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Reducing musculoskeletal disorders by "t" and "chi-square" statistical analyses

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ABSTRACT

Students spend a significant amount of time in the classroom and university library, mostly sitting. Prolonged sitting in incorrect posture and on inappropriate furniture can cause serious musculoskeletal disorders (MSDs) such as back injuries, neck and shoulder pain, ligament injuries, etc. This study aimed to design ergonomic furniture for both classrooms and libraries. To fulfill this objective, a total of 300 students (aged 19-24 years) were randomly selected from 10 different departments. Fifteen anthropometric measurements (popliteal height, stature, sitting eye height, sitting height, sitting elbow height, thigh clearance, knee height, buttock-knee height, elbow-to-elbow breadth, hip breadth, sitting shoulder height, sitting lowest rib bone height, sitting upper hip bone height, forearm fingertip length, buttock-popliteal length) and eleven furniture dimensions were selected and evaluated to identify potential mismatches between them. Moreover, "*t*" and "*chi-square*" statistical analyses were performed to compare the users' body measurements and furniture dimensions. Results showed that a significant level of mismatch was found between the body measurements and furniture dimensions. The results also indicated that the students' anthropometric measurements and the existing furniture dimensions were distinct. Finally, this study proposed redesigned academic furniture according to users' anthropometric measurements, which will reduce MSD problems among students.

Contribution/Originality: The primary contribution of this paper is the inclusion of two different statistical analysis methods ("t" and "chi-square") to identify differences in user body measurements and existing furniture, which previous studies did not include.

1. INTRODUCTION

Furniture has a significant influence on learning purposes. Both classroom and library furniture are the main sources of learning environments in the university. Most students spend approximately one-third of the day at university learning. During that time, students are engaged in various education-related activities such as reading, writing, drawing, and presenting ideas [1]. However, human health is greatly influenced by many factors, such as the work environment, external factors, and personal dispositions [2]. In the workplace, students use non-ergonomic furniture that causes fatigue, such as musculoskeletal diseases [3]. Commonly, students spend most of their time sitting on poorly designed classroom and library furniture [4-8], which has added a high rate of musculoskeletal disorders [9] and pain in different body parts among the students [10]. Several researchers have found that mismatches between furniture dimensions and student body measurements are the main sources of musculoskeletal disorders, pain, and discomfort among students [10-15]. A mismatch means an inability to match

or a discrepancy between two [16]. Female students seem to be at much higher risk of musculoskeletal disorders than male students [17]. Moreover, students cannot concentrate in the classroom due to postural discomfort. Anthropometric measurements of school children, with their age [18], differ from one land to the next or from state to state with minimal alterations [19]. The percentages of mismatch vary from one country to another due to differences in the demographic characteristics of students. The mismatch between furniture and students' body measurements could lead to various dangerous consequences, such as uncomfortable body posture, musculoskeletal pain, and, ultimately, it could hinder students' learning activities [20]. While assembly and stock expenses are vital concerns, there are additional costs associated with products that do not consider design based on appropriately chosen anthropometric information and ergonomics. Without legitimate design, sitting will require more muscular force and control to maintain steadiness and balance. This, thus, results in greater discomfort and fatigue, and probably causes pain in the neck or back of the students [21].

Salminen, Salminen [22]; Balague et al. [23] and Troussier et al. [24] researchers found that static sitting position and prolonged sitting position have been observed to be the real reason for low back pain. Osquei et al. [25] conducted research on an Iranian public university, where students were classified into the "tall," "medium," and "small" categories and found that not all the library desks and chairs were designed with consideration of students' anthropometry. Among the three major principles of anthropometry, the first principle is "design for the ultimate individual," which can be either designed for the maximum population, as commonly the 95th-percentile male, or designed for the minimum population value, as commonly referred to as the 5th-percentile female [26]. The second is "Designing for a Flexible Range," which puts the thought of both the 5th female and 95th male keeping in mind the end goal to suit 90% of the population [27, 28]. The third principle is to "design for average," which is mostly used. Based on the third principle, there are many designs, but few are based on a design for an adjustable range. Straker et al. [29] define that adjustable seats are favored for adult students or school children, to advance well-being and comfort in sitting. Noro and Lueder [30] expressed that seat tallness adjustability is the most essential component of a workstation and is utilized frequently. Ismaila et al. [31] defined that there is no indication that a student's discomfort is the reason for school furniture, also whether discomfort is related to a mismatch between a student's anthropometric dimensions and the dimensions of the student's school desk or seat. In spite of this, Grimes and Legg [32] defined that students' sitting discomfort is significantly related to a mismatch between seat depth and buttock-popliteal length.

Asian countries need to consider their students' anthropometric dimensions. This can be very supportive for designers and manufacturers in creating ergonomically suitable furniture that maintains students' concentration, safety, and comfort, enhances satisfaction levels, and ultimately reduces musculoskeletal disorders (MSDs) [5]. Various studies have examined the design of different types of furniture [33]. Nevertheless, Bangladesh has limited innovation in furniture design based on students' anthropometry. Hoque et al. [13] examined two types of university furniture and designed ergonomically fit classroom furniture. A simulation study was conducted focusing on local areas of the musculoskeletal system to find the optimum dimension [34]. In this paper, the mismatches between students' anthropometric dimensions and university furniture (classroom and library) have been calculated, and proposed dimensions have also been provided. The objective of this study is to calculate mismatch percentages and to propose ergonomically suitable furniture dimensions.

2. RESEARCH METHODOLOGY

2.1. Sample

A total of 300 undergraduate students from Khulna University of Engineering & Technology, Khulna, Bangladesh, participated in the research. As the number of male students is higher than that of female students in the university, 180 male and 120 female students (aged from 19 to 24 years) were selected with no physical disorders.

2.2. Anthropometric Measurements

Fifteen body dimensions of respondents, including Popliteal Height, Stature, Sitting Eye Height, Sitting Height, Sitting Elbow Height, Thigh Clearance, Knee Height, Buttock-Knee Height, Elbow-to-Elbow Breadth, Hip Breadth, Sitting Shoulder Height, Sitting Lowest Rib Bone Height, Sitting Upper Hip Bone Height, Forearm Fingertip Length, and Buttock Popliteal Length, were measured using an anthropometer and a height measuring scale. Except for stature, all measurements were taken while each participant was sitting in a relaxed position on a flat sitting surface, barefoot, wearing light, normal clothing, with knees bent at 90°.

The body dimensions were measured by adapting the definitions from Pheasant [35] during the measurement. All body dimensions are shown in Figure 1.

