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CONSIDERATIONS OF ANTHROPOMETRICS IN THE DESIGN OF LECTURE HALL FURNITURE

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Abstract

An anthropometric survey of Federal University of Technology Owerri students was carried out in order to determine the anthropometric data needed for proper design of seats used in the classroom. A total of four hundred students, of different gender and level were involved in the survey and their anthropometric measurement were taken and recorded with the help of anthropometric tools. The anthropometric measurements taken were, Stature, sitting height, sitting shoulder height, Popliteal height, Hip breadth, Elbow rest height, Buttock popliteal length, Buttock knee length, Thigh clearance, Sitting eye height, Shoulder breadth and Knee height. The data obtained were analysed using SPSS, Excel and Minitab statistical packages to get the mean, standard deviation and percentiles. Comparing the dimensions of the existing furniture with the anthropometric measures obtained revealed that the existing furniture are not ergonomically suitable for the students. Using the results of the analysed anthropometric data, a model classroom seat was suggested which takes into consideration the seat height, seat depth, seat width, backrest height, armrest height and backrest angle.

Keywords: Anthropmetrics; Ergonomics; Furniture; Measurement; Lecture hall.

1. Introduction

Anthropometry is the branch of the human sciences that deals with body measurements: particularly with measurements of body size, shape, strength and working capacity. Anthropometric data is used in ergonomics, to fit the workplace, and tools the man, rather than fit the man to the workplace. The aim is to create a conducive working environment for maximum work efficiency and maximum worker health and safety (Johnsen, et al 2004).

In the university, the lecture halls become the work environment for the students and effort has to be made to ensure that it is comfortable and can allow efficient learning. Hence, the school

furniture such as chairs and desks are some of the most important facilities in the university since students spend most of their time using them. Considering the amount of time spent at school and specifically while sitting, it is important that school furniture should suit the students' requirements, and it should also allow for the changing of posture (Savanur, et al 2007). Many researchers have tried to establish theoretical recommendations for the principles that relate school furniture design to students' anthropometry, and some have also attempted to define the "appropriate" dimensions for school furniture based on anthropometric measurements. Also, there have been studies related to school furniture design that have investigated differences in body dimensions due to age and gender. In some countries, there were attempts to design desk and chairs based on anthropometric data (Oyewole, et al, 2010).

Thariq et al (2010) observed that chairs are a very essential part of a learning environment. They opined how seats used in the lecture halls are designed, goes a long way to determining if the students will learn comfortably or not and hence recommended that seats must be made to fit the users.

The basic philosophy of ergonomics is to make any design of furniture to lead to comfortability, physical health, safety, well-being, convenient and bring motive towards studies (Tunay & Melemez, 2008). Students need well-designed furniture due to the incidence that whenever they become confined in an awkward posture while carrying out certain academic activities such as writing, receiving lectures, drawing, reading on desktops, aggravates psychological stress and can impact negatively on the students' performance. According to the study done by Castellucci, et al (2010), a mismatch of seats and the students leads to a drop in the students' learning interest. Also, seats that are poorly designed, especially those that do not consider the anthropometric data of its users, have negative health implications (Metin etal, 2008). This is also buttressed by a study carried out on the anthropometric match in South Africa which it stated that an incorrect body alignment reduces the ability of antigravity muscles to generate torque (Van Niekerk, et al 2013).

It is very essential for an institution of learning to have their own anthropometric measurements regarding students so that it can be used by designers who intend to make ergonomic furniture, for them. This is imperative as it can guarantee comfortability, safety and increased satisfaction level and ultimately reduce Musculoskeletal disorders (MSDs). MSDs are said to be injuries or pain in the joints of the body, muscles, ligaments, tendons, nerves, and structures that support limbs, back and neck. In long run, these MSD which are degenerative diseases and inflammatory conditions can result in pain and impair normal activities of the students (Adu, et al 2014).

Since anthropometric data vary considerably for individuals within a family or a nation and between nations, reliable anthropometric data for a target population are necessary when designing for that population otherwise the product may not be suitable for the users.

