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Research Article

Anthropometric measures of young Nigerians for ergonomic furniture design

Abstract

Background: Ergonomic furniture design which is based on the application of the anthropometric measurements of the intended users does not only reduce the risk of developing musculoskeletal disorders such as low back pain, but also improves work performance.

Aim: The main aim of this study was to survey and describe Nigerian University students based on important anthropometric measures relevant to ergonomic classroom furniture design.

Method: A total of five hundred and ninety (undergraduate and graduate) students where surveyed using the traditional methods of data capture. The measurement considered were the most important anthropometric features relevant to ergonomic furniture design.

Result: The result of the survey was stratified according to gender and age. Across all age groups, males had higher mean values for anthropometric measurement except for the hip width which was found to be higher in females than in males. When the participants were considered broadly as just males and females without consideration for their age groups, sexual dimorphism was seen to still exist. The males had higher mean values for all the anthropometric measurement except for hip width (males = 30.7±2.7cm; females = 33.9±3.7cm). Dimensions for ergonomic furniture design for the study population was also determined and presented.

Conclusion: The study anthropometrically describes young Nigerians and therefore provides data which can be deployed by furniture designers for ergonomic product manufacture.

Abbreviations

SHH: Shoulder Height; EH: Elbow Height; KH: Knee Height; PH: Popliteal Height; BPL: Buttock–Popliteal Length; HW: Hip Width; TT: Thigh Thickness; STA: Stature; BW: Body Weight

Introduction

The science of ergonomics is aimed at fitting work and environment to the end user such that the ease of use, safety and effectiveness of the user is improved [1]. Anthropometry, one of the oldest tools of ergonomics, is defined as the science which deals with body shapes, sizes, strength and working capacity [2], for the purpose of design [3]. Anthropometric measurements when considered in design, improves usability, creates feeling of comfort and reduces the risk of developing musculoskeletal disorders arising from the use of such designs [4–6]. Sitting is an important part of human daily activity and the use of ill-fitted furniture can mar this experience as well as diminish performance and productivity in those activities that may be carried out in a sitting position [7,8]. Mismatch between students' anthropometric measures and furniture dimensions can affect classroom activities such as writing, reading and typing; causing pain in the back, shoulders, neck, legs and eyes [9–11]. It is for these reasons that classroom furniture should be designed using anthropometric data of the intended users [12]. The need for ergonomic classroom furniture is not only applicable to children alone but in a University environment as well, because repetitive strain injuries which may occur from poor sitting postures not only affect primary school children and teenagers but are also noticeable in college students [13]. Ergonomic designs which suit users and reduce discomfort resulting from use rely on a number of tools one of which is the anthropometric measures of the end-user [1]. Sadly, there is a dearth of information on the ergonomic suitability of educational furniture for students, especially in the higher institutions of learning in Nigeria [14], resulting in a large number of mismatch between anthropometric measures of users and furniture dimensions [15]. The design of

classroom furniture for Nigerian schools with anthropometric measurements obtained from other parts of the world is unacceptable because body composition, size and shape have been reported to differ across races and nations [16].

Therefore, this study aims to survey and anthropometrically describe a student's population in a Nigerian University using measures relevant to ergonomic furniture design.

Materials and Methods

Instruments

Several researchers have reported the existence of 3-D body scanners for making anthropometric measurements; they also report the relative unavailability of such scanners [1,17]. As a result, researchers use the traditional methods for obtaining data. According to studies [11,18], anthropometric data obtained with the use of the traditional methods have been shown to be accurate and reliable as those obtained using some hi-tech equipment. Traditional methods have also been used for similar studies in Nigeria [14,15,19]. An anthropometer was used for taking all measurements of the participants while in sitting position. The standing height (stature) was measured with the use of a stadiometer and all dimensions were recorded in centimetres (cm). The body mass was measured with the use of a calibrated mechanical bathroom scale and recorded in kilograms (kg). The data obtained was collated and analysed using Microsoft excel (2007) and SPSS (version 21).

Data collection

The study was conducted within the Federal University of Technology, Akure, Nigeria. A total of 590 (295 males and 295 females) students were selected by simple random sampling. The purpose of the study was clearly explained to the participants and an informed consent was obtained from each participant. They were all told to present themselves for the measurements in light clothing. The anthropometric dimensions of the students were taken from the right side of each person, while they were sitting in an erect position on a height-adjustable chair with a horizontal surface and had no shoes on them. The knees and elbows were flexed at 90° during the measurements.

