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*Original Article*

# Association between anthropometric measurements of chairs and biomechanical variables leading to musculoskeletal problems in students at different government universities of Multan

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**Abstract:** Objective: To determine the association between anthropometric measurements of chairs and biomechanical variables leading to musculoskeletal problems in students at different government universities in Multan. Methods: The cross-sectional study was done on 383 students at different government universities in Multan, Pakistan. There were 23 anthropometric measurements like shoulder height (SH), shoulder breadth (SB), knee height (KH), popliteal height (PH), elbow height sitting (EHS), elbow-fingertip length (EFL), abdominal depth (ABD), buttock-popliteal length (BPL), thigh thickness (TT), forearm width (FW), hip angle (HA), knee angle (KA), cervical flexion (CF), cervical extension (CE), cervical lateral flexion (CLF), cervical rotation (CR), thoracic flexion (TF), thoracic extension (TE), lumber flexion (LF), lumber extension (LE), lumber lateral flexion (LLF), and lumber rotation (LR). There were 11 dimensions of chairs: seat height (SH), seat depth (SD), seat width (SW), desk length (DL), desk width (DW), desk height (DH), backrest height (BH), backrest depth (BD), and seat pan depth (SPD) were measured in six types of commonly used chairs in different universities in Multan. This research was done to determine the fitness of chairs using combinational equations. Results: There was a huge difference between most anthropometric measurements of students and chairs. The recommended measurements were SH (33.2 cm), SW (43.6 cm), SD (42 cm), DH (24.5 cm), DL (51.1 cm), DW (95 cm), BW (42.6 cm), BD (2 cm), BH (55 cm), and SPD (4 cm). Conclusions: None of the chairs used in the universities of Multan were found to be designed according to the anthropometric dimensions of students, resulting in musculoskeletal problems. It is necessary to revise the design of chairs according to the anthropometric data of students to minimize musculoskeletal problems.

**Keywords:** Ergonomics, anthropometric measurements, chairs, university students, musculoskeletal problems

## Introduction

People interact with different tools and equipment in their daily activities, which affects them physically or mentally. If these are unfit or uncomfortable, it decreases their productivity and leads to musculoskeletal problems [1]. Students face different biomechanical abnormalities directly linked to faulty ergonomics of furniture used in education sectors, primarily chairs because they spend approximately 7-8 hours a day sitting on chairs during lectures and other activities during university time [2]. Static posture leads to the softness of intervertebral discs and reduces flexibility or causes severe muscle tension, restricted blood flow, faulty posture, and numbness. Long periods of upright sitting can cause an increase in intra-disc pressure or end plate rupture, a narrowing of the disc and anterior annular bulge, and posterior or posterolateral prolapse of disc contents [3]. Being mid-upright, the seated position has the worst condition; the axial loading is 2.5 times that of lying supine. Flexion force tends to tilt the pelvis backward, flattening the lumber lordosis, and reducing the protective wedge angle [4]. It also results in anthropometric dimensions and stress. These musculoskeletal problems also affect the performance and concentration in studying these students and other activities [5, 6].

Furniture designed on the principles of ergonomics and anthropometry may prove helpful in reducing accidents or physical symptoms or increasing efficiency. Various anthropometric parameters, like body size, motion space, and various motion angles, can be used by various individuals. When anthropometric data is used to design chairs, it saves time and money. It also promotes education concerning students' posture [7, 8]. According to previous studies, low back pain is most prevalent in students due to bad sitting posture. In adult classrooms, the critical work needs proper posture and ergonomically designed chairs, which universities neglect. It is proposed that students who feel pain in the lower back as teenagers might have lower back pain in later life [8, 9]. Sitting erect for a maximum time is necessary to avoid the effects of cervical flexion. For the perfect hip position in the chair, it is necessary to be at more than 90° and reduce the lumbar lordosis. Most students sit on their toes because their feet cannot touch the ground. It is incredibly harmful to the spine and results in deformities in the students [10].

Coccydynia is also called the pain of the Coccyx, a triangular-shaped bone of the spine that contacts the seating surface while sitting. However, the coccyx is not the cause of pain in coccygodynia because the pain initially arises from the levator ani or coccygeus and also due to the gluteus maximus muscle, and the coccyx's shape or, size and position have no relationship to coccygodynia [11]. So, adding some ergonomic parameters based on physique or psychological need and the user's abilities is essential. Therefore, it is necessary to create a tension-free workstation based on ergonomics.

Every year, the government spends a lot of money on education. They should also concentrate on the furniture of the education system, including chairs. The chairs could be more comfortable in the private and government setup. These are causing many disabilities and deformities in students, leading to disease in their later lives. In the government educational system, the chairs must be appropriately designed ergonomically. Therefore, it is necessary to improve this flaw in the educational system. Many previous studies focused on working stations and a few on education sectors.