Many researchers have proposed numerous methodologies for various furniture designs in the past. Until recently, the design of student chairs has received little or no interest. Ergonomic designs of furniture have been traditionally based on the design of work furniture using the anthropometry and biomechanics of the human body. The main anthropometric measurements that are necessary to determine the dimensions of school furniture that will enable students to maintain correct sitting posture are popliteal height, knee height, buttock to popliteal length and elbow height (Parcells,e

tal 1999). The main anthropometric dimension and specification used in student furniture design is the popliteal height which determines appropriate seat height. In designing a chair to suit a population, the popliteal height is used to ensure that members of the population are able to sit with their feet supported on the floor, and without undue pressure behind the knees. Likewise, comparing the popliteal height of an individual to the seat height of the available chairs can assist in selecting the most suitable size for that individual. Students run the risk of negative effects from poorly designed and ill-fitting furniture, due to prolonged periods of sitting during school. Grimes & Legg, (2004), suggested that the combination of bad posture and poor seating coupled with long periods of immobility can lead to the development of lower back pain. Further, they have stated that with expectations and emphasis (in some sectors) on greater educational achievements, the duration of sitting is likely to increase. An uncomfortable sitting posture can lead to health-related consequences, and also the student's learning interest, even during the most stimulating and interesting lessons. Ayoub, (2000) emphasized the need for the feet to be firmly rested on the floor or foot support in order to prevent the thighs from supporting the weight of the lower leg. Literature shows that providing an optimal design solution with sufficient comfort is an extremely difficult task when a fixed-type chair is used. According to Straker, et al (2006), workstations with adjustable seats are favored, since people differ in size and postural preference. Adjustable chairs are preferred for school students or adults, to promote health and comfort in sitting. Further, he stated that seat height adjustability is the most important element of a workstation and is used the most often.

Robinette & McConville, (1981), urged that a classroom furniture ultimate success depends on how the variations in shape and size of the user population will be accommodated. Toomingas & Gavhed, (2008) conducted a study of call center operators, and concluded that optimal adjustment of the chair may contribute to less frequent neck/scapulae and back pain. Adjustability of school furniture is an important feature in ensuring equal educational opportunities, increased comfort, and decreased incidence of musculoskeletal symptoms. It is stated that a mismatch between thigh length and seat depth is significantly related to general sitting discomfort, and a mismatch in seated elbow height and desk height is significantly related to reported neck and shoulder pain. HIRA, (1980) after investigating fixed-type university chairs, suggested that the seats should be adjustable. Khanam, et al (2006) evaluated fixed-type university furniture, including a mounted desktop chair, and concluded that students preferred the furniture height to be adjustable Many authors have tried to establish theoretical recommendations for the principles that relate school furniture design to children's anthropometry, and some have also attempted to define the ''appropriate'' dimensions for school furniture based on anthropometric measurements. Without proper design, sitting will require greater muscular force and control to maintain stability and equilibrium. This, in turn, results in greater fatigue and discomfort and is likely to lead to poor postural habits as well as neck or back complaints. Instead, a one-size-fits-all philosophy has been adopted in the industry, because such furniture is less costly to manufacture and easier to sell at a lower price, and lessens the inventory problems for manufacturers and schools. Existing designs have basically been unaltered for years. Therefore, there is need for ergonomists to treat the issue of furniture design for students as a necessity and educational institutes/universities should treat the selection of right kind of furniture as social responsibility towards the students' community.

2. Description of Anthropometric Dimensions.

According to (Roebuck,1999), the anthropometric dimensions used when designing a classroom seat are:
1) Stature: Top of the head, standing in erect stretched posture. The vertical distance from the floor to the vertex (i.e. the crown of the head).
2) Sitting height: Top of the head sitting in a normal relaxed posture.
3) Sitting shoulder height: Height of uppermost point on the middle level of the shoulder.
4) Popliteal height: Height of the underside of the thigh immediately behind the knee.
5) Hip breadth: Maximum horizontal distance across the hips.
6) Elbow rest height: Distance between the seat and lowermost part of the elbow.
7) Buttock popliteal length: Horizontal distance from the most posterior point on the uncompressed buttocks to the back of the lower leg at the knee.
8) Buttock knee length: Horizontal distance from the most posterior point on the uncompressed buttocks to most anterior point on the knee.
9) Thigh clearance: The vertical distance from the seat surface to the maximum bulge on the anterior surface of the thigh measured with a shortened anthropometer.
10) Sitting eye height: Height of inner corner of the eye sitting in a normal relaxed posture.
11) Shoulder breadth: Maximum horizontal distance across the shoulders.
12) Knee height: Height of uppermost point on the knee.
13) Back Rest Angle: As noted above, research has shown that the best seated posture is a reclined posture of $100°–110°$. The back rest angle is the angle between the backrest and the seating surface.
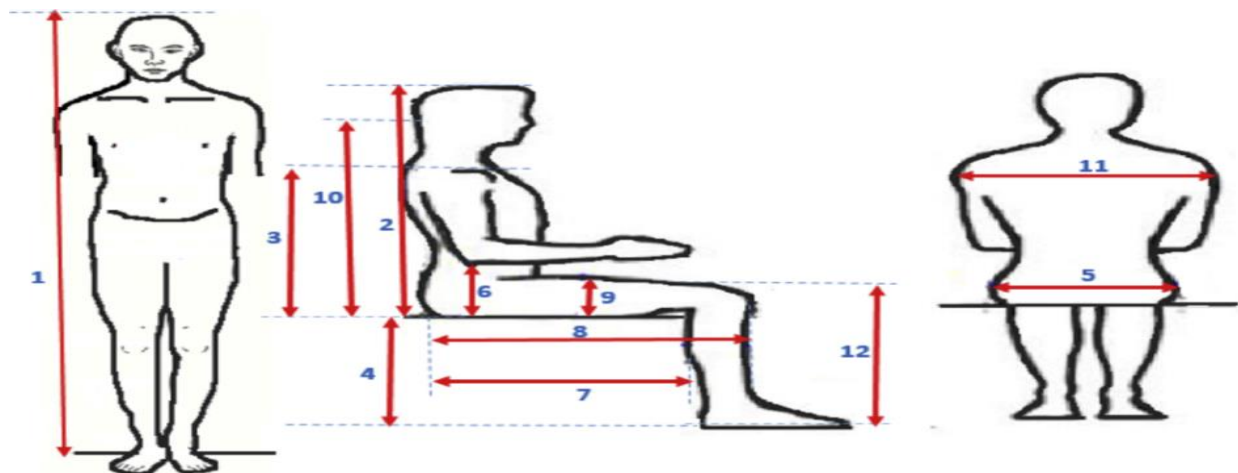