Body dimensions

Several researchers have reported that certain anthropometric dimensions are to be considered in ergonomic furniture design. These include popliteal height, buttock-popliteal length, hip width, shoulder height, elbow rest height, thigh thickness and knee height [1,13,20,21]. In addition to these, the present study included stature, body weight and shoulder breadth. The anthropometric dimensions are as defined by ISO 7250 (1996) and reported by [17,22].

Results

The anthropometric measures of the participants in this study are shown in Table 1. The result is presented for males and females as well as for the different age stratification in the study. The combined result of all participants (males and females) in the study is shown in Table 2. The result also includes the 5th, 50th and 95th percentile values of all the measures. The anthropometric measures of all males in the study was also analysed and is presented in Table 3. In addition, the anthropometric measures of all females in the study was also analysed and is as presented in Table 4. The differences in the mean values of the anthropometric measures of the male and female participants in the study are shown in a chart in Figure 1.

Sexual dimorphism in anthropometric measures in young nigerian adults

The results of the study show sexual dimorphism of anthropometric measures. As shown in Table 1, differences exist between the male and female anthropometric measures across the various age stratifications. For participants between 18-21 years of age, the males have higher mean values for anthropometric measures than the females except for the hip width (males = 30.2±2.4cm; female = 33.7±3.8cm). A similar pattern is seen in the next age group, 22-25 years. The anthropometric measures of the males turned out higher than those of the females except elbow heights which were found to be the same (males = 18.0±3.3cm; females = 18.0±4.5cm) and the hip width which was found to be higher in the females (males = 31.0±2.6cm; 34.2±4.0cm). The 26-29 years category did not show a different pattern. The males also had higher mean values except for the hip width (males = 30.4±2.5cm; females = 33.4±3.3cm). The last category was found to be consistent with the previous three categories. The males returned higher values for mean anthropometric measures except for the hip width as in the other age categories (males = 30.4±2.5cm; females = 33.4±3.3cm).

When the overall results for both genders (without stratification into age groups) were considered, the sexual dimorphism in anthropometric measurement was found to still exist. The results are as shown in Tables 3,4 and Figure 1. The males had higher mean values for anthropometric measurement than the females except the hip widths (males = 30.7±2.7cm; females = 33.9±3.7cm). The higher mean hip width values in females can be attributed to enlargement of the hips following puberty; whereas hip enlargement is not a consequence of puberty in males.

Comparison with similar studies

Similar studies have been conducted in Nigeria [14,19] and outside Nigeria [11]. The former study surveyed the anthropometric measures of students at the University of Ibadan, Nigeria [14] and at a publics University in Iran [11] and compared the features with the dimensions of classroom furniture and Library furniture respectively, within the Universities. A third study [19], conducted a similar study within three institutions of higher learning (Moshood Abiola Polytechnic, University of Agriculture, and the Federal college of Education) in Abeokuta with participants aged between 17-27 years. The mean values for the anthropometric measures

Table 1: The anthropometric measures of the participants according to their gender and age stratifications, N = 590.