The chairs used in the universities of Multan must be aligned with students' dimensions. The following study examined the physical impact of chairs on university students. This study aims to determine the association between anthropometric measurements of chairs and biomechanical variables leading to musculoskeletal problems in final-year students of different government universities of Multan.

## Materials and methods

A cross-sectional analytical study was conducted from March to June 2023 from the final year students of different government universities of Multan like Muhammad Nawaz Sharif University of Agriculture, Bahauddin Zakariya University Multan, Emerson University of Multan, and Government College University Faisalabad, Faisalabad (Sub campuses in Multan). This study was approved by the ethical review committee of Muhammad Institute of Medical and Allied Sciences Multan, Pakistan (2023/IRB/2/PT/22). Students of both genders, aged 20-30 years, and having a history of prolonged sitting (> 7 hrs/day/3 years) without other musculoskeletal deformities were included in this study. Students not willing to participate, patients with a history of trauma, fracture, radiating leg pain, degenerative joint disease, active systemic disorder, psychological unfit, and pregnant females were excluded from this study.

The sample size was calculated using the following formula from the online Raosoft calculator with a significant level set at 0.05 [12, 13]. The data was collected from a sample of 383 individuals. The sample was measured by keeping the power of study at 95% and the probability of error at 5%.

$X = Z^{(c/100)2} r\ (100\text{-}r)$

$N = Nz^2\delta^2/Nd^2+z^2\delta^2$

Where n = sample size; N = population size; E = margin of error (5%) based on research [12, 13]. The students (400) were selected for the following study, but the total number of students, according to the equation, the sample size was predicted to be 383.

In this study, 23 types of anthropometric dimensions were measured. Physio measuring tape used for length and width of different segments of the body like shoulder height (SH), shoulder breadth (SB), knee height (KH), popliteal height (PH), elbow height sitting (EHS), elbow-fingertip length (EFL), buttock-popliteal length (BPL), abdominal depth (ABD), forearm width (FW), and thigh thickness (TT). Goniometers used for measurement of joint angles like hip angle (HA), knee angle (KA), and bubble inclinometer (with the accuracy of 0.1 and 0.5 mm) used for measurement of range of motion (ROM) of different segments of the spine like cervical flexion (CF), cervical extension (CE), cervical lateral flexion (CLF), cervical rotation (CR), thoracic flexion (TF), thoracic extension (CE), lumber flexion (LF), lumber extension (LE), lumber lateral flexion (LLF), and lumber rotation (LR). All anthropometric dimensions were taken according to the significant International Organization of Standardization (IOS) standard shown in **Figure 1**. Physio measuring tape was used for eleven different types of anthropometric measurements chairs like seat height (SH), seat depth (SD), seat width (SW), desk length (DL), desk width (DW), desk height (DH), backrest height (BH), backrest depth (BD), and seat pan depth (SPD) shown in **Figure 2**.

For statistical analysis, collected anthropometric data was put in the statistical software SPSS, version 23 (SPSS Inc., Armonk, NY, USA) for the result of mean, standard deviation, minimum, maximum, and 5$^{th}$, 50$^{th}$, and 95$^{th}$ percentiles.

For accurate, ergonomically designed chairs and a suitable design for students, it was essential to take the following dimensions of the students and chairs according to anthropometric parameters. The use of percentile is necessary to fix the standard dimension of chairs and links with the anthropometric dimension. In this study, the combinational equations developed by Gouvali and Boudolos were used to assess chair standards and also helped recognize the supreme and the most diminutive dimensions of the chairs [12-14] (**Table 1**).

## Results

In this study, 383 students were selected, of which 221 were male and 162 were female. The students' mean age was 24.45±1.56 years, mean weight was 60.75±13.2 kg, mean height was 156±4.91 cm and 170.31±6.32 cm in females and males individually. The anthropometric measurements of the male and female students were given in **Table 2A** and **2B**. Moreover, the ROM of different spine segments is shown in **Figure 3**. The anthropometric dimensions of chairs used in different universities in Multan were also described in **Table 3A**. The standard ergonomics measurements for designing a proper chair corresponding with a more significant percentage of students were given in **Table 3B**.

According to the results, each anthropometric dimension linked with percentile was used to define the standard dimension of the chairs. The standard dimension of chairs was based on the anthropometric dimension of the students and the percentage below or above the dimension of standard limits shown in **Table 1**. In the following study, the 300 chairs' dimensions were assessed. The seat height was not up to the mark of IOS standards. In this study, 6 types of chairs were used for a different assessment: 16.66% for chair 1, 21.66% for chair 2, 18.33% for chair 3, 15% for chair 4, 13.33% for chair 5, and 15% for chair 6. As a result, various things cause problems for students, such as seat height, seat depth, seat width, backrest height, and desk height. The height of chairs 3 and 4 was unacceptable because this may disturb the shoulder. After all, it restricted the shoulder's joint movement, leading to muscle spasms, stiffness, and pain, resulting in muscle impairment. According to the 5$^{th}$ percentile, the shoulder height was 44 cm in male and female students. The 95$^{th}$ percentile of shoulder height was 59 cm in both genders. The mean and standard deviation was