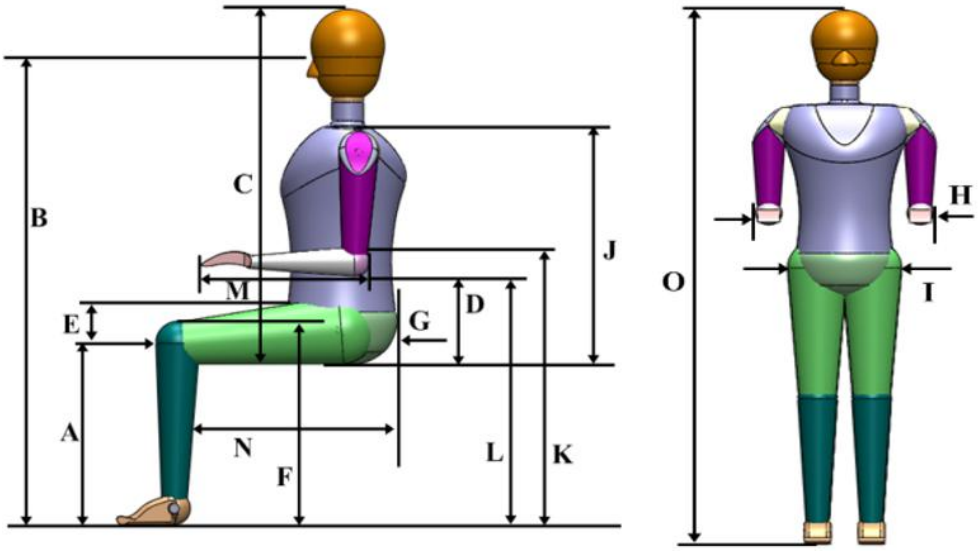


Figure 1. Anthropometric measurements of human body [(A) Popliteal height, (B) Sitting eye height, (C)Sitting height, (D) Sitting Elbow height, (E) Thigh clearance, (F) Knee height, (G) Buttock knee length, (H) Elbow to elbow breadth, (I) Hip breadth, (J) Sitting shoulder height, (K) Sitting lowest rib bone height, (L) Sitting upper hip bone height, (M) Forearm fingertip length, (N) Buttock - popliteal length, (O) Stature.].

2.3. Furniture Dimensions

In this research, four types of academic furniture were examined. Two types of furniture (mounted desktops and desks and chairs) and two types of library furniture (single-user and multiple-user desks and chairs) were measured and evaluated. A standard measuring tape was used to measure all dimensions of academic furniture. These are made by local furniture shops and do not have standard measurements. Due to a lack of ergonomic knowledge among furniture producers, incorrect or ill-fitted furniture was produced. Thus, the following dimensions were measured for classroom and library furniture. The furniture dimensions are shown in Figure 2.

2.4. Classroom Furniture and Body Dimensions Mismatch

In order to identify the mismatch between user body measurements and classroom furniture dimensions, it is necessary to have proper knowledge of different mismatch equations. Different relations have been used to recognize a match or mismatch.

Figure (a): Representation of mounted desktop

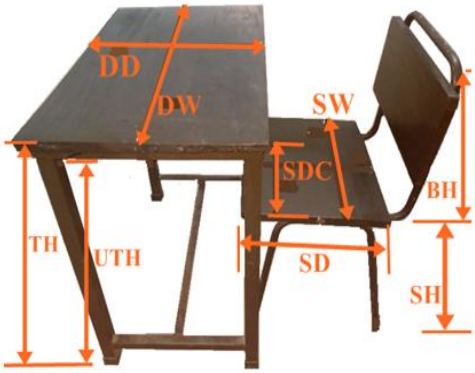


Figure (b): Representation of desks and chairs

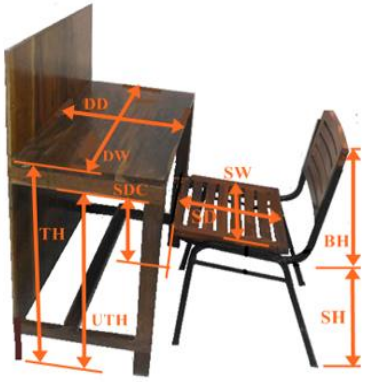


Figure (c): Representation of library desk and chair for single user

Figure (d): Representation of library desk and chair for multiple user

Figure 2. Representation of existing classroom and library furniture (a, b, c, d) [Seat width (SW), Seat depth (SD), Desk width (DW), Desk depth (DD), Desk Height (TH), underneath table height (UTH), Backrest height (BH), and Seat height (SH), Seat to desk clearance (SDC)].

2.4.1. Popliteal Height (PH) against Seat Height (SH)

PH should be higher than the SH [21]. Accordingly, Parcells et al. [21] defined mismatch by the seat tallness would either be <85% or >95% of the PH. The lower leg constitutes a 5–30° angle regarding the vertical, and the shin-thigh edge is in the region of 95 and 120° [10]. For this examination work, a 3 cm rectification for shoe stature is consolidated to the popliteal height. In this way, a coordinate measure is built up as per condition (1), the connection between PH and SH.

$$(PH + 3)\cos 30° \leq SH \leq (PH + 3)\cos 5° \quad (1)$$

2.4.2. Buttock Popliteal Length (BPL) against Seat Depth (SD)

Seat depth should be no less than 5 cm, and not exceed the popliteal length measured from the butt cheek [36]. Diverse researchers [37-41] have clarified that the seat depth should be estimated based on the fifth percentile of the BPL (biacromial-pelvic length) measurement, ensuring that the backrest of the seat can support the lumbar spine without compressing the popliteal surface. Consequently, a mismatch between seat depth (SD) and BPL is observed when SD is either less than 80% or greater than 95% of BPL [21]. In this way, a coordinate measure is built according to condition (2), the connection between BPL and SD.

$$0.80BPL \leq SD \leq 0.95BPL \quad (2)$$

2.4.3. Hip Breadth (HB) against Seat Width (SW)

The seat width must be adequately broad to accommodate the customer with the greatest hip breadth to ensure strength and allow space for level improvements [38-40]. The distinctive request has [41-46] exhibited that the HW should be thinner than the SW, remembering the ultimate objective of having a suitable fit in the seat, and a perfect seat width is decided for the 95th percentile of HB movement or the greatest HB. The proposed condition demonstrates that the SW should be less than 10% (to accommodate hip broadness) and close to 30% (for space economy) greater than the hip breadth.

$$1.10HB \leq SW \leq 1.30HB \quad (3)$$

2.4.4 Sitting Elbow Height (SEH) against Desk Height (DH)

Different audits, Dul and Weerdmeester [47] and Molenbroek et al. [48], showed that elbow height is estimated as the main issue for the work region's stature. As the load on the spine diminishes, the arms are maintained on the work surface, and the work surface height is at risk of shoulder flexion and shoulder abduction, which is obtained by the fifth percentile. Therefore, the work zone height should be 3–5 cm higher than the SEH. Thus, a coordinate measure is set with a modified condition (4) that recognizes the SEH as the minimum height of DH and considers that the maximum height of DH should not be higher than 5 cm above the SEH.

$$SEH \leq DH \leq SEH + 5 \quad (4)$$

2.4.5. Thigh Clearance (TC) against Seat to Desk Clearance (SDC)

The sensible seat-to-work zone ought to be more vital than thigh flexibility, remembering the ultimate objective of making leg improvement accessible [49]. The ideal seat height for a work area should be 2 cm higher than the thigh leeway. In this way, a proper ergonomic posture is maintained, as indicated by the following condition:

$$TC + 2 < SDC \quad (5)$$

2.4.6. Sitting Shoulder Height (SSH) against Backrest Height (BH)

The proper backrest height (BH) should be considered with a specific end goal to encourage portability of the back and arms. The estimation of the BH ought not to be less than the scapula [44]. Accordingly, Gouvali and Boudolos [10] and Agha [49] suggested keeping the backrest lower than or nearly on the upper edge of the scapula, and an ideal BH ought to be kept at 60–80% of shoulder height. In this way, a matching model is dictated by condition (6), and the connection between SSH and BH.

$$0.6SSH \leq BH \leq 0.80SSH \quad (6)$$

3. DATA ANALYSIS

SPSS Statistics version 20 and Microsoft Excel 2010 were used for calculating descriptive statistics (5th percentile, 50th percentile, 95th percentile, minimum, maximum, mean, and standard deviation) of participants to analyze the anthropometric characteristics of the students. Two statistical analyses (T-test analysis and chi-square analysis) were performed, and a match/mismatch analysis was also conducted to analyze the collected data.