Age	Anthropometric parameters	Male				Female			
		Min	Max	Median	Mean±SD	Min	Max	Median	Mean±SD
18-20 years n = 188	Shoulder height	46.7	62.0	56.5	56.0±3.7	48.0	60.0	52.0	52.2±2.6
	Elbow height	12.0	25.0	18.0	18.2±3.1	12.5	28.0	16.5	17.3±3.5
	Knee height	43.8	62.5	55.5	55.0±4.1	44.3	59.0	50.0	50.5±3.5
	Popliteal height	38.0	51.5	45.0	45.1±2.8	39.0	47.5	43.2	43.3±2.2
	Buttock-popliteal height	41.5	57.5	48.5	48.8±3.2	41.5	53.0	46.5	46.7±2.4
	Hip width	23.0	35.0	30.5	30.2±2.4	23.0	43.5	34.0	33.7±3.8
	Thigh thickness	10.0	18.0	14.0	13.5±2.1	8.5	19.0	13.0	12.9±1.8
	Shoulder breadth	30.4	47.5	41.8	40.6±4.0	33.0	48.0	39.4	39.5±2.9
	Stature	146.0	190.0	173.0	172.4±7.7	148.0	173.0	162.8	162.6±6.2
	Body weight	48.0	104.0	65.5	65.9±10.2	44.0	80.0	58.5	59.7±9.2
21-23 years n = 176	Shoulder height	44.0	63.0	56.0	56.1±3.8	44.0	60.0	52.0	52.1±3.4
	Elbow height	11.4	24.5	18.0	18.0±3.3	11.0	30.0	17.3	18.0±4.5
	Knee height	45.0	69.0	56.0	56.4±4.1	46.0	60.0	53.0	53.2±3.6
	Popliteal height	40.2	55.0	44.5	44.8±3.0	38.5	48.0	42.9	42.8±2.4
	Buttock-popliteal height	41.5	59.0	48.0	48.3±3.3	40.0	52.5	46.0	46.0±3.1
	Hip width	27.0	38.0	30.0	31.0±2.6	28.0	43.0	34.0	34.2±4.0
	Thigh thickness	9.5	17.0	13.0	12.8±1.9	10.0	18.0	13.0	13.0±2.2
	Shoulder breadth	31.5	49.0	42.0	42.2±3.0	35.0	45.8	39.0	39.0±2.6
	Stature	157.0	188.0	171.0	171.8±6.9	154.0	174.0	163.5	162.5±4.7
	Body weight	41.0	83.0	64.0	64.4±8.6	41.0	90.0	58.5	59.3±9.9
24-26 years n = 140	Shoulder height	46.0	62.0	55.8	55.3±4.2	48.0	60.0	52.0	52.3±2.9
	Elbow height	12.0	25.0	18.0	17.9±3.9	13.0	30.0	17.0	17.1±3.2
	Knee height	46.0	62.0	55.8	55.2±4.3	45.0	58.5	50.5	51.2±3.3
	Popliteal height	40.2	52.0	45.0	45.1±2.6	39.0	50.0	43.0	43.2±2.5
	Buttock-popliteal height	41.2	56.0	48.0	48.8±3.4	41.0	51.5	46.0	46.3±2.3
	Hip width	22.0	38.0	31.0	30.9±3.1	28.0	43.0	34.5	34.1±3.7
	Thigh thickness	10.0	17.0	14.0	13.7±1.7	10.0	18.0	13.0	13.0±1.9
	Shoulder breadth	35.0	47.0	41.5	41.7±2.4	34.0	49.0	39.0	39.2±3.0
	Stature	159.0	189.0	170.0	172.8±7.6	152.0	172.0	163.0	162.4±4.9
	Body weight	48.0	90.0	64.0	65.2±9.1	44.0	80.0	60.0	61.0±9.7
27-30 years n = 86	Shoulder height	50.0	62.0	56.0	56.2±3.1	47.0	55.0	51.0	51.1±2.1
	Elbow height	13.0	24.0	19.0	19.2±3.0	12.8	19.5	14.8	15.4±1.9
	Knee height	46.0	67.0	56.0	55.8±4.2	44.4	58.5	50.0	50.5±2.9
	Popliteal height	37.0	51.0	44.5	44.5±3.1	39.5	47.5	43.7	43.6±2.2
	Buttock-popliteal height	45.0	56.0	48.0	48.8±2.9	40.0	53.0	46.0	46.4±2.7
	Hip width	26.0	34.7	30.0	30.4±2.5	28.5	43.5	33.2	33.4±3.3
	Thigh thickness	9.5	16.0	13.1	14.0±1.5	10.0	19.0	13.0	13.1±2.1
	Shoulder breadth	38.0	46.0	41.0	41.5±2.2	33.0	43.0	40.0	39.8±2.5
	Stature	160.0	186.0	171.0	172.2±6.7	148.0	174.0	160.5	161.8±6.1
	Body weight	50.0	74.0	63.0	64.0±7.2	50.0	77.0	61.0	62.1±7.3

All dimensions are in centimetres (cm) except body weight which is recorded in kilograms (kg).

from [19], are compared with those obtained from the present study in Table 5. The result from [14], was not presented in the form shown in Table 5; however, sexual dimorphism in the anthropometric measures of male and female participants was obvious in the result as presented. The males had higher mean values for all the measures.