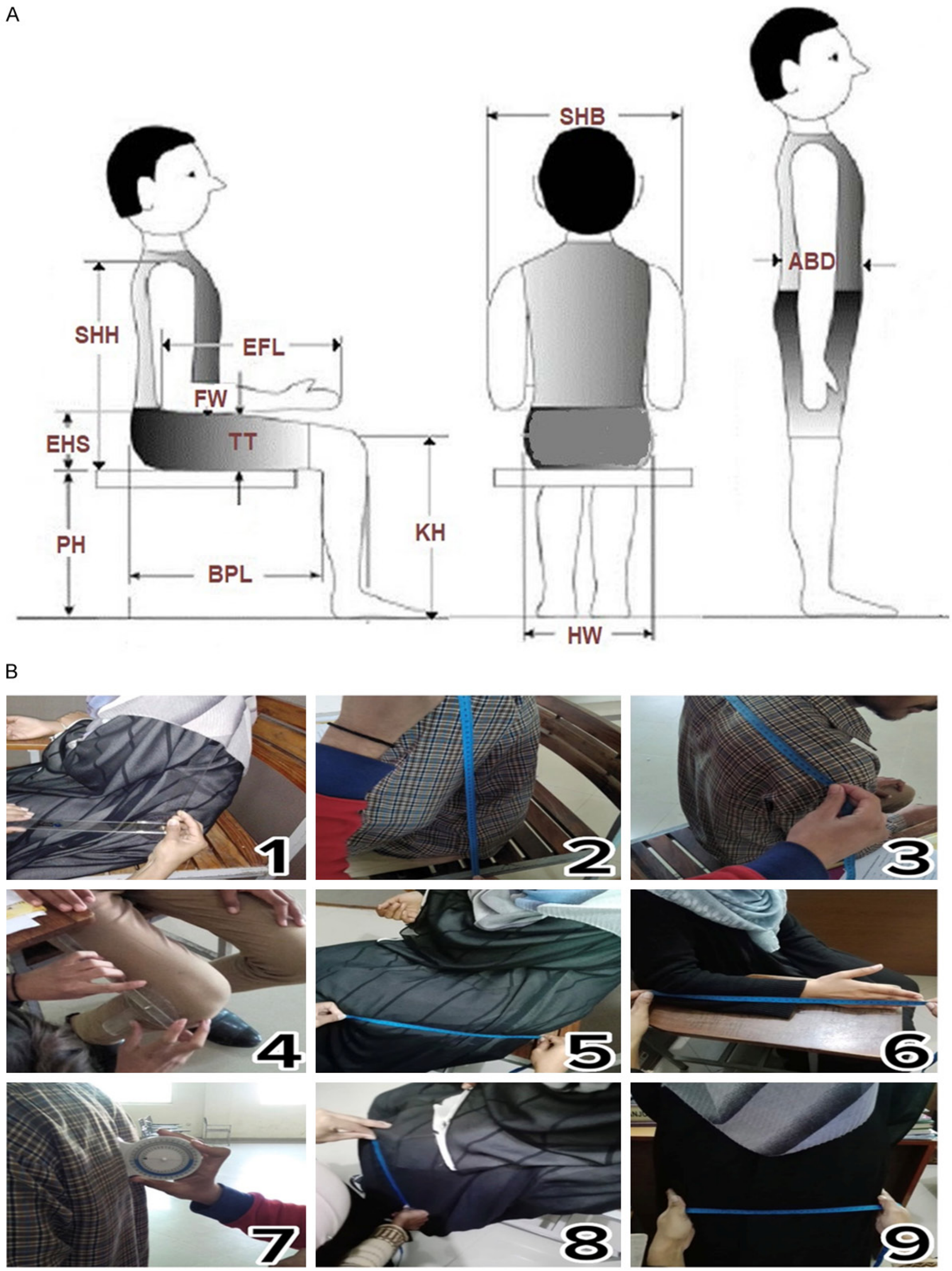


**Figure 1.** A. Anthropometric dimensions of the students. SHH: shoulder height; EHS: elbow height sitting; SHB: shoulder breadth; PH: popliteal height; KH: knee height; HW: hip width; EFL: elbow-fingertip length; BPL: buttock-popliteal length; ABD: abdominal depth; FW: forearm width; TT: thigh thickness. B. Photographic representation of methodology used for students' anthropometric measurements.