4. RESULTS AND DISCUSSION

Figure 3 depicts the percentage of musculoskeletal disorders in the corresponding areas experienced by students. A survey has found that Bangladeshi university students suffer from different types of body pain. Neck pain was 38.04%, making it the most severe for students. Shoulder pain was reported at 29.35%, upper back at 13.04%, mid to lower back at 26.09%, knee at 17.39%, lower leg at 13.04%, buttock at 7.61%, upper arm at 10.87%,

thigh at 13.04%, foot at 13.04%, wrist at 9.78%, hand at 8.70%, and hip/waist at 28.26%. In all cases, girls appear to have experienced more musculoskeletal pain than male students.

Table 1 displays the descriptive statistics of the fifteen anthropometric measurements of different grades of 300 undergraduate students (180 male and 120 female). The average popliteal height for males is 43.75 cm (SD 2.22 cm), greater than the mean of female students, which is 39.80 cm (SD 1.69 cm). The mean buttock popliteal length for males is 42.55 cm (SD 3 cm), and for females, it is 40.45 cm (SD 3.71 cm). The mean hip breadth for females is 3.22 cm (SD 3.22 cm), larger than that of males, which is 34.71 cm (SD 3.03 cm). The mean sitting shoulder measurement for males is 57.34 cm (SD 5.99 cm), greater than for female students at 51.44 cm (SD 4.02 cm). Sitting elbow height averages 23.75 cm for males and 23.74 cm for females. Thigh clearance averages 15.12 cm for males and 15.99 cm for females. Stature averages 166.71 cm for males and 153.90 cm for females. Elbow-to-elbow breadth is 46.02 cm on average. Knee height for males is 53.00 cm on average. Sitting eye height averages 119.12 cm. Sitting height is 86.43 cm for males, greater than 79.45 cm for females. Buttock popliteal length averages 57.45 cm for males and 54.52 cm for females. The lowest rib bone height averages 74.32 cm for males and 67.60 cm for females. The mean upper rib bone height for males is 65.76 cm, and for females, it is 61.57 cm. Forearm fingertip length averages 44.93 cm for males and 42.58 cm for females. All measurements for males are greater than those for females, except for hip breadth and thigh clearance.

Table 2 provides two types of classroom furniture, i.e., chairs with mounted desktops, desks, and chairs dimensions, and another two types of library furniture, i.e., desks and chairs for single users, and desks and chairs for multiple users in cm. Tables 3, 4, and 5 show the means of desks and chairs dimensions, and the means of the assimilated anthropometric dimensions of students have statistical variation. Tables 6,7,8 display the dimensions of classroom and library desks and chairs that are not associated with the related anthropometric measurements, except the underneath table height of the desk in Table 7, i.e., there is a relation between underneath table height and corresponding anthropometric dimensions (knee height and table height). These outcomes recommend that the design of classroom and library furniture for university students should give anthropometric measurements as the main consideration for promoting a right sitting posture and therefore diminish musculoskeletal issues.

Comparative equations are used to calculate the mismatch percentage between furniture dimensions and anthropometric measurements. Table 9 shows that there is a little match between popliteal height and seat height for females (1.67%) and an almost appropriate match for males (63.33%). A high mismatch indicates that the seat height is too high, preventing the student's foot from touching the floor. High mismatch results in increased pressure on the thighs of students. There are 100 percent high mismatches for seat depth against buttock-popliteal length for students (male and female), indicating that seat depth is too deep for the students. For seat width, there is also a high mismatch (96.67%) for females and a high mismatch (100%) for males. Additionally, backrest height is too high (84.17%) for most female students and almost acceptable for males (64.44%). The desktop height from sitting is 50.83% for female students and 41.67% for male students. Seat-to-desk clearance shows a 100 percent match for students.

Table 10 displays that there is a little match (22.5%) between popliteal height and seat height for females and an almost perfect match (77.78%) for males in the case of classroom desks and chairs. Both students experienced a high mismatch. A high mismatch indicates that the seat height is too high, preventing the student's foot from touching the floor. High mismatch results in increased pressure on the thighs of students. There exists a high mismatch (74.17%) for seat depth against buttock-popliteal length in female students, which means that seat depth is too high for them, whereas there is a major match (51.11%) for males. For seat width, there is a low mismatch (7.5%) and a high mismatch (46.67%) for female students, and a major high mismatch (53.33%) for male students. Again, backrest height is too high for most female students (84.17% high mismatch) and almost acceptable for boys (33.33%). For both students, the desktop height (70% for males and 74.44% for females) is not appropriate. Seat-to-desk clearance is a 100 percent match for students because the desk height is high enough for them.

Table 11 shows that there is a 100% mismatch (high) between popliteal height and seat height for females and a 60% mismatch (high) for male students in the case of library desks and chairs. A high mismatch indicates that the seat height is too high, preventing the student's foot from touching the floor. High mismatch results from high pressure in the thigh of students. There is a 53.83% mismatch (high) for seat depth against buttock-popliteal length for female students, which means that seat depth is too deep for females. Seat depth (SD) is almost appropriate for the majority of males, with 80.56% matches. For seat width, there is also a high mismatch for students, indicating that the foot does not touch the floor for most students. Additionally, backrest height is too high for most male students (71.67%) and almost acceptable for females (24.17%). Desktop height from sitting position is appropriate for a minority, as there is no mismatch between the seat-to-desk clearance for single-user library furniture. However, there is a high mismatch for females (92.50%) and a smaller mismatch for males (42.22%).