A graphical comparison of the mean values for anthropometric measures in the present study with those from previous studies [11,19], is shown in Figure 2.

Ideal furniture dimensions for the study population

For the population studied, suitable classroom furniture was designed for the anthropometric measures obtained. The design deployed some criterion equations established in literature and utilised the 5th percentile or 95th percentile values of the anthropometric measures of the population as presented in Table 2. The ideal furniture dimensions for the study population were calculated and the results are presented in Table 6. The seat dimensions were obtained using the criterion

Table 2: Combined results of all the participants (male and female) in the study, N = 590.

Anthropometric parameters	Min	Max	Median	Mean±SD	5th percentile	50th percentile	95th percentile
Shoulder height	44.0	63.0	54.0	54.0±3.8	48.0	54.0	61.0
Elbow height	11.0	30.0	17.0	17.7±3.5	13.0	17.0	24.0
Knee height	43.8	69.0	53.0	53.5±4.4	46.0	53.0	60.5
Popliteal height	37.0	55.0	44.0	44.0±2.8	40.0	44.0	49.0
Buttock-popliteal height	40.0	59.0	47.5	47.5±3.1	43.0	47.5	53.0
Hip width	22.0	43.5	32.0	32.3±3.6	27.5	32.0	38.0
Thigh thickness	8.5	19.0	13.0	13.1±1.9	10.0	13.0	17.0
Shoulder breadth	30.4	49.0	40.5	40.4±3.2	35.0	40.5	45.8
Stature	146.0	190.0	167.0	167.3±8.1	155.0	167.0	181.0
Body weight	41.0	104.0	62.0	62.7±9.4	48.0	62.0	79.0

All dimensions are in centimetres (cm) except body weight which is measured in kilograms (kg).

Table 3: Results for all male participants (N = 295) in the study.

Anthropometric parameters	Min	Max	Median	Mean±SD	5th percentile	50th percentile	95th percentile
Shoulder height	44.0	63.0	56.0	55.9±3.7	48.5	56.0	61.4
Elbow height	11.4	25.0	18.0	18.2±3.4	13.0	18.0	24.0
Knee height	43.8	69.0	56.0	55.6±4.1	47.8	56.0	61.0
Popliteal height	37.0	55.0	45.0	44.9±2.9	40.5	45.0	50.5
Buttock-popliteal height	41.2	59.0	48.0	48.6±3.2	43.8	48.0	55.5
Hip width	22.0	38.0	30.5	30.7±2.7	27.0	30.5	35.5
Thigh thickness	9.5	18.0	13.5	13.3±1.9	10.0	13.5	16.0
Shoulder breadth	30.4	49.0	42.0	41.5±3.2	34.8	42.0	46.0
Stature	146.0	160.0	171.0	172.3±7.2	160.0	171.0	185.5
Body weight	41.0	104.0	65.0	65.0±9.0	51.5	65.0	80.5

All dimensions are in centimetres (cm) except body weight which is measured in kilograms (kg).

Table 4: Results for all female participants (N = 295) in the study

Anthropometric parameters	Min	Max	Median	Mean±SD	5th percentile	50th percentile	95th percentile
Shoulder height	44.0	60.0	52.0	52.0±2.9	48.0	52.0	58.7
Elbow height	11.0	30.0	16.5	17.1±3.6	13.4	16.5	25.0
Knee height	44.3	60.0	50.5	51.4±3.5	46.0	50.5	58.0
Popliteal height	38.5	50.0	43.0	43.2±2.3	39.8	43.0	47.0
Buttock-popliteal height	40.0	53.0	46.0	46.4±2.6	42.1	46.0	51.0
Hip width	23.0	43.5	34.0	33.9±3.7	28.2	34.0	41.7
Thigh thickness	8.5	19.0	13.0	13.0±2.0	10.0	13.0	17.0
Shoulder breadth	33.0	49.0	39.0	39.4±2.8	35.0	39.1	43.4
Stature	148.0	174.0	163.0	162.4±5.5	153.6	163.0	172.4
Body weight	41.0	90.0	59.0	60.3±9.2	45.8	59.0	76.0

All dimensions are in centimetres (cm) except body weight (BW) which is measured in kilograms (kg).

equation presented in literature [1,10,11,13,15,17,19,23-25]. The anthropometric measures used to obtain these dimensions are those presented in Table 2.