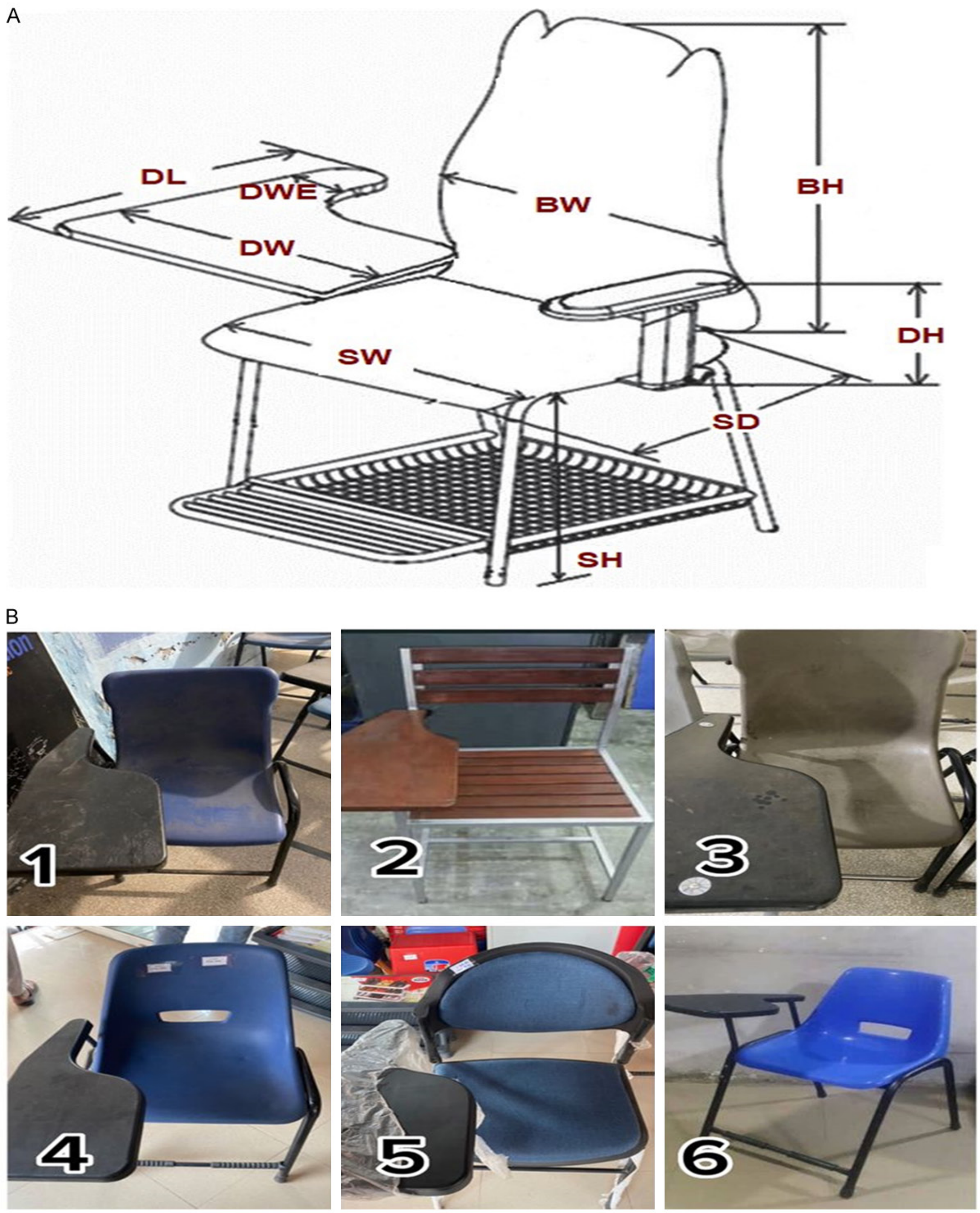


**Figure 2.** A. Dimensions of the classroom chairs. SH: seat height; SD: seat depth; SW: seat width; DH: desk height; DWE: armrest width elbow; DW: desk width; DL: desk length; BW: backrest width; BH: backrest height. B. Different types of classroom chairs were used in the study.

51.280±5.71888 cm in males, with a slight difference in females, which was 51.3889± 5.70414 cm.

The remaining chairs 1, 2, 4, and 6 met the standard requirements. Chairs 3 and 5 were suitable for the seat depth and did not cause any problems for students, but chairs 1, 2, 4, and 6 differed from the IOS standard. Chair 1 and 6 were lesser than the acceptable limits, while other chairs 2 and 4 were more significant than the limits, resulting in pain and pres-

**Table 1.** Combinational equations to determine the minimum and maximum acceptable dimensions of chairs

| | | |
|---|---|---|
| DH | E + [(p+2) cos30°] ≤ D ≤ [(p+2) cos5°] + (E0.8517) + (S0.1483) | EHS |
| BH | 0.6S ≤ B ≤ 0.8S | SHS |
| SW | 1.1H ≤ SW ≤ 1.30H | HW |
| SD | 0.8PB ≤ SD ≤ 0.89PB | PB |
| SH | (p+2) cos30° ≤ SH ≤ (p+2) cos5° | PH |

DH: desk height; BH: backrest height; SW: seat width; SD: seat depth; SH: seat height; DL: desk length; EHS: elbow height sitting; SHS: shoulder height sitting; HW: hip width; PB: popliteal to buttock length; PH: popliteal height.