Figure 1: Anthropometric data required in classroom furniture design.

However, actual chair dimensions are determined by measurements of the human body (anthropometric measurements). The two most relevant anthropometric measurement for chair design is the popliteal height and buttock popliteal length.

For someone seated, the popliteal height is the distance from the underside of the foot to the underside of the thigh at the knees. It is sometimes called the "stool height". The term "sitting height" is reserved for the height to the top of the head when seated. The popliteal height, after adjusting for heels, clothing and other issues, is used to determine the height of the chair seat.

For someone seated, the buttock popliteal length is the horizontal distance from the back most part of the buttocks to the back of the lower leg. This anthropometric measurement is used to determine the seat depth.

Additional anthropometric measurements may be relevant to designing a chair. Research has shown that the best seated posture is a reclined posture of 100°–110° Hedge, (2016). Hip breadth is used for chair width and armrest width. Elbow rest height is used to determine the height of the armrests. The buttock-knee length is used to determine "leg room" between rows of chairs. "Seat pitch" is the distance between rows of seats.

3. Materials

In this study the body dimensions were taken using traditional anthropometric tools.

Dimensions were measured using a flexible measuring tape with an accuracy of 0.1 mm, steel ruler for marking the level, non-adjustable plastic chair and plastic ruler. The non-adjustable chair was a plastic seat that had a high back rest for reducing measuring error due to poor gesture of students. It was used to take measurements such as sitting height, shoulder height, etc. Also, the non-adjustable chair had no arm rest which could hinder elbow rest height measurement. The backrest and seat were lined up at right angle to each other and the seat acted as reference point during measurements taking especially in the sitting position. The students' height (stature) was measured using a wall mounted straight ruler with measuring tape attached to it while calibrated in centimeters.

The materials used are:
- **A Flexible Measuring Tape:** This was used to measure the bodily dimensions.
- **Non-adjustable Plastic Chair:** This was used to make the subjects sit while measurements were being taken.
- **Vernier Calliper (Range 0-300mm with error 0.1mm):** This was used to measure the thigh clearance.
- **SPSS:** used to carry out statistical analysis of the recorded data.
- **Minitab:** used to carry out statistical analysis of the recorded data.
- **Microsoft Excel:** used to record the data.
- **Autodesk Inventor:** used to design the seat model.

3.1. Methods

To carry out this research, different anthropometric measures of the students were taken by adopting proper definitions and standard measuring techniques. 400 students from the Federal University of Technology Owerri were selected to participate in the research. They were randomly drawn from amongst the first through final year students of the institution.

The body size of each student was assessed using standard anthropometric measurement techniques based on study. All anthropometric measures were taken with the subjects wearing their clothes and shoes but as they were dressed for lectures. Measurements were taken every lecture day for 18 days altogether and were done on a level floor in the lecture halls of the subjects in the

institution. When measuring body dimensions under sitting condition, the subjects were asked to sit in such a way that the upper leg and lower leg remained at right angle to each other. To ensure accuracy and repeatability of measurement, there was practice prior to the data collection session. The measuring instruments were passed through trial runs. The measurements during the trial runs were checked for consistency and accuracy. Also recorded with the measurements are the information regarding the subject's level in the university and sex.