Tables 12, 13, and 14 display the guidelines for designing ergonomically fit furniture. According to Taifa and Desai [5], Seat height is identified with popliteal stature and, for adjustable design reasons, ought to be the fifth percentile (female) of popliteal stature to the 95th percentile (male) of popliteal height, with the permissible allowance for shoes. Seat depth is outlined based on the 5th percentile (female) of butt cheek popliteal width. Seat width is the 95th percentile (female) of hip expansiveness for the most extreme sitting space [5]. For the design of the upper piece of the backrest, the shoulder height (sitting) is considered. The fifth percentile of Sitting Shoulder Stature (female) utilized by Taifa and Desai [5] is reported in the present investigation. Pheasant [35] suggested that the working height for writing ought to be elbow level or above. In this way, the fifth percentile (female) to 95th percentile (male) of elbow rest tallness is considered for the work area range from the seat. Seat-to-desk clearance is considered as per existing desktops according to Hoque et al. [13]. Desktop length ought to be the 95th percentile (male) of forearm fingertip length [5]. Desktop width is considered based on the existing desktop. In the Hong Kong guidelines, the 95th percentile elbow rest height of the students has been added to the seat height [43]. Table height ought to be 5th percentile (female) to 95th percentile (male) of elbow rest heights added to chair heights [5]. Table height ought to be the 95th percentile of the forearm fingertip length [5]. Table width should be the 95th percentile of shoulder breadth (elbow to elbow length) for desks and chairs. For library furniture, the existing table width is used. Hira [50] most university and college students prefer the desktop angle of 10 to 15 degrees. The inclined angle of the work area ought to be 10 degrees [51]. There is no compelling reason to lean forward towards the work area, since the use of a side-mounted desktop keeps the object reclining onto the backrest, along these lines, enhancing a straight back Thariq et al. [52]. Woo et al. [53] demonstrated that armrests enhance posture by decreasing burdens on the neck, back, arms, and shoulders. So, an armrest is added to the library furniture for a more comfortable posture.

Table 15 shows that the match percentages for both male and female are increased after calculating by the proposed dimension than the existing furniture. To enhance the seat with-mounted-work area outline measurements, considering students' anthropometry, the mismatch rates (i.e., low mismatch and high mismatch values) are ascertained for every ideal measurement that augments the match rate for that measurement.

Figures 4 and 5 depict ergonomically fit furniture by the recommended dimensions for classroom desks and chairs, and a library chair. The desk angle to the horizontal is recommended as 10 degrees for reducing neck flexion, pain in the spinal cord, and fatigue. An armrest is added in the proposed design of a library chair for a more relaxed sitting posture during study. The design of chairs with mounted desktops is the same, but the recommended dimensions should be followed when they are manufactured.

Guidelines have been followed appropriately while proposing dimensions. For the library chair, a new design has been proposed, which will be more comfortable for students with its proposed dimensions. For other furniture, the design has not been changed as its configuration is already comfortable; only dimensions have been adjusted to achieve ergonomic fitness. Wood is proposed as the material for manufacturing the furniture because of its low cost relative to its durability.

Table 1. Descriptive statistics of students by gender.

Anthropometric measurements	Gender	5th percentile	50th percentile	95th percentile	Minimum	Maximum	Mean	Standard deviation
Popliteal height	Male	40.00	44.20	47.50	39.50	48.00	43.75	2.22
	Female	37.59	39.20	42.33	37.20	43.00	39.80	1.69
Buttock popliteal length	Male	37.00	42.65	47.42	36.20	48.40	42.55	3.00
	Female	35.49	39.41	46.30	35.10	46.90	40.45	3.71
Hip breadth	Male	30.10	34.60	39.10	29.10	40.00	34.71	3.03
	Female	32.90	36.25	42.10	32.90	42.50	36.73	3.22
Sitting shoulder Height	Male	45.20	57.50	66.50	43.40	66.50	57.34	5.99
	Female	48.00	49.10	59.40	45.00	60.00	51.44	4.02
Sitting elbow height	Male	19.70	23.80	28.30	19.00	29.30	23.75	2.74
	Female	19.80	24.05	28.51	19.20	28.70	23.74	2.97
Thigh clearance	Male	10.80	16.00	17.22	10.50	18.60	15.12	1.92
	Female	13.00	16.00	18.70	12.00	19.00	15.99	1.64
Stature	Male	154.17	165.60	177.80	152.40	178.00	166.71	7.08
	Female	138.80	152.40	169.81	136.90	170.18	153.90	9.06
Elbow to elbow breadth	Male	40.60	45.90	53.93	40.60	55.00	46.02	3.92
	Female	36.00	42.30	50.61	34.90	51.10	42.91	4.29
Knee height	Male	49.48	52.90	56.51	47.70	57.50	53.00	2.15
	Female	47.50	50.00	56.20	47.00	57.20	50.91	2.65
Sitting eye height	Male	106.95	118.65	130.10	105.40	131.00	119.12	6.15
	Female	104.00	110.00	122.20	102.30	126.00	111.04	5.56
Sitting height	Male	79.70	86.10	94.70	79.10	96.10	86.43	4.49
	Female	71.90	78.80	85.03	71.00	89.20	79.45	4.81
Buttock knee length	Male	49.50	58.00	62.21	49.00	63.50	57.45	3.71
	Female	48.70	54.10	59.80	48.20	63.40	54.52	4.27
Sitting lowest rib bone height	Male	54.58	75.70	82.60	54.50	85.00	74.32	7.66
	Female	63.10	67.70	71.90	62.60	72.00	67.60	2.78
Sitting upper hip bone height	Male	60.10	66.00	73.70	56.80	76.00	65.76	4.29
	Female	58.10	61.70	65.00	57.77	65.00	61.57	2.42
Forearm fingertip length	Male	38.49	44.25	51.43	35.80	52.10	44.93	4.08
	Female	35.80	42.85	49.26	34.60	51.20	42.58	4.00

Table 2. Furniture dimensions for classroom (cm).

Furniture dimension	Classroom furniture		Library furniture	
	Type A (Chairs with mounted desktop)	Type B (Desks and chairs)	Type A (Desks and chairs for single user)	Type B (Desks and chairs for multiple user)
Seat height	45.70	44.60	47.55	47.55
Seat depth	51.40	40.70	38.10	38.10
Seat width	55.00	45.80	37.00	37.00
Backrest height	45.20	45.00	33.50	33.50
Desktop/desk height from seat	23.80	31.00	29.85	29.85
Seat to desk clearance	21.20	23.00	24.55	15.55
Desktop/desk width	28.50	76.40	75.00	152.8
Desktop length/desk depth	67.00	51.00	43.50	102
Lumber support height	27.00	_	_	_
Table height	75.50	77.00	74.30	76.40
Underneath table height	62.20	67.60	72.10	63.10

Table 3. T-test analysis of furniture (chairs with mounted desktop) dimensions and related anthropometric measurements.

Anthropometric dimension (n_1= 40)			Chair seat dimensions (n_2=3)			Difference	T_{cal}	T_{cri}	Decision
	Mean	SD		Mean	SD				
For chair									
Popliteal height (PH)	41.96	2.64	Chair seat height (SH)	45.70	1.45	-3.74	-3.99	±0.04	Reject
Buttock Popliteal length (BPL)	42.59	3.54	Chair seat depth (SD)	51.40	0.10	-8.81	-15.66		Reject
Hip Breadth (HB)	35.14	3.44	Chair seat width (SW)	55.00	1.56	-19.86	-18.86		Reject
Mid shoulder sitting height (SSH)	54.93	5.08	Chair backrest height (BH)	33.50	0.95	21.43	22.00		Reject
For mounted desktop									
Popliteal height (PH)+sitting elbow height (SEH)	64.96	4.51	Table Height (TH)	75.50	1.28	-10.54	-10.28	±0.77	Reject
Knee Height (KH)+ Thigh Clearance (TC)	67.26	2.31	Underneath Table Height (UTH)	62.20	1.95	5.06	4.28		Reject

Table 4. T-test analysis of classroom desks and chairs for classroom dimensions and related anthropometric measurements.