**Table 2A.** The anthropometric measurement of the male students

| Male | Mean ± Standard Deviation | $5^{th}$ percentile | $50^{th}$ percentile | $95^{th}$ percentile |
|---|---|---|---|---|
| SHH | 51.280±5.71888 | 44.0000 | 51.0000 | 59.0000 |
| SHB | 40.1991±7.37848 | 19.1000 | 43.0000 | 48.0000 |
| KH | 49.5973±4.60294 | 41.1000 | 50.0000 | 57.0000 |
| EFL | 46.1538±4.89655 | 39.0000 | 46.0000 | 55.0000 |
| ABD | 16.3937±6.04181 | 9.0000 | 15.0000 | 25.0000 |
| TT | 12.4525±3.72019 | 6.0000 | 12.0000 | 19.0000 |
| KA | 96.7738±17.43595 | 70.0000 | 95.0000 | 125.0000 |
| EHS | 44.9683±7.48011 | 11.0000 | 17.0000 | 40.0000 |
| PH | 44.9683±5.44592 | 38.1000 | 46.0000 | 51.0000 |
| HW | 39.1584±5.97398 | 31.0000 | 40.0000 | 49.0000 |
| BPL | 43.1719±4.51737 | 36.0000 | 43.0000 | 51.0000 |
| FW | 7.4027±1.52429 | 5.0000 | 7.0000 | 10.0000 |
| HA | 98.1900±15.73676 | 65.0000 | 100.0000 | 120.0000 |

SHH: shoulder height; SHB: shoulder breadth; KH: knee height; EFL: elbow-fingertip length; ABD: abdominal depth; TT: thigh thickness; KA: knee angle sitting; EHS: elbow height sitting; PH: popliteal height; HW: hip width; BPL: buttock-popliteal length; FW: forearm width; HA: hip angle sitting. All dimensions were in cm and angles in degrees.

**Table 2B.** The anthropometric measurement of the female students

| Female | Mean ± Standard deviation | $5^{th}$ percentile | $50^{th}$ percentile | $95^{th}$ percentile |
|---|---|---|---|---|
| SHH | 51.3889±5.70414 | 44.0000 | 51.5000 | 59.0000 |
| SHB | 40.4877±7.03870 | 20.0000 | 43.0000 | 48.0000 |
| KH | 49.8457±4.46320 | 42.1500 | 50.0000 | 57.0000 |
| EFL | 46.3333±4.96322 | 39.0000 | 46.0000 | 55.8500 |
| ABD | 16.4259±6.15111 | 9.0000 | 15.0000 | 26.0000 |
| TT | 12.5247±3.62222 | 6.0000 | 12.0000 | 19.0000 |
| KA | 96.9815±17.66826 | 70.0000 | 95.0000 | 125.0000 |
| EHS | 19.3148±7.54240 | 11.0000 | 17.0000 | 40.0000 |
| PH | 45.0432±5.48442 | 38.1500 | 46.0000 | 51.0000 |
| HW | 38.9259±6.03052 | 31.0000 | 39.0000 | 49.0000 |
| BPL | 43.0185±4.72797 | 36.0000 | 43.0000 | 51.0000 |
| FW | 7.3765±7.3765 | 5.0000 | 7.0000 | 10.0000 |
| HA | 98.4568±16.02835 | 100.0000 | 100.0000 | 120.0000 |

SHH: shoulder height; SHB: shoulder breadth; KH: knee height; EFL: elbow-fingertip length; ABD: abdominal depth; TT: thigh thickness; KA: knee angle sitting; EHS: elbow height sitting; PH: popliteal height; HW: hip width; BPL: buttock-popliteal length; FW: forearm width; HA: hip angle sitting. All dimensions were in cm and angles in degrees.

sure on the posterior side of the thigh while sitting on the chair. The seat width of chair 2 was not causing discomfort in students but was more significant than acceptable limits.

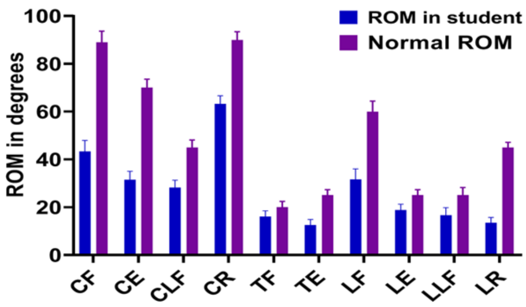


**Figure 3.** The normal range of motion of different segments of the spine compared with university students. ROM: range of motion; CF: cervical flexion; CE: cervical extension; CLF: cervical lateral flexion; CR: cervical rotation; TF: thoracic flexion; TE: thoracic extension; LF: lumber flexion; LE: lumber extension; LLF: lumber lateral flexion; LR: lumber rotation.