3.2. Data Analysis

The collated data were analysed statistically using SPSS 16.0, Minitab and Microsoft Excel (2007) programs. From the anthropometric data, its average, minimum, maximum, variance, standard deviation, 5th percentile, 50th percentile and 95th percentile was extracted. Results of the analysis are shown in Table 1 and Table 2. Only specific parts of the analysed data were used in the design of the classroom furniture. It is worth noting that not all the anthropometric measures are considered in the design of a model classroom seat.

4.   Results and Discussion

4.1. Results

The results obtained from the analysis of the collected data with SPSS, EXCEL and MINTAB software were presented on figures 3 and 4 as well as tables 1 to 5.

Figure 3 shows the results of the frequency for the major anthropometric parameters while figure 4 presents a bar chart of frequency of the measured parameters.

Tables 1, 2 and 3 shows the descriptive statistics, the percentiles analysis and the average values of the measured parameters. Table 4 show the selected parameters for the suggested ergonomically suited model seat for the students in Federal University of Technology Owerri, and table 5 is the comparison of the data obtained with that of existing classroom seats.
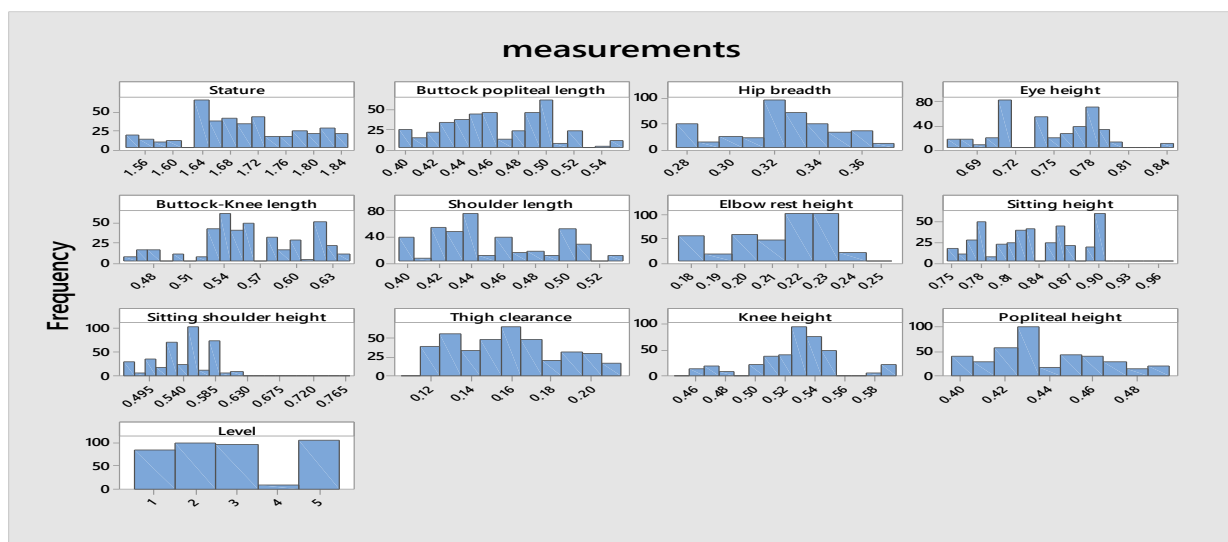

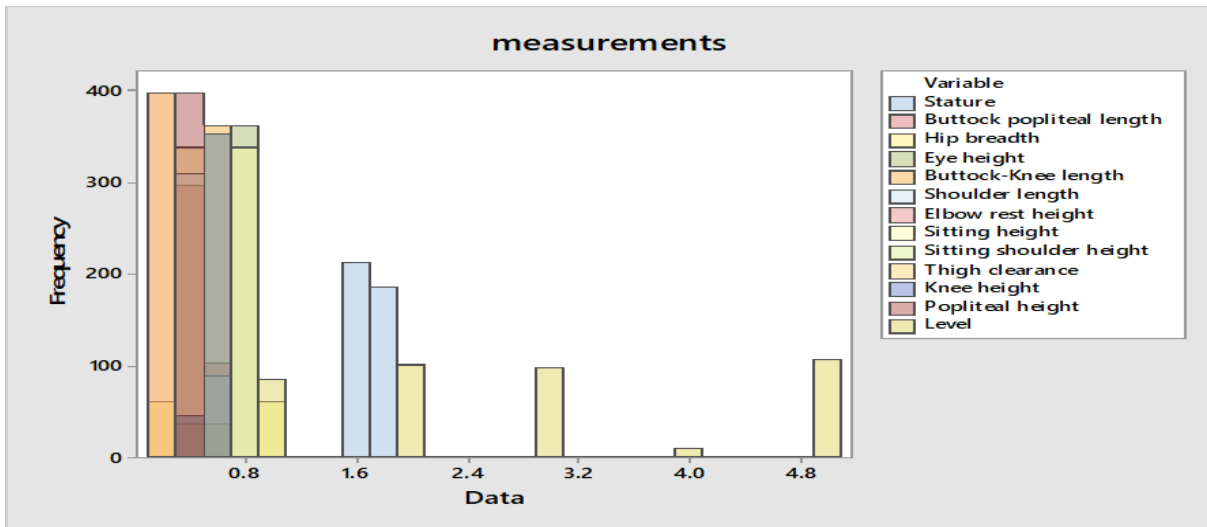Figure 3: A diagram showing the outcome of the frequency analysis