Anthropometric Dimension (n_1= 25)			Chair Seat Dimensions (n_2=3)			Difference	T_{cal}	T_{cri}	Decision
	Mean	SD		Mean	SD				
For classroom chair									
Popliteal height (PH)	41.96	2.64	Chair seat height (SH)	44.6	0.46	-2.64	-5.34	±0.26	Reject
Buttock Popliteal length (BPL)	42.59	3.54	Chair seat depth (SD)	40.7	0.66	1.89	2.80		Reject
Hip Breadth (HP)	35.14	3.44	Chair seat width (SW)	45.8	0.56	-10.66	-16.87		Reject
Mid shoulder sitting height (SSH)	54.93	5.08	Chair backrest height (BH)	33.5	0.96	21.43	22.00		Reject
For classroom desk									
Popliteal height (PH) + sitting elbow height (SEH)	64.96	4.51	Table height (TH)	77	1.15	-12.04	-12.34	±0.40	Reject
Knee Height (KH) + Thigh clearance (TC)	67.26	2.31	Underneath table height (UTH)	67.6	0.62	-0.34	-0.66		Reject

Table 5. T–test analysis of library desks and chairs dimensions and related anthropometric measurements.

Anthropometric dimension (n_1= 40)			Chair seat dimensions (n_2=3)			Difference	T_{cal}	T_{cri}	Decision
	Mean	SD		Mean	SD				
For library chair									
Popliteal height (PH)	41.96	2.64	Chair seat Height (SH)	47.55	0.48	-5.59	-11.18	±0.82	Reject
Buttock Popliteal length (BPL)	42.59	3.54	Chair seat depth (SD)	38.10	0.56	4.49	6.96		Reject
Hip Breadth (HB)	35.14	3.44	Chair seat width (SW)	37.00	1.61	-1.86	-1.73		Reject
Mid shoulder sitting height (SSH)	54.93	5.08	Chair backrest height (BH)	33.50	0.95	21.43	22.00		Reject
For desk for single users									
Popliteal height (PH)+ sitting elbow height (SEH)	64.96	4.51	Table height (TH)	74.3	1.249	-9.34	-9.21	±0.05	Reject
Knee height (KH)+Thigh Clearance (TC)	67.26	2.31	Underneath table height (UTH)	72.1	1.25	-4.84	-5.97		Reject
For desk for multiple users									
Popliteal height (PH)+ sitting elbow height (SEH)	64.96	4.51	Table height (TH)	76.40	0.44	-11.44	-15.13	±0.68	Reject
Knee height (KH)+ Thigh Clearance (TC)	67.26	2.31	Underneath table height (UTH)	63.10	1.25	4.16	5.15		Reject

Table 6. Chi-square test for the dimensions of classroom chairs with mounted desktop and related anthropometric measurements.

Anthropometric dimensions and seat dimensions	Values	5th percentile	50th percentile	95th percentile	Total χ^2_{cal}	χ^2_{cri}	Decision
For chair (DOF=2)							
Popliteal height (PH) and seat height (SH)	Observed value (O)	38.10	41.70	45.81	1.28	0.10	Reject
	Expected Values (E)	44.36	45.80	46.97			
	$(O-E)^2$- E	0.88	0.37	0.03			
Hip breadth (HB) and seat width (SW)	Observed value (O)	30.10	34.30	39.61	22.97		Reject
	Expected Values (E)	54.02	54.20	56.54			
	$(O-E)^2$- E	10.59	7.31	5.07			
Buttock popliteal length (BPL) and seat depth (SD)	Observed value (O)	37.14	43.46	46.81	5.57		Reject
	Expected Values (E)	51.31	51.40	51.49			
	$(O-E)^2$- E	3.92	1.23	0.43			
Sitting elbow height (SEH) and Desktop Height (DH)	Observed value (O)	19.70	23.00	27.51	4.77		Reject
	Expected Values (E)	28.56	29.95	31.08			
	$(O-E)^2$- E	2.75	1.61	0.41			
Thigh clearance (TC) and seat to desk clearance (SDC)	Observed value (O)	12.74	16.15	17.60	3.29		Reject
	Expected Values (E)	18.66	20.10	21.27			
	$(O-E)^2$- E	1.88	0.78	0.63			
For mounted desktop (DOF=3)							
Popliteal height (PH)+ Sitting elbow height (SEH) and Table Height (TH)	Observed value (O)	58.79	65.00	71.59	5.08	0.35	Reject
	Expected Values (E)	74.27	75.80	76.52			
	$(O-E)^2$- E	3.23	1.54	0.32			
Knee height (KH)+ Thigh clearance (TC)and Underneath Table height (UTH)	Observed value (O)	63.66	67.80	70.00	1.16		Reject
	Expected Values (E)	60.29	62.90	63.85			
	$(O-E)^2$- E	0.19	0.38	0.59			

Table 7. Chi-square test for the dimensions of classroom desks and chairs and related anthropometric measurements.

Anthropometric dimensions and seat dimensions	Values	5th percentile	50th percentile	95th percentile	Total χ^2_{cal}	χ^2_{cri}	Decision
For classroom chair (DOF=2)							
Popliteal height (PH) and seat height (SH)	Observed value (O)	38.10	41.70	45.81	1.05	0.10	Reject
	Expected Values(E)	44.16	44.70	44.97			
	$(O-E)^2$- E	0.83	0.20	0.02			
Hip breadth (HB) and seat width (SW)	Observed value (O)	30.10	34.30	39.61	8.97		Reject
	Expected Values (E)	45.27	45.90	46.26			
	$(O-E)^2$- E	5.08	2.93	0.96			
Buttock popliteal length (BPL) and seat depth (SD)	Observed value (O)	37.14	43.46	46.81	1.16		Reject
	Expected Values (E)	40.15	40.60	41.32			
	$(O-E)^2$- E	0.23	0.20	0.73			
Thigh clearance (TC) and seat to desk clearance (SDC)	Observed value (O)	12.74	16.15	17.60	7.73		Reject
	Expected Values (E)	22.53	22.80	23.61			
	$(O-E)^2$- E	4.26	1.94	1.53			
For classroom desk (DOF=3)							
Popliteal height (PH)+ Sitting elbow height (SEH) and Table Height (TH)	Observed value (O)	58.79	65.00	71.59	6.28	0.35	Reject
	Expected Values (E)	76.00	76.90	78.07			
	$(O-E)^2$- E	3.90	1.84	0.54			
Knee height (KH)+Thigh clearance (TC)and Underneath Table height (UTH)	Observed value (O)	63.66	67.80	70.00	0.22		Accept
	Expected Values (E)	66.99	67.80	68.07			
	$(O-E)^2$- E	0.17	0.00	0.05			

Table 8. Chi-square test for the dimensions of library desks and chairs and related anthropometric measurements.