However, chairs 1, 3, 4, 5, and 6 were the best for the seat width. Chair 3 and 6 were most suitable in the following chairs and did not even cause any discomfort for students. Chair 3 and 6 had the highest fitness in terms of desk height, and then, respectively, chairs 1, 2, and 4 were the better options for desk height. The chair 6 had greater desk height than the limit, so it was not in the acceptable range. Chairs 3, 2, and 5 had the highest fitness for the backrest height and were according to the standard limits. These chairs also do not cause any discomfort. The other chairs 1, 4, and 6 were ranked respectively, but these chairs had lower backrest height than the standard requirements. So, these chairs cause pain in the scapular region and restrict motion.

## Discussion

The anthropometric measurements of students were performed by sitting on chairs for ergonomic dimensions of chairs. Because this study found that none of the chairs was suitable for the students' anthropometric dimensions. In the following study, the seat height of the ideal chair was the popliteal height in the 5$^{th}$ percentile; the seat height of chairs differed from that examined. It helps the short students who cannot touch their feet to the ground; using the 5$^{th}$ percentile of popliteal height seat chairs, they can easily rest their feet on the ground. Therefore, the ergonomically designed chairs should be based on the 5$^{th}$ percentile. The ideal seat height is 33 cm, which is consistent with the result of the study [12, 15]. This study found that seat height was higher than the ideal chair seat height, and it could be designed on the 95$^{th}$ or 50$^{th}$ percentile, which was not according to the students' dimensions. The statement of students, especially girls, showed that they could not place their feet on the ground even when wearing shoes or heels of 3-4 cm. It leads to musculoskeletal deformities and tremendous pressure or pain on the anterior or posterior parts of the legs and causes a decrease in blood supply to the lower extremities. It also exerts an extra load on the hip joint [13, 16].

In this study, the seat depth was calculated at 36 cm based on the 5$^{th}$ percentile of the buttock-popliteal length. Previous studies described the seat depth to be 40.9 cm. Some studies found that the dimension should be higher than the result [12, 17]. This study found that chair number 5 matched the standardized seat depth dimension. This study also found that chairs 1, 2, and 6 have the worst seat depth dimension, affecting body posture or musculoskeletal pain, resulting in bending of the trunk and head and radiating in the arm forward and involving shoulder, arm, and back pain. High seat depth can lead to pressure on the anterior or posterior thighs and affect the blood supply to the following areas. On the other hand, a low dimension of seat depth involved pressure on the back and knee to avoid falling [18].

The typical seat depth was determined based on the 95$^{th}$ percentile of the hip width. In a recent study, previous researchers found these dimensions to be between 30.03 cm and 41 cm, less than 43.55 cm. This difference was found due to the number of students participating and the dimensions of the students being different, the other difference was that the females have a wider hip width. Previous studies indicated that seat width was 43 cm and 43.6 cm [19]. In the following study, chairs 3, 4, and 6 were the best seat width options compared to chairs 1, 2, and 5. They were not according to anthropometric data of seat width. Chair number 2 could have been better than the other. Using this chair, students had many issues with hip bone or muscle. The following issues were extra loading on the hips and pressure on the sides of the thighs.

Elbow height was used to define the height of the desk. It might be because sitting on a chair

**Table 3A.** Dimensions of the commonly used chairs in different universities of Multan

| Dimensions | Chair 1 | Chair 2 | Chair 3 | Chair 4 | Chair 5 | Chair 6 |
|---|---|---|---|---|---|---|
| SH | 45 | 45 | 48 | 50 | 45 | 43 |
| SW | 42 | 48 | 45 | 44 | 42 | 45 |
| DWE | 7 | 9 | 7 | 7 | 7 | 6 |
| DL | 56 | 49 | 58 | 56 | 56 | 56 |
| BH | 36 | 41 | 40 | 38 | 42 | 37 |
| SPD | 6 | 0 | 7 | 5 | 2 | 5 |
| SD | 39 | 48 | 40 | 45 | 43 | 34 |
| DH | 20 | 21 | 22 | 20 | 29 | 22 |
| DWE | 24 | 21 | 25 | 24 | 24 | 24 |
| BW | 39 | 47 | 43 | 39 | 46 | 38 |
| BD | 9 | 4 | 7 | 7 | 10 | 4 |

SH: seat height; SW: seat width; DW: desk width; DL: desk length; BH: backrest height; SPD: seat pan depth; SD: seat depth; DH: desk height; DWE: armrest width elbow; BW: backrest width; BD: backrest depth. All dimensions were in cm.