Figure 4: Bar chart of Frequency against Measurement

Table 1 shows the descriptive statistics of the recorded data. These descriptive statistics include the mean, standard deviation, variance, sum, minimum, maximum and range of the entire data collated.

Table 1: Descriptive statistics of the recorded data.

Variable	Mean	St. Dev.	Variance	Sum	Min	Median	Max	Range
Stature	1.6934	0.0796	0.00633	673.9700	1.5400	1.6900	1.8400	0.3000
Buttock popliteal length	0.46495	0.03632	0.00132	185.0500	0.40000	0.46000	0.55000	0.15000
Hip breadth	0.32377	0.02414	0.00058	128.8600	0.28000	0.32000	0.37000	0.09000
Eye height	0.74598	0.03908	0.00153	296.9000	0.67000	0.75000	0.84000	0.17000
Buttock-Knee length	0.56136	0.04475	0.00200	223.4200	0.46000	0.56000	0.64000	0.18000
Shoulder length	0.45249	0.03567	0.00127	180.0900	0.40000	0.44000	0.53000	0.13000
Elbow rest height	0.21304	0.01790	0.00032	84.79000	0.18000	0.22000	0.25000	0.07000
Sitting height	0.83065	0.04687	0.00220	330.6000	0.75000	0.83000	0.97000	0.22000
Sitting shoulder height	0.54354	0.03803	0.00145	216.3300	0.46000	0.55000	0.77000	0.31000
Thigh clearance	0.15867	0.02613	0.00068	63.15000	0.11000	0.16000	0.21000	0.10000
Knee height	0.52678	0.02883	0.00083	209.6600	0.45000	0.53000	0.59000	0.14000
Popliteal height	0.43786	0.02498	0.00062	174.2700	0.40000	0.43000	0.49000	0.09000

Also, the percentile analysis of the recorded data is shown in Table 2. This percentile analysis took into cognizance, the 5th, 50th and 95th percentile. The percentile analysis is considered in this research in order to accommodate as much persons in the population group as possible.

Table 2: Percentile analysis of the recorded data

Variable	5th Percentile	50th Percentile	95th Percentile
Stature	1.5500	1.6900	1.8300
Buttock popliteal length	0.4000	0.4600	0.5200

Hip breadth	0.2800	0.3200	0.3600
Eye height	0.6800	0.7500	0.8000
Buttock-Knee lengths	0.4700	0.5600	0.6300
Shoulder length	0.4000	0.4400	0.5100
Elbow rest height	0.1800	0.2200	0.2400
Sitting height	0.7600	0.8300	0.9000
Sitting shoulder height	0.4700	0.5500	0.5900
Thigh clearance	0.1200	0.1600	0.2000
Knee height	0.4700	0.5300	0.5900
Popliteal height	0.4000	0.4300	0.4900

Following the results above, Table 3 below gives a summary of the anthropometric measures based on the average of the collated anthropometric data, which can be used in designing a seat for FUTO students:

Table 3: Average of the anthropometric measures

Stature	1.6934
Buttock popliteal length	0.46495
Hip breadth	0.32377
Eye height	0.74598
Buttock-Knee length	0.56136
Shoulder length	0.45249
Elbow rest height	0.21304
Sitting height	0.83065
Sitting shoulder height	0.54354
Thigh clearance	0.15867
Knee height	0.52678
Popliteal height	0.43786

Table 4: Table showing the values selected and the criteria

Seat feature	Anthropometric measure	Design Value	Criteria/Determinant
Seat Height	Popliteal length	0.438 metres	Average of popliteal height
Seat Width	Hip breadth	0.360 metres	95th percentile of hip breadth
Seat Depth	Buttock-popliteal length	0.400 metres	5th percentile of buttock-popliteal length
Back rest width	Hip breadth	0.360 metres	95th percentile of hip breadth
Upper seat backrest height	Sitting shoulder height	0.544 metres	Average of sitting shoulder height
Armrest height/Lower backrest height	Elbow rest height	0.180 metres	5th percentile of elbow rest height
Backrest angle		110 degrees	Literature review suggestion

As noted in the introduction to this project work, a survey was carried out on the existing seats in the Federal University of Technology Owerri. In the table below, the results from the survey is listed and compared against the values for the proposed ergonomic seat.