Anthropometric dimensions and seat dimensions	Values	5^{th} percentile	50^{th} percentile	95^{th} percentile	Total χ^2_{cal}	χ^2_{cri}	Decision
For library chair (DOF=2)							
Popliteal height (PH) and seat height (SH)	Observed value (O)	38.10	41.70	45.81	2.54	0.10	Reject
	Expected values(E)	47.26	47.30	48.02			
	$(O-E)^2$- E	1.78	0.66	0.10			
Hip breadth (HB) and seat width (SW)	Observed value (O)	30.10	34.30	39.61	1.08		Reject
	Expected values (E)	35.49	37.20	38.37			
	$(O-E)^2$- E	0.82	0.23	0.04			
Buttock popliteal length (BPL) and seat depth (SD)	Observed value (O)	37.14	43.46	46.81	2.52		Reject
	Expected values (E)	37.64	38.00	38.63			
	$(O-E)^2$- E	0.01	0.78	1.73			
Thigh clearance (TC) and seat to desk clearance (SDC) (For Multiple users)	Observed value (O)	12.74	16.15	17.60	0.51		Reject
	Expected values (E)	14.98	15.70	16.02			
	$(O-E)^2$- E	0.34	0.01	0.16			
Thigh clearance (TC) and seat to desk clearance (SDC) (For single user)	Observed value (O)	12.74	16.15	17.60	10.35		Reject
	Expected values (E)	23.58	24.70	25.42			
	$(O-E)^2$- E	4.98	2.96	2.41			
For library desk for a single user (DOF=3)							
Popliteal height (PH)+ Sitting elbow height (SEH) and table height (TH)	Observed value (O)	58.28	63.55	69.53	6.97	0.35	Reject
	Expected values (E)	76.11	76.20	76.83			
	$(O-E)^2$- E	4.18	2.10	0.69			
Knee height (KH)+ Thigh clearance (TC) and underneath table height (UTH)	Observed value (O)	57.50	60.00	66.20	0.52		Reject
	Expected values (E)	62.16	62.70	64.32			
	$(O-E)^2$- E	0.35	0.12	0.05			
For library desk for multiple users (DOF=3)							
Popliteal height (PH)+ Sitting elbow height (SEH) and table height (TH)	Observed value (O)	58.79	65.00	71.59	4.23	0.35	Reject
	Expected values (E)	73.08	74.70	75.24			
	$(O-E)^2$- E	2.79	1.26	0.18			
Knee height (KH)+ Thigh clearance (TC)and underneath table height (UTH)	Observed value (O)	63.66	67.80	70.00	1.15		Reject
	Expected values (E)	71.01	72.00	73.26			
	$(O-E)^2$- E	0.76	0.25	0.15			

This implies there is a significant mismatch between understudy anthropometric measurements and furniture measurements, which are calculated in percentages below.

Table 9. Match/mismatch percentages for existing chairs with mounted desktop.

Criteria	Furniture dimension	Gender	Low mismatch	High mismatch	Total mismatch	Total match
Seat height	45.7	Female	0	98.33	98.33	1.67
		Male	0	36.67	36.67	63.33
Seat depth	51.4	Female	0	100	100	0
		Male	0	100	100	0
Seat width	55	Female	0	96.67	96.67	3.33
		Male	0	100	100	0
Backrest height	45.2	Female	0	84.17	84.17	15.83
		Male	0	35.56	35.56	64.44
Desktop/desk height from seat	23.8	Female	50.83	0	50.83	49.17
		Male	41.67	0	41.67	58.33
Seat to desk clearance	21.2	Female	_	0	0	100
		Male	_	0	0	100

Table 10. Match/mismatch percentages for existing classroom desks and chairs.

Criteria	Furniture dimension	Gender	Low mismatch	High mismatch	Total mismatch	Total match
Seat height	44.6	Female	0	77.5	77.5	22.5
		Male	0	22.22	22.22	77.78
Seat depth	40.7	Female	0	74.17	74.17	25.83
		Male	0	51.11	51.11	48.89
Seat width	45.8	Female	7.5	46.67	54.17	45.83
		Male	0	53.33	53.33	46.67
Backrest height	45	Female	0	84.17	84.17	15.83
		Male	0	33.33	33.33	66.67
Desktop/Desk height from seat	31	Female	0	70	70	30
		Male	0	74.44	74.44	25.56
Seat to desk clearance (Single user)	23	Female	_	0	0	100
		Male	_	0	0	100

Table 11. Match/mismatch percentages for existing library desks and chairs.

Criteria	Furniture dimension	Gender	Low mismatch	High mismatch	Total Mismatch	Total match
Seat height	47.55	Female	0.00	100.00	100.00	0.00
		Male	0.00	60.00	60.00	40.00
Seat depth	38.10	Female	0.00	55.83	55.83	44.17
		Male	4.44	15.00	19.44	80.56
Seat width	37.00	Female	73.33	0.00	73.33	26.67
		Male	66.67	0.00	66.67	33.33
Backrest height	33.50	Female	24.17	0.00	24.17	75.83
		Male	71.67	0.00	71.67	28.33
Desktop/Desk height from seat	29.85	Female	0.00	59.17	59.17	40.83
		Male	0.00	67.78	67.78	32.22
Seat to desk clearance (Single user)	24.55	Female	_	0.00	0.00	100.00
		Male	_	0.00	0.00	100.00
Seat to desk clearance (Multiple user)	15.55	Female	_	92.50	92.50	7.50
		Male	_	42.22	42.22	57.78

