching or prevent full contact with the backrest, undermining spinal support.

Backrest width (BW), although often overlooked in design, plays a vital role in upper back and shoulder blade support. The proposed width of 48.50 cm was based on the 95th percentile of male elbow-elbow breadth (EEB), the widest relevant upper body measurement. This specification ensures that the backrest accommodates a broad range of body types without limiting movement or causing shoulder misalignment. A properly dimensioned backrest supports the thoracic spine and improves seating posture.

Seat-to-table height (STH), the vertical distance from the seating surface to the underside of the table, was calculated using the 5th percentile of male elbow-seat height (ESH), with additional adjustments for wire basket height (HBa) and tabletop thickness (TTp). The final value of 29.00 cm ensures that users can comfortably rest their forearms on the tabletop without lifting or dropping their shoulders. This relationship helps reduce upper back and neck strain, particularly during extended periods of writing or typing.

Upper edge of the backrest (UEB) was set at 25.00 cm, which corresponds to the minimum subscapular height (SCH) among females. This measurement ensures that the lower edge of the shoulder blade receives adequate support when seated. While it is important to consider the 95th percentile for some components, using the minimum here ensures that even shorter users benefit from consistent lumbar and mid-back support without excessive pressure or obstruction around the scapula.

Table clearance (TC), the vertical space under the table available for the user's thighs and knees, was calculated as 53.67 cm, combining seat height and the 5th percentile of female ESH. This dimension ensures sufficient legroom without creating unnecessary elevation of the table surface. Adequate clearance is essential to prevent compression of the thighs, reduce awkward leg positioning, and facilitate smooth movement into and out of the seating space.

Table length (TL) was based on the buttock-knee length (BKL), a measure that determines the forward space a seated user occupies. The design value of 64.00 cm, taken from the 95th percentile of female BKL, ensures that users have enough space to move their lower limbs and shift positions without hitting table edges. Sufficient table length also helps accommodate writing materials and devices without compromising sitting posture.

Table width (TW) was determined using a combined consideration of elbow-elbow breadth (EEB) and elbow-fingertip length (EFL). The chosen value of 66.75 cm represents the 95th percentile male EEB plus one-third of the 95th percentile female EFL, offering an ergonomic balance between horizontal reach and arm space. This width allows users to place their elbows and forearms on the surface comfortably, promoting shoulder relaxation and improving access to study materials.

Finally, the backrest angle (BA) was set at 102 degrees, following ergonomic recommendations in the literature (Mahantesh et al., 2023). This angle between the seat pan and the backrest supports the natural curvature of the spine, particularly the lumbar region. It encourages an upright yet relaxed posture that reduces spinal loading during extended lecture periods. A poorly angled backrest, either too upright or too reclined, can lead to fatigue, muscular imbalance, or disengagement in the learning environment.

Together, these furniture dimensions form a comprehensive ergonomic model that responds directly to the physical realities of student users. By applying a user-centred design framework grounded in anthropometric evidence, institutions can create lecture hall environments that are not only inclusive but also conducive to health, comfort, and improved academic performance. The integration of both the 5th and 95th percentiles reflects a design philosophy that aims to serve as many users as possible without the need for costly customisation or adjustment features.

3.4. Interpretation of results

The interpretation of the analysed anthropometric data reveals a critical and pervasive gap in the design and procurement of educational furniture in tertiary institutions, namely, the lack of ergonomic consideration for user-specific body dimensions. The current practice of employing standardised, "one-size-fits-all" furniture fails to accommodate the natural variation in human anthropometry, particularly within a student population characterised by diversity in gender, age, and physical build.

By applying a percentile-based analysis, specifically focusing on the 5^{th} to 95^{th} percentile range, this study has demonstrated a feasible strategy for achieving inclusive and ergonomic furniture design. Designing to accommodate this percentile range ensures that approximately 90% of the student population can use the furniture comfortably, thereby minimising health-related discomfort and postural strain. Students seated in furniture that aligns with their anthropometric characteristics are more likely to maintain a neutral sitting posture, experience reduced musculoskeletal stress, and sustain higher levels of concentration and alertness during prolonged lectures.