Table 5: Comparism of existing seat against ergonomically designed seat.

Seat feature	Value from the existing seat (m)	Value from the ergonomically designed seat (m)
Seat Height	0.400	0.438
Seat Width	0.450	0.360
Seat Depth	0.430	0.400
Back rest width	0.450	0.360
Upper seat backrest height	0.470	0.544
Armrest height/Lower backrest height	0.230	0.180
Backrest angle	90 degrees	110 degrees
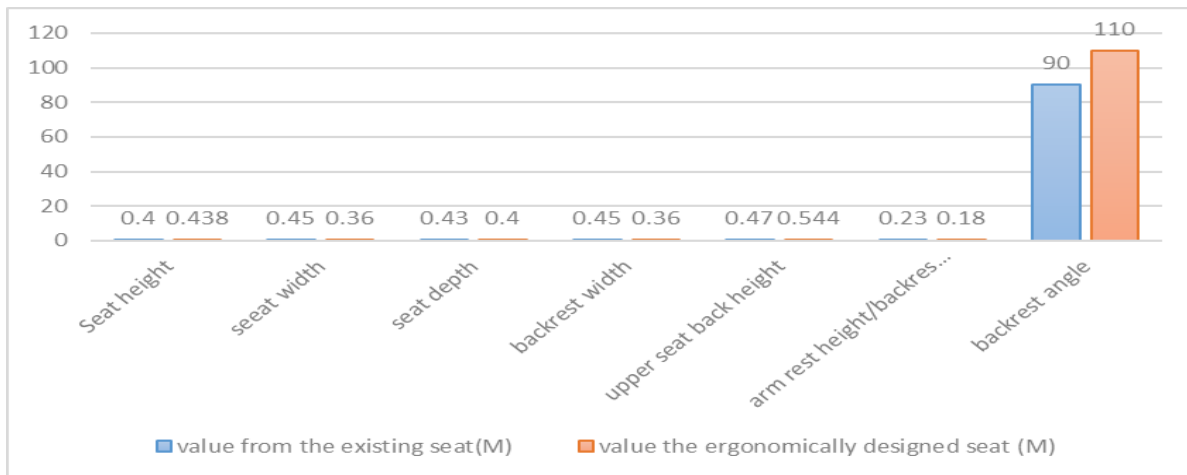
Figure 5: Comparison of existing seat against ergonomically designed seat.

After running the analysis of the recorded data, the model was designed using Autodesk Inventor software with the values and criteria in Table 4. Figure 6 shows the diagrammatic view of the model seat. Also, figure 7 shows the orthographic projection of the model seat and figure 8 shows the exploded view of the seat model.

4.2. Discussion

From the analysed results, the anthropometric dimensions for the model classroom seats are presented. The 5th, 50th and 95th percentiles of the various body dimensions as presented in table 2 are considered in the selection of the design values to be used in the model classroom seat design.

4.3. Considerations for Anthropometric Dimensions for the Design of the Model Classroom Seat.

Seat Height
The popliteal height is considered in the design of seat height especially for a seat that cannot be adjusted. The 5th percentile is considered as the maximum seat height allowable. This is to accommodate a larger number of students and give room for short students to use the seat comfortably for a long period of time without being exposed to any health related risk. In this research the 5th percentile for the popliteal height is 0.400 meters., but the average of the

percentiles is taken to take care of the shoe clearance. Hence 0.438 Meters is used in the design of the seat height.

Seat Depth

In the design of the seat width, the anthropometric dimension considered is the buttock – popliteal length. The 5th percentile of the buttock – popliteal length is considered to accommodate the shortest user. However, 0.400 Meter is selected seat depth.

Seat Width

The hip breath is used to determine the seat width. The seat width should be wide enough to accommodate very fat students with their hips and clothing. It should also allow the students to use the seat arms comfortably. The 95th percentile of the seat breath is considered for the design of seat width. For this research, 0.36 Meter is considered.

Arm Rest Angle Height

The elbow height is considered in the design of the arm rest height. The   5th percentile of the elbow height is considered in the design of the arm rest height. The arm rest height is 0.18 Meter as shown in table 4.

Back Rest Angle

From available literature, the recommended backrest angle is 110^0.