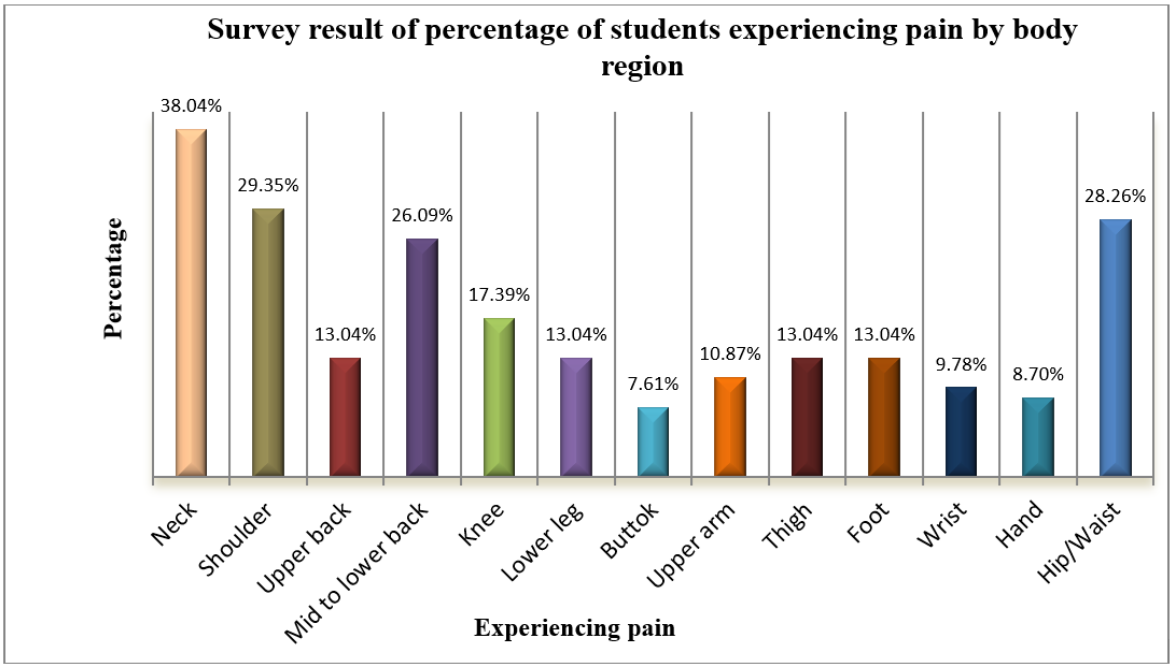
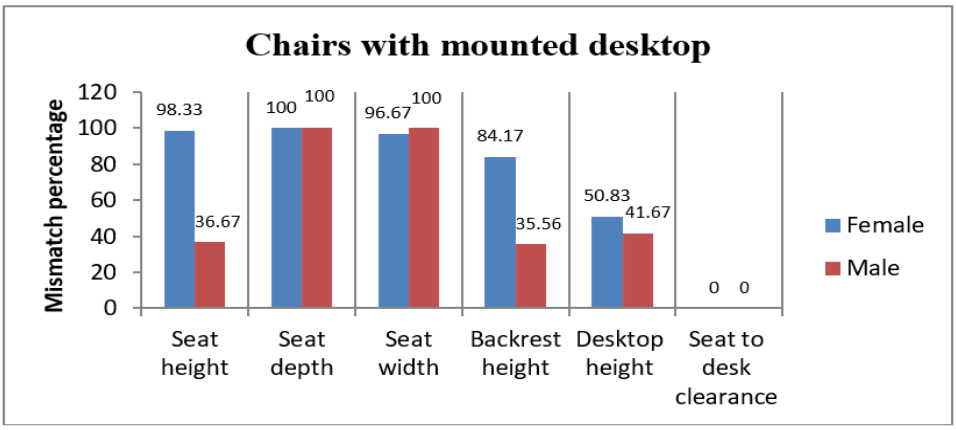
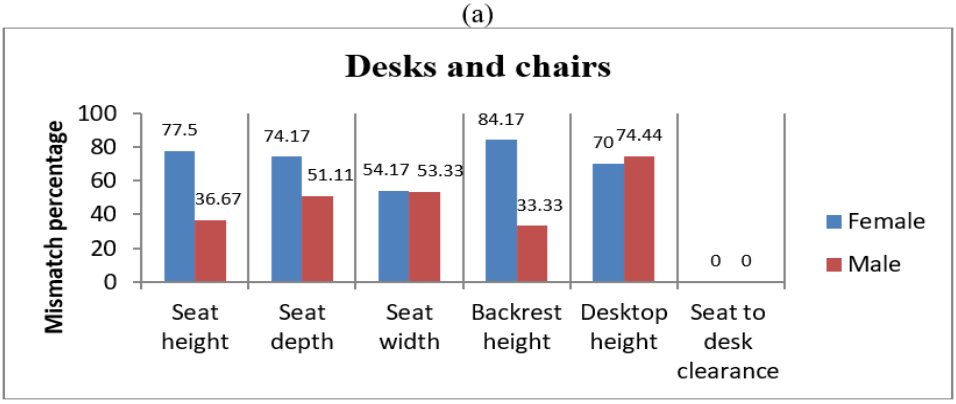


Figure 3. Percentage of Musculoskeletal disorders in the corresponding areas.



(a)



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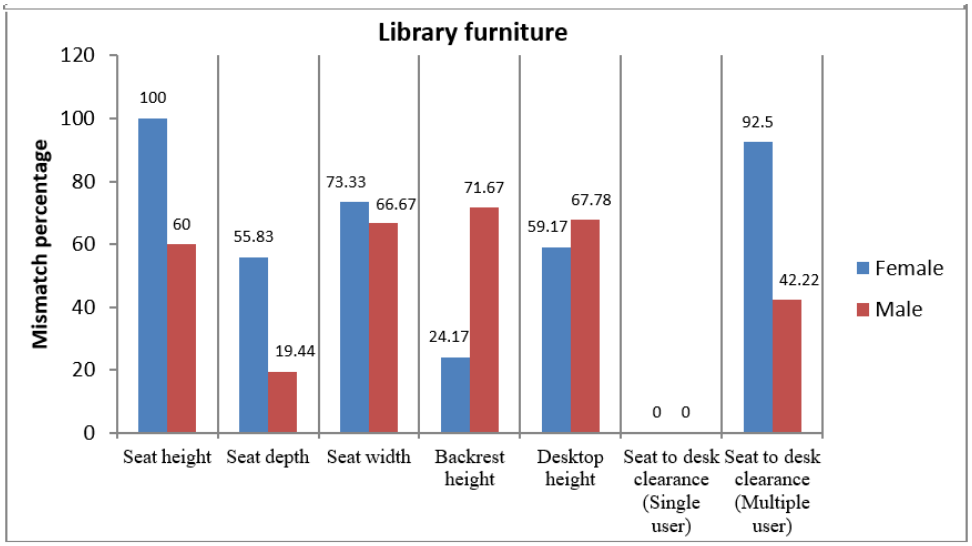

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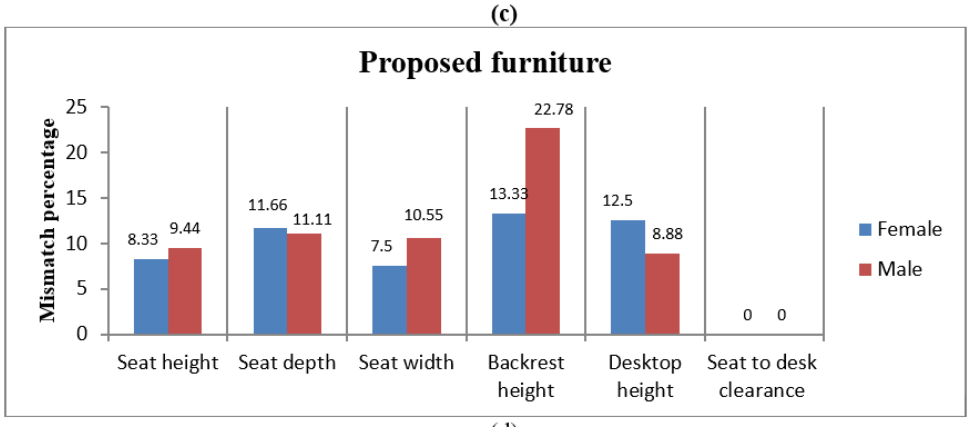

(d)

Figure 4. Mismatch percentage for various measurements by gender (a) Chairs with mounted desktop (b) Desks and chairs for classroom (c) Desks and chairs for library (d) Newly proposed dimensions.

Table 12. Guidelines for Design Criteria for Mounted Desktop.

Furniture dimension	Anthropometric dimension	Design dimension	Criteria determinants
Seat height	Popliteal height	40.09cm to 50cm	5th percentile (female) to 95th percentile (male) of popliteal height + 2.5 cm for shoes allowance.
Seat Depth	Buttock popliteal length	42.5cm	5th percentile (Female) of buttock popliteal length
Seat width	Hip breadth	42.1cm	95th percentile (Female) of hip breadth
Backrest height	Sitting shoulder height	48 cm	5th percentile (Female) of sitting shoulder height
Desktop height or arm rest height	Sitting elbow height	19.8	5th percentile (Female) of sitting elbow height
Seat to desk clearance	Thigh clearance	21.2 cm	As per existing seat to desk clearance
Desktop length	Forearm fingertip length	51.45cm	95th percentile (Male) of forearm fingertip length
desktop width	_	28.5cm	As per existing desktop width
Desk angle to horizontal	_	10 degree	_
Seat angle to horizontal	_	0 degree	_
backrest angle to horizontal for seat	_	95 degree	_

Table 13. Guidelines for design criteria for classroom furniture.