Discussion

Ergonomic furniture design requires the utmost consideration of the anthropometric measures of the end users. This study therefore presents the relevant anthropometric measurements required for the design of ergonomic classroom furniture for University students.

The applications of these results to ergonomic furniture design are as follows:

1. **Popliteal height:** This body dimension is usually used for the design of the seat height and is expected to be higher that the height of the seat [23-25]. The seat
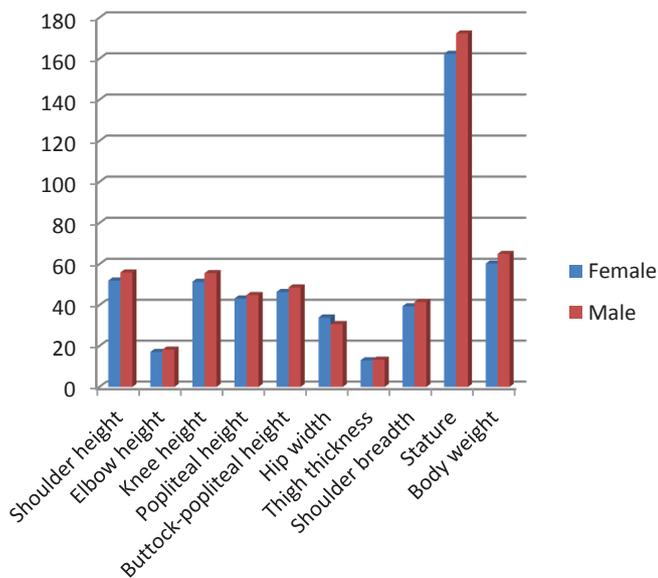
Figure 1: Showing the comparison between the mean values of male and female anthropometric measurements.
All dimensions are in centimetres (cm) except body weight which is recorded in kilograms (kg).
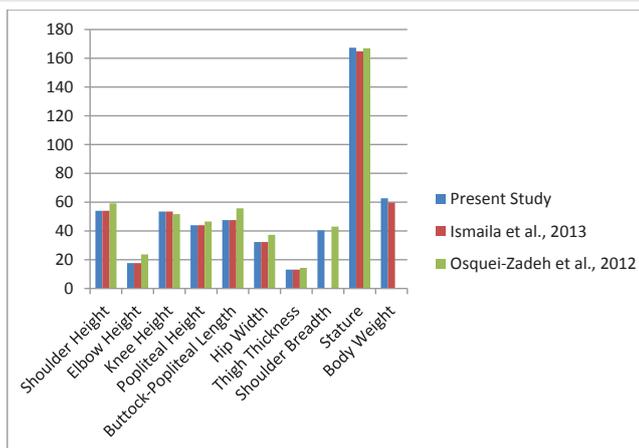

Figure 2: Graphical comparison of mean values from the present study and some previous studies [11,19].
All dimensions are in centimetres (cm) except body weight which is recorded in kilograms (kg).

height should be designated for the fifth percentile of popliteal height.

2. **Buttock-popliteal length:** This body dimension is used for the design of the seat depth. The seat depth needs to the ergonomically designed to enable the user make use of the backrest to support the spine while in a sitting position. The seat depth is usually designed using the fifth percentile value of the buttock-popliteal length for optimum benefit.

3. **Thigh thickness:** The thigh thickness is used to design the seat-desk clearance, SDC, (the distance between the seating surface and the under-surface of the desk/table). The seat-desk clearance is considered appropriate when it is higher than the thigh thickness leaving enough room to permit leg movement. The SDC is designated for the ninety-fifth percentile of the thigh thickness.

4. **Hip width:** Is used for the design of seat width. The ninety-fifth percentile of the hip width is used for optimum seat width design. A seat width that accommodates the largest hip breadth will also accommodate the smaller hip breadth.

5. **Shoulder height:** This body dimension is used to design the backrest height of the seat. For optimum backrest benefit, the fifth percentile of the shoulder height is designated for the backrest height design.

