An innovative ergonomic design of classroom furniture based on anthropometric measurements at tertiary institutions

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An innovative ergonomic design of classroom furniture based on anthropometric measurements at tertiary institutions

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ABSTRACT: In many institutions, classroom furniture does not meet any national ergonomic criteria. This study aimed to use the concept of ergonomics to design a classroom desktop–chair for students in Uasin-Gishu County, Kenya. Anthropometric data were collected from a total of 382 students of both genders. The fourteen anthropometric measurements were taken from students with the help of anthropometric tools. The research applied fundamental engineering principles of product design and was carried out in compliance with ISO 7250-1:2017. The data obtained was analysed using Minitab 17.0 statistical package. Using the collected anthropometric data, a students' desktop–chair was proposed. In conclusion, one type of ergonomically suitable classroom desktop–chair design was proposed to improve the match between classroom desktop–chairs' dimensions and students' anthropometric characteristics. It is highly recommended that similar scientific research should be carried out in other countries.

Keywords: Desktop–chair, Classroom environment, MSDs, Awkward position.

1 INTRODUCTION

1.1 *Problem statement, significance, and purpose of the study*

The basic philosophy of ergonomics is to make any design comfortable. Students require well-designed classroom furniture for their comfort in the learning context. This requires that in designing classroom furniture, designers should include anthropometric sciences (Igbokwe et al. 2019b; Taifa & Desai 2017). According to some estimations, about 44 million workers in Europe suffer from occupational musculoskeletal disorders (Yusop et al. 2018). This shows that the ergonomics problem is a major issue that needs to be solved to avoid further suffering in the future. 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 the right kind of furniture as a social responsibility towards the students' community (Igbokwe et al. 2019). It is very essential for an institution of learning to have their anthropometric measurements regarding students so that they can be used by designers who intend to make ergonomic furniture, for them. This will ensure safety, comfort, adaptability, suitability, and ultimately guarantee user satisfaction, as well as result in the reduction of musculoskeletal disorders (MSDs) (Igbokwe, Osueke, Opara, Ileagu, & Ezeakaibeya 2019a). This research is of paramount importance because it expended current knowledge in the field of anthropometry to provide a database for future research and it is potentially beneficial to all future student. This research, therefore, seeks to use anthropometry for the design of classroom furniture for students to improve physical responses and their performance. The main purpose of the study is to conduct anthropometric measurements of students from four selected tertiary institutions and to design a desktop–chair using the collected anthropometric measurements.

2 LITERATURE REVIEW

Al-Hinai et al. (2018a) noted that the compatibility between classroom furniture dimensions and students' anthropometric characteristics has been identified as a key factor in improving some students' physical responses. Besides, there is a large amount of research worldwide (Castellucci, Gonçalves, & Arezes 2010; Chung & Wong 2007; Saarni et al. 2007) that shows a clear mismatch between anthropometric characteristics and the dimensions of classroom furniture. This mismatch might affect the learning process, even during the most stimulating and interesting lessons,

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and can produce some MSDs, such as low back pain and neck shoulder pain. This study, therefore, will fill the research gaps by providing an innovative ergonomically desktop–chair design based on students' anthropometric measurements. Thus, it will make a contribution to the existing literature on the compatibility between classroom desktop–chair dimensions and students' anthropometric characteristics, and improve the performance of students in terms of attentiveness while professors or instructors are teaching them.

3 RESEARCH METHODOLOGY

The entire methodology of the study can be divided into the steps that are described in Figure 1.

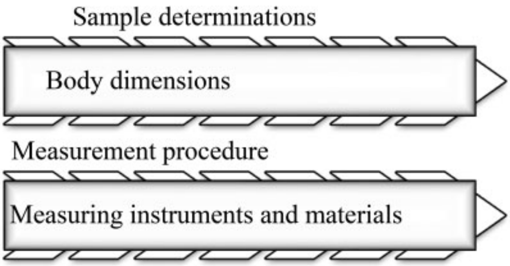

Figure 1. Main steps of the study methods.