Furniture dimension	Anthropometric dimension	Design dimension	Criteria determinants
Seat height	Popliteal height	40.09cm to 50cm	5th percentile (Female) to 95th percentile (Male) of popliteal height+2.5 cm for shoes allowance
Seat depth	Buttock popliteal length	42.5cm	5th percentile (Female) of buttock popliteal length
Seat width	Hip breadth	42.1cm	95th percentile (Female) of hip breadth
Backrest height	Sitting shoulder height	48 cm	5th percentile (Female) of sitting shoulder height
Desktop height or armrest height	Sitting elbow height	19.8	5th percentile (Female) of sitting elbow height
Seat to desk clearance	Thigh clearance	21.2 cm	As per existing seat-to-desk clearance
Table height	Sitting elbow height and popliteal height	59.89cm to 78.3 cm	5th percentile (Female) to 95th percentile (Male) of elbow rest heights is added to chair heights
Table depth	Forearm fingertip length	51.45 cm	95th percentile (Male) of forearm fingertip length
Table width	Elbow to elbow breadth	53.95cm	50th percentile (Male) of elbow to elbow breadth
Desk angle to horizontal	_	10 degree	_
Seat angle to horizontal	_	0 degree	_
Backrest angle to horizontal for seat.	_	95 degree	_
Bag shelf depth	size of medium bag	39.8cm	Direct measurements of the available bags for students
Bag shelf width	size of medium bag	49.45cm	Direct measurements of the available bags for students.

Table 14. Guidelines for design criteria for library furniture.

Furniture dimension		Anthropometric dimension	Design dimension	Criteria determinants
Seat height		Popliteal height	40.09cm to 50cm	5th percentile (female) to 95th percentile (Male) of popliteal height+2.5 cm for shoes allowance
Seat depth		Buttock popliteal length	42.5cm	5th percentile (Female) of buttock popliteal length
Seat width		Hip breadth	42.1cm	95th percentile (Female) of hip breadth
Backrest height		Sitting shoulder height	48 cm	5th percentile (Female) of sitting shoulder height
Desktop height or armrest height		Sitting elbow height	19.8	5th percentile (Female) of sitting elbow height
Seat to desk clearance		Thigh clearance	21.2 cm	As per existing seat to desk clearance
Table height		Sitting elbow height and popliteal height	59.89cm to 78.3 cm	5th percentile (Female) to 95th percentile (Male) of elbow rest height is added to chair heights
Table depth	For single user	Forearm fingertip length	51.45 cm	95th percentile (Male) of forearm fingertip length
	For multiple user	Forearm fingertip length	102 cm	As per the existing library table (for multiple users)
Table width	For single user	_	75cm	As per existing library table (For single user)
	For multiple user	_	152.8 cm	As per existing library table (For multiple user)
Desk angle to horizontal		_	0 degree	_
Seat angle to horizontal		_	0 degree	_
backrest angle to horizontal for seat		_	95 degree	_

Table 15. Match/Mismatch calculation using proposed dimensions.

Criteria	Furniture dimension	Gender	Low mismatch	High mismatch	Total mismatch	Total match
Seat height	41.5	Female	0	8.33	8.33	91.67
		Male	9.44	0	9.44	90.56
Seat depth	35.2	Female	0.83	10.83	11.66	88.34
		Male	6.11	5	11.11	88.89
Seat width	42.1	Female	7.5	0	7.5	92.5
		Male	3.33	7.22	10.55	89.45
Backrest height	45	Female	0	13.33	13.33	86.67
		Male	0	22.78	22.78	77.22
Desktop/Desk height from seat	19.8	Female	7.5	5	12.5	87.5
		Male	4.44	4.44	8.88	91.12
Seat to desk clearance (Single user)	21.2	Female	_	0	0	100
		Male	_	0	0	100

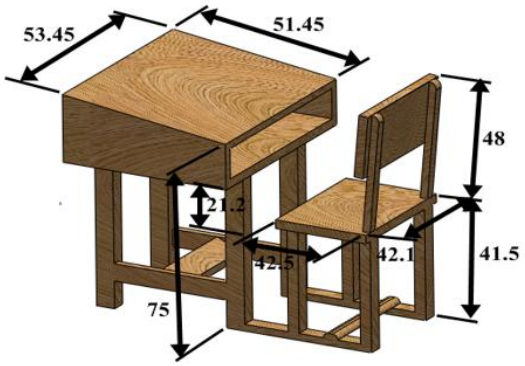

Figure (a): Proposed furniture (Classroom desk and chair) with dimensions

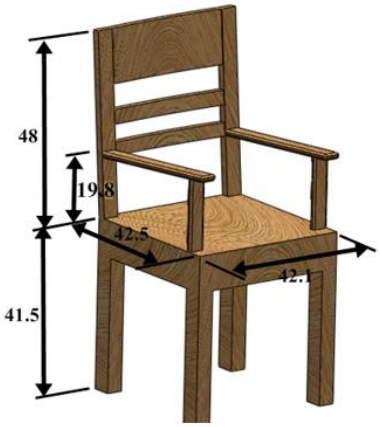

Figure (b): Proposed furniture (Library chair) with dimensions

Figure 5. Proposed furniture with dimensions (a, b) (cm).

5. CONCLUSION

As the furniture is not designed with consideration of anthropometry, there are related problems among students. That is why it is fundamental to make all the furniture easy to use, outlining every part of the furniture with consideration of the anthropometric measurements of users accurately, with proper care. The makers intend to further look at this issue of the mismatch between students' body estimations and the furniture used in the research. During the manufacturing of university furniture, the anthropometric measurements of the pupils ought to be utilized. The furniture ought to be intended to suit a larger part of the student population; subsequently, it ought to be focused between the fifth percentile female and the 95th percentile male, which covers the major share of the student population. Even though it is hard to plan for every one of the students, however, an item that matches the greater part of the student population can be planned and the issues unraveled to an impressive degree. The anthropometric estimations from the present review might be useful in planning the students' study areas. The creators mean to additionally examine this issue of mismatch between students' body measurements and furniture utilized by examination facilities in a larger number of universities, and take anthropometry measurements from a larger number of students. Using unfit furniture with poor posture is the reason for a lot of musculoskeletal disorders. It has a greater negative effect on the spinal cord, muscles, eyes, etc. If the redesigned furniture is used, it becomes ergonomically fit, and the users may get away from all those injurious effects.

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Institutional Review Board Statement: The study involved minimal risk and adhered to ethical guidelines for social science fieldwork. Formal approval from an Institutional Review Board was not required under the policies of Adekunle Ajasin University, Nigeria. Informed verbal consent was obtained from all participants, and all data were anonymized to ensure participant confidentiality.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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