**Table 3B.** The recommended ergonomics measurement of the chair dimension

| Chair dimension | Anthropometric parameters | Criteria determinant | Design dimension |
|---|---|---|---|
| SH | PH | 5$^{th}$ percentile of female popliteal height | 33.2 |
| SD | BPL | 5$^{th}$ percentile of female buttock popliteal length | 42.0 |
| DH | HW | 95$^{th}$ percentile of female hip width | 24.5 |
| SW | EH | 50$^{th}$ of all elbow height | 43.6 |
| DW | FW | 95$^{th}$ percentile of male forearm width | 95.0 |
| DL | EFL | 95$^{th}$ percentile of male elbow fingertip length | 51.1 |
| BW | SHB | 95$^{th}$ percentile of male shoulder breadth | 42.6 |
| BH | SH | 5$^{th}$ percentile of female shoulder height | 55.8 |

SH: seat height; SD: seat depth; SW: seat width; DH: desk height; DW: desk width; DL: desk length; BW: backrest width; BH: backrest height; SHH: shoulder height; EHS: elbow height sitting; SHB: shoulder breadth; PH: popliteal height; HW: hip width; EFL: elbow-fingertip length; BPL: buttock-popliteal length; ABD: abdominal depth; FW: forearm width. All dimensions were in cm.

or working with one hand consistently resulted in neck or shoulder problems. During this study, the calculated desk height was 29 cm. It was higher than the dimension of 22.9 cm in the previous studies [20]. Differences in the dimensions in countries may occur in people due to their physiques. There was less difference in desk height in chairs number 1, 2, 3, 4, and 6 were less in height of desk than chair 5. This results in shoulder or neck pain, leading to elevation of the hands during writing and causing muscle fatigue and tension or pressure on the shoulder muscles. It resulted in the difference between elbow height sitting and desk length, leading to shoulder or neck pain [21]. In this study, the calculated elbow sitting height was 19.1 cm. The desk height of chairs 3 and 6 was more comfortable than those 1, 4, and 5. The desk height of chairs 1 and 4 was low, which caused the bending of the upper limb during working or writing, resulting in pain in the neck, shoulder, elbow, and arms or postural problems among the students. In research, the desk height of wooden chairs was only fitted to males, and plastic chairs were only fitted to females. Therefore, it is needed to solve the problem of desk height or elbow sitting height. Chair numbers 3 and 6 were more suitable based on combinational equations, and other chairs were less suited to the students. In a previous study, the height of the chair's desk was fitted for 23% of the students' anthropometric dimension [22].

According to previous studies, there should be a minimum of 2 cm between the top of one's thigh and the underneath of the desk for comfort [23]. Not all the chairs fit 100% of the space below the desk. However, only chairs 3 and 6 were slightly better than the rest. With other chairs, the problem was that the students could not move their legs because the thighs of the students were in contact with the desk. It led to muscle spasms due to restricted movement and the continued static position of the legs.

For the measurement of the parallel distance between all kinds of chairs and students, this study used the abdominal depth dimension in the 95$^{th}$ percentile. For obese students, this caused several problems, and chair number 1 or 4 was problematic for high abdominal depth students because the parallel distance was low. Only chair number 5 had no problem for the obese or high abdominal depth students. The chair desk width was measured on the base of the 95$^{th}$ percentile, and it should be according to the width of the forearm. After measurement, this study found that chair number 6 was less in width, which led to pain in the elbow and forearm when the students were writing or learning.

The desk length was considered 50 cm according to a study and also told that the students' dimensions or seat dimensions were only matched in desk length [24]. The following study found that desk length in chairs 1, 3, 4, 5, and 6 was more significant than required, so these chairs were unsuitable and caused problems. However, contradictory results were found in the previous studies. This contradiction was due to the difference in the dimensions and percentile used in this study because they used the 50$^{th}$ percentile of elbow-fingertip length and buttock-popliteal length [12, 25].

The shoulder width of the students was compared with the backrest width by the 95$^{th}$ percentile. The dimension was lower than the standard chair, resulting in shoulder or scapular pain. Therefore, the backrest should be designed to support the shoulder and should be 60 to 80% according to the shoulder height. It should be adjusted according to the shoulder so that the backrest does not restrict the motion of the shoulder region. The 5$^{th}$ percentile was used, which allows movement in the arms or waist. According to a previous study, the backrest height was more appropriate if the backrest height was less than the shoulder height and lower than the scapula [26]. According to the standard, the minimum or maximum acceptable limits of backrest height were between 36.3 cm and 48.4 cm, according to the study by Gouvali and Boudolos [13, 27]. It might become perfect for students if the backrest height is lower than the shoulder or scapula height. In this study, chairs 1, 4, and 6 were in the minimum range, and chairs 2 and 5 were better for the students.