Upper Back Seat Height

The 5th percentile of the shoulder height is considered in the design of the seat back rest height. 0.544 Meter was considered.
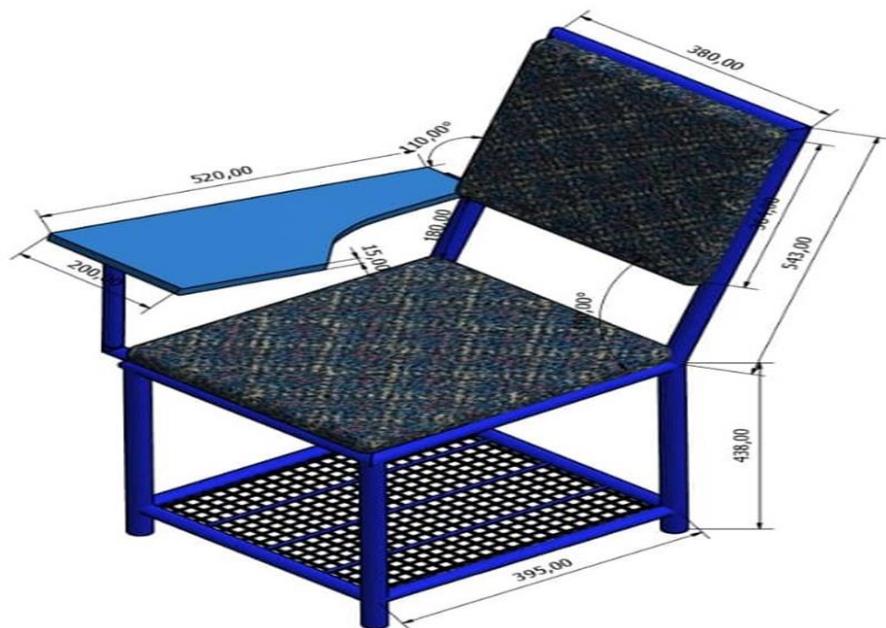