The findings also highlight a significant incidence of mismatches between existing lecture hall furniture dimensions and student body measurements. For instance, disparities in seat height, depth, and writing surface distance were observed, which could contribute to chronic discomfort, including back pain, neck stiffness, and general fatigue. Such physical discomfort has been correlated in literature with reduced academic performance, increased absenteeism, and diminished engagement, especially during long-duration classroom sessions (Fidelis et al., 2018; Parvez et al., 2019).

Moreover, the mismatch data go beyond numerical evidence; they reflect a deeper institutional oversight regarding student-centred learning environments. The absence of ergonomically designed furniture is symptomatic of a broader neglect of health-supportive infrastructure in educational settings. This insight underscores the urgent need for institutional reforms, particularly in the development and implementation of ergonomics-informed procurement policies.

Universities and technical institutions must integrate anthropometric data and ergonomic principles into their procurement, manufacturing, and refurbishment processes. Such a paradigm shift would not only improve the physical health and comfort of students but also promote long-term productivity and academic achievement.

In summary, this study's findings advocate for a data-driven and user-responsive approach to educational furniture design, one that acknowledges body variability and promotes inclusivity, comfort, and well-being as fundamental elements of academic infrastructure.

Journal of Interior Design and Academy
INda 2021, 6(1):1-19
e-ISSN: 2791-7436

4. DESIGN SPECIFICATION AND RECOMMENDATIONS

Using the anthropometric data and ergonomic criteria, model furniture dimensions were proposed:

1. Seat Height (SH): 38.17 cm (5^{th} percentile PFH + 3 cm shoe allowance)
2. Seat Width (SW): 40.00 cm (95^{th} percentile WoB)
3. Seat Depth (SD): 36.05 cm (5^{th} percentile BPL)
4. Seat-to-Table Height (STH): 29.00 cm (5^{th} percentile ESH + adjustment)
5. Table Clearance (TC): 53.67 cm
6. Backrest Width (BW): 48.50 cm (95^{th} percentile EEB)
7. Upper Edge of Backrest (UEB): 25.00 cm
8. Table Width: Based on the 95^{th} percentile EEB and EFL

The model includes a backrest-to-seat angle of 102°, which is optimal for spinal alignment and lumbar support (Mahantesh et al., 2023). These specifications can be used by manufacturers and institutions to create ergonomically appropriate furniture.

5. CONCLUSIONS

In summary, this study was driven by the need to address the widespread ergonomic inadequacies in lecture hall furniture through a user-centred design approach. The primary purpose was to evaluate how well existing furniture dimensions matched the anthropometric characteristics of students at Kumasi Technical University and to propose data-informed design specifications that enhance comfort, posture, and learning outcomes. The findings revealed substantial mismatches, particularly in seat height, seat depth, and table height, factors that significantly influence student posture and physical well-being. The evidence showed that a majority of students were exposed to discomfort and potential musculoskeletal stress due to poorly fitted furniture. By using detailed anthropometric data and established ergonomic relationships, this study generated a set of furniture dimensions tailored to the actual needs of the student population.

The originality of this research lies not just in identifying mismatches, as previous studies have done, but in offering practical, scalable design solutions rooted in the physical realities of users. The application of percentile-based anthropometric measures in furniture specification marks a shift from generic furniture standards to inclusive and responsive design.

Moving from a general problem of ergonomic mismatch to specific, evidence-based recommendations, this study contributes both theoretically and practically to the field of interior and furniture design. It demonstrates that a data-driven, user-centred design framework can play a transformative role in shaping healthier and more effective academic environments.

By adopting the proposed ergonomic specifications, institutions can foster a more inclusive, safe, and performance-enhancing learning experience for students. Future research could explore implementation across different campuses, examine long-term health impacts, and expand the design model to accommodate adjustable or modular furniture solutions.

Acknowledgement and Information Note

The authors sincerely thank the 300 students who volunteered their time for this study. Special appreciation goes to Kumasi Technical University for its logistical and administrative support. We are also grateful to Mr. Acheampong Kingsley and Mr. Ezekiel Adebanji for their assistance during data collection, and to Mr. Prince Saah for his contribution to the design illustrations.

Conflict of Interest Declaration

The authors declare no conflict of interest.

Contribution Rate Declaration Summary of Researchers

The authors declare that they have contributed equally to the research.

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Journal of Interior Design and Academy
INda 2021, 6(1):1-19
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