In sitting, the spine has different postural positions and different kinds of pressure transferred to the specific position. There are three types of sitting: anterior, posterior, and middle. So, in this study, different segments of the spine, like cervical, thoracic, lumbar, and sacrococcygeal were studied. Most of the chairs used in this study had backrest curves for the thoracic region. If this curve increased from the standard, it might lead to increased stretch of muscles and ligaments, resulting in mechanical deformities of the thoracic spine [28]. So, most students were suffering from an increased thoracic spine curve known as kyphosis. In this study, chairs 2 and 6 were suitable according to standard measurements, and chairs 3 and 4 were higher than standard measurements and caused increased pressure on the thoracic spine. However, chairs number 1 and 5 were worse than usual. So, these things must be clear for the safety of the students. Most of the chairs used in this study had no cervical and lumber support, which resulted in increased stress on muscles and ligaments around the cervical and lumber spine and caused a decrease in normal cervical and lumber curvature of the spine and caused pain in these regions [10, 29, 30]. So, none of the chairs used in different universities was suitable for cervical and lumber regions. The lumbar region analysis showed a considerable difference in the spine's mobility. There was hypomobility found in the lumbar spine region of students that was occurring from prolonged sitting on chairs. Lumber extension was not much affected as compared to lumbar flexion. The main work of the coccyx is to support while sitting. The most common causes of coccydynia were overweight, outer or inner injury, degeneration of the vertebral disc, and coccyx spicule. Other causes of it included poor muscular function of the pelvic floor or long continuous strain on the coccygeal ligament. One of the pathogeneses of coccydynia is also coccygeal mobility.

During the dynamic radiographic examination, the normal coccyx flexion mobility in standing or sitting has been between 5° to 25°. The hypermobility of coccygeal flexion surpasses 25° in sitting, or the same as the immobility of this joint was below 5° in sitting.

When students with spicule sit longer with lousy posture, they disturb the coccyx bone, which may move inward or outward, causing pain in sitting or affecting the daily activities associated with the coccyx bone. In this study, coccygodynia was happening due to the un-ergonomically designed chair and its seat pan depth of the seat [11]. Mainly, chairs made of wood or plastic are used in education sectors, which cannot be pressed down during sitting. In this study, 6 types of chairs, chair number 2 was made up of wood, and the seat pan had no pan curve nor the ability to provide cushioning and press down, so they were not suitable for prolonged sitting. So, this chair has the worst effect on the coccyx bone. Chair numbers 1, 3, 4, and 6 were made of plastic and had seat pan curves but could not provide cushioning and press down, so they were also causing the coccygodynia. Chair 5 can press down about 1.5 inches, which is closer to the standard seat pan depth. So, these types of chairs were not causing the coccygodynia. Therefore, it is necessary to modify the students' chair to reduce the stretch pressure on muscles involved in coccygodynia.

In sitting posture, the pelvis has to rotate backward and cause a decline in lumbar lordosis that's undoubtedly affected by the knee and hip angle. Many factors cause the seated posture: the angle of the seat back or the seat's lowest angle and the seat's foam by the height overhead floor or the presence of the armrest [31]. The knee angle is the most common reason for lumbar lordosis. The chairs that incline 110 to 130 degrees the backrest with lumbar supports have lower lumbar disc pressure. A posterior inclination of less than 5 degrees of the seat bottom with an armrest also helps to reduce lumbar disc pressure. To reduce further pressure on translated head posture, an inclination of 110 degrees of the seat backrest is required. According to the results of this study, the mean ± STD of the knee angle was 96.87 degrees, and the hip angle was 98.32 degrees.

In classrooms, the students sit with a poor posture with cervical flexed and lumber or thoracic region also bend forward. Therefore, the students should be involved in ergonomics programs to prevent musculoskeletal dysfunction. The sitting posture of students can be improved by the anthropometric dimension of students and by designing classroom chairs. The anthropometric or chair dimensions mismatch leads to musculoskeletal disorders [32].

Some subjects were unwilling to take anthropometric measurements, and another social factor, like students' lifestyle, needed to be addressed in this study. The categorization process should be based on more advanced systems and tools to obtain more accurate results. Other different musculoskeletal problems should be addressed in further studies.

## Conclusion

None of the chairs used in different government universities of Multan was related entirely to the anthropometric measurements of the students and the chair's dimensions. The anthropometric measurements of students must be incorporated into the design of chairs to prevent musculoskeletal problems and improve student performance in studies.

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## Disclosure of conflict of interest

None.

## Abbreviations

SHH, shoulder height; SHB, shoulder breadth; KH, knee height; EFL, elbow-fingertip length; ABD, abdominal depth; TT, thigh thickness; KA, knee angle sitting; EHS, elbow height sitting; PH, popliteal height; HW, hip width; BPL, buttock-popliteal length; FW, forearm width; HA, hip angle sitting; SH, seat height; SW, seat width; DW, desk width; DL, desk length; BH, backrest height; SPD, seat pan depth; SD, seat depth; DH, desk height; DWE, armrest width elbow; BW, backrest width; BD, backrest depth; ROM, range of motion; CF, cervical flexion; CE, cervical extension; CLF, cervical lateral flexion; CR, cervical rotation; TF, thoracic flexion; TE, thoracic extension; LF, lumber flexion; LE, lumber extension; LLF, lumber lateral flexion; LR, lumber rotation; IOS, International Organization of Standardization.

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