Figure 6: A diagram showing the dimension of the chair based on the average anthropometric data
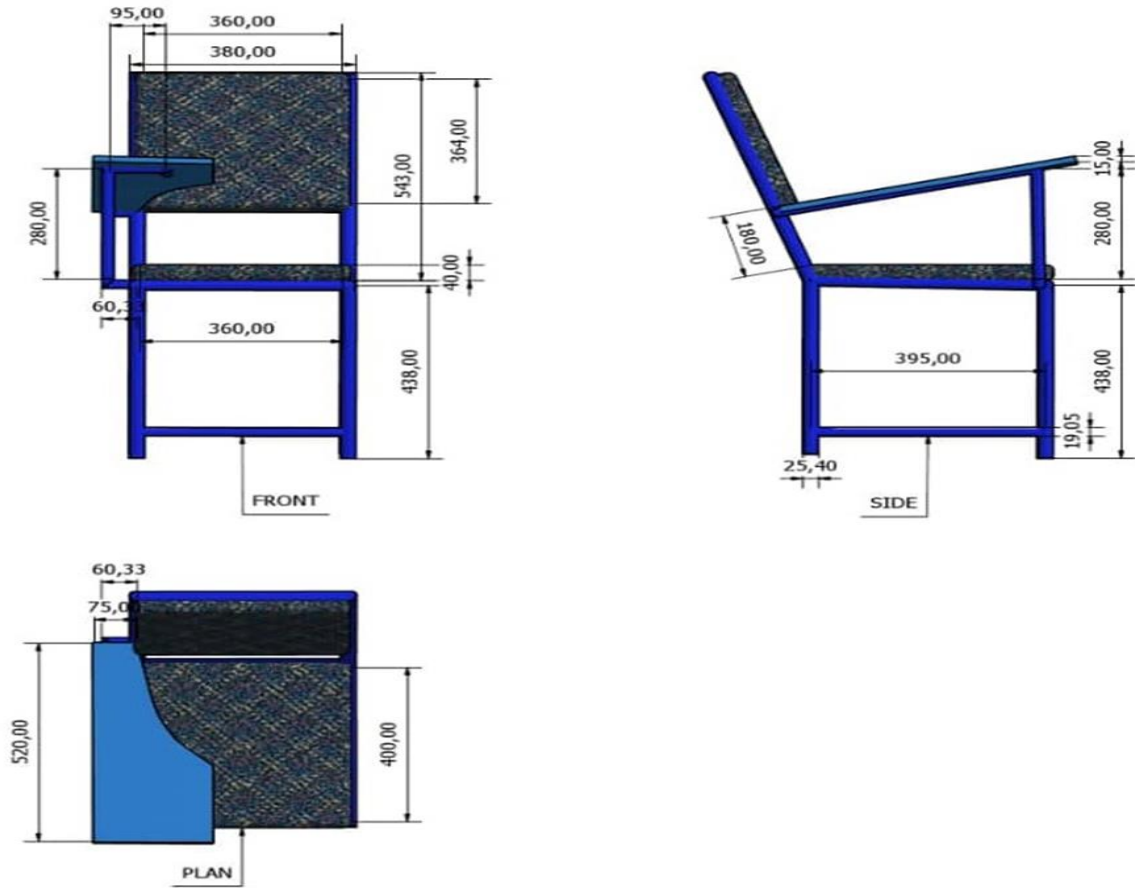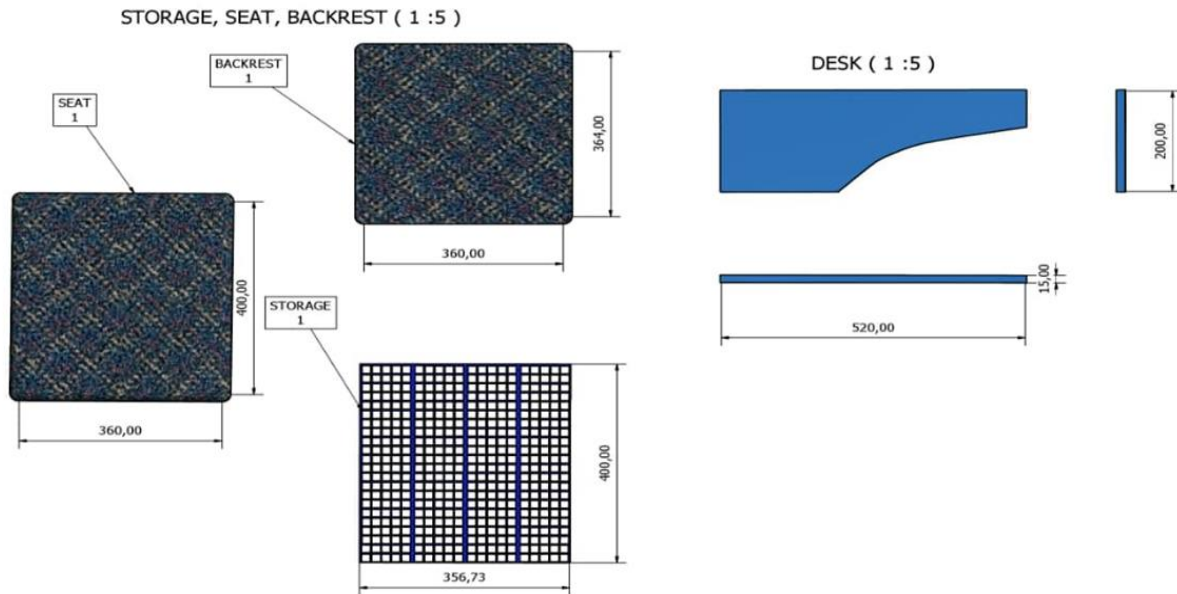
Figure 7: Orthographic projection of the model seat design
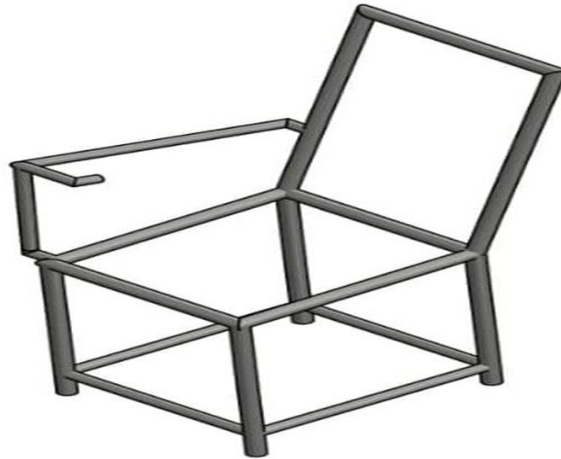

Figure 8: Exploded view of the component par

Figure 9: Conceptual framework of the design analysis

5. Conclusion

This research is necessary to ensure that the comfort of the students is taken into consideration in the design of classroom furniture. From this research, a model classroom seat was designed which is ergonomically suitable for the students in Federal University of Technology Owerri. It is recommended that the analysed anthropometric data from this research be used for the design of classroom furniture for students in Federal University of Technology, Owerri. Achieving this, will ensure safety, comfort, adaptability, suitability, and ultimately guarantee user satisfaction.
The results from this research shows that the existing university furniture is not compatible with the anthropometric measurements of the students because this furniture were designed by manufacturers without proper considerations of the students' anthropometry.

Lastly, it is recommended that similar study should be carried out in other universities in order to have enough anthropometric data for the design of classroom furniture that are ergonomically friendly for all the institutions of higher learning in Nigeria.

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