6. **Knee height:** The knee height is alternatively used to design the under-desk height. The optimum under-desk height is estimated to be between 20mm–50mm higher than the knee height [25] and designated for ninety-fifth percentile of the knee height.

7. **Elbow height:** The elbow height is used to determine appropriate seat-desk height and/or arm rest height because when arms can be supported, there is a reduction in the load on the spine [24]. The desk/table surface height is designated for the fifth percentile of the elbow height.

The designed classroom furniture for the study population (dimensions in Table 6) is expected to create comfort and reduce the risk of musculoskeletal disorder in persons who use such furniture. This is a major significance of a study like this. The use of furniture designed without appropriate anthropometric consideration has severe health implications. According to [25], when seating surfaces are too high, it causes discomfort and impaired blood circulation around the thighs. The user often has to move forward on the seat as a compensatory measure, thus, assuming a kyphotic posture due to lack of back support. When a seat is too low, the weight of the user is transferred to a small area of the ischial tuberosities resulting in an uneven distribution of pressure over the posterior thigh.

Seats that are too deep for a user usually result in reduced blood flow to the legs and feet because the front edge of the seat presses against the back of the knee. The use of poorly designed classroom furniture will require greater muscular force and control to maintain stability and equilibrium [25] and often results in discomfort (in the form of irritation) as well as pain on the back and neck and even an alteration in the normal posture of the individual. On the other hand, maintaining an upright sitting posture is beneficial to the back muscles [4], just as much as well-fitting classroom furniture will improve classroom comfort and facilitate learning.

Conclusion

In conclusion, this study provides classroom furniture designers and importers with a baseline description of the anthropometric dimensions of young Nigerians. More of this kind of study is recommended for a number of reasons; to anthropometrically describe young Nigerian adults at any given era and to provide anthropometric data for ergonomic furniture designs.

Table 5: Comparison between the results from the present study with the results from previous studies [11,19].

Anthropometric parameter	Present Study				[19]				[11]			
	Mean±SD	5th percentile	50th percentile	95th percentile	Mean±SD	5th percentile	50th percentile	95th percentile	Mean±SD	5th percentile	50th percentile	95th percentile
Shoulder height	54.0±3.8	48.0	54.0	61.0	49.66±4.9	42.00	50.00	55.00	59.1±4.9	51.0	59.5	66.0
Elbow height	17.7±3.5	13.0	17.0	24.0	19.18±2.1	15.50	19.00	22.50	23.7±2.6	19.0	23.7	29.9
Knee height	53.5±4.4	46.0	53.0	60.5	50.50±4.2	44.00	50.00	58.95	51.7±3.0	46.0	52.0	66.0
Popliteal height	44.0±2.8	40.0	44.0	49.0	40.92±4.7	36.00	40.00	49.00	46.6±2.7	41.4	46.8	51.2
Buttock-popliteal length	47.5±3.1	43.0	47.5	53.0	40.72±3.5	32.05	42.00	46.00	55.7±4.5	50.0	55.5	62.0
Hip width	32.3±3.6	27.5	32.0	38.0	32.88±2.4	29.00	33.00	36.00	37.3±2.5	33.0	37.0	41.9
Thigh thickness	13.1±1.9	10.0	13.0	17.0	13.81±1.23	12.00	14.00	16.00	14.3±1.7	11.0	14.5	17.0
Shoulder breadth	40.4±3.2	35.0	40.5	45.8					43.0±3.7	36.0	42.2	49.9
Stature	167.3±8.1	155.0	167.0	181.0	164.87±8.1	153.00	163.75	180.00	166.9±9.16	152.0	166.7	182.8
Body weight	62.7±9.4	48.0	62.0	79.0	59.66±6.2	52.00	59.00	73.00				

All dimensions are in centimetres (cm) except body weight (BW) which is measured in kilograms (kg).

Table 6: Ergonomic furniture dimensions for the study population.

Furniture dimension	Seat Height, SH	Seat Width, SW	Seat Depth, SD	Seat-Desk Clearance, SDC	Seat-Desk Height	Back-Rest Height
Values	Min = 44.2 Max = 50.8	SW≥38.0	Min = 34.4 Max = 40.9	SDC≥19.0	Min = 13.0 Max = 18.0	Min = 28.8 Max = 38.4

All dimensions are in centimetres (cm).

Acknowledgement

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