3.1 *Sample determination*

Four higher institutions in Uasin Gishu County, Kenya, namely, (i) Moi University (MU), (ii) University of Eldoret (UoE), (iii) Rift Valley Technical Training Institute (RVTTI), and (iv) The Eldoret National Polytechnic (TENP), were selected to participate in the study. The students sample in the study was three hundred and eighty-two, through the use of equations given by Madara (2016):

$$\frac{\text{Students per institutions}}{\text{Total number of students in institutions}} * \text{Sample size}$$

3.2 *Body dimensions*

The design of standard furniture needs the direct involvement of anthropometric measurements. Various researchers (Igbokwe, Osueke, Opara, Ileagu, & Ezeakaibeya 2019b) have recommended the body dimensions which are essential in designing furniture, especially for students. Figure 2 shows all twelve body dimensions that were selected for the study with the addition of weight and forearm–fingertip length as the fourteenth body measurement. Two dimensions were collected while the participant was in the standing position, whereas the remaining twelve dimensions were taken while the participants were seated. The two most relevant anthropometric measurements for chair design are the popliteal height and buttock popliteal length (Igbokwe et al. 2019b). Table 1 indicates the serial number and descriptions of the selected student's body dimensions.

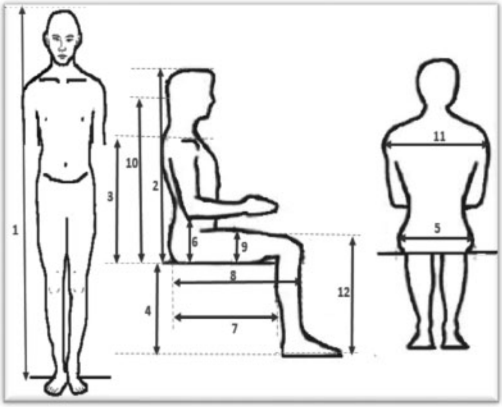

Figure 2. Anthropometric data required in classroom furniture design. *Keys:* (1) Stature, (2) Sitting height, (3) Shoulder height, (4) Popliteal height, (5) Hip breadth, (6) Elbow height, (7) Buttock popliteal length, (8) Buttock knee length, (9) Thigh clearance, (10) Eye height, sitting, (11) Shoulder breadth and (12) Knee height.

3.3 *Measurement procedures*

Three hundred and eighty-two students (191 males and 191 females) were selected (at random) from four selected tertiary institutions. The body size of each student was assessed using standard anthropometric measurement techniques (Esmaeel & Order 2017). The consent of all students was obtained before the commencement of the measurements. In this study, stature (body height) dimensions for each student were taken while they were standing, along with body mass. All other dimensions were measured while they were sitting erect on an adjustable desk with their knees bent at 90°. All anthropometric measurements were taken with the subjects wearing light clothing in a relaxed and erect posture, without shoes and with respect to the local culture. The time taken to measure and record all the dimensions per subject was about 15–20 minutes. Furthermore, measurements were taken every working day for 20 days in February in year 2020. The students' measurements were done in the hostels for each of the four selected tertiary institutions and all measurements were measured in centimetre (cm) except for the body mass (kg).

3.4 *Measurement instruments and materials*

According to ISO 7250-1:2017, the standard measuring instruments recommended are anthropometer, sliding callipers, spreading callipers, weighing scale, and tape measure.

Table 1. Selection of body dimensions to be measured for classroom furniture design.

S/NO. According to ISO 7250	Basic students' body dimensions	Description according to ISO 7250-1:2017
6.1.2	Stature (body height)	The vertical distance from the floor to the highest point of the head (vertex).
6.2.1	Sitting height (erect)	The vertical distance from a horizontal sitting surface to the highest point of the head (vertex).
6.2.4	Shoulder height, sitting	The vertical distance from a horizontal sitting surface to the acromion.
6.2.11	Popliteal height, sitting	The vertical distance from the foot-rest surface to the lower surface of the thigh immediately behind the knee, bent at right angles.
6.2.10	Hip breadth, sitting	The breadth of the body measured across the widest portion of the hips.
6.2.5	Elbow height, sitting	The vertical distance from a horizontal sitting surface to the lowest bony point of the elbow bent at a right angle with the forearm horizontal.
6.4.7	Buttock popliteal length (seat depth)	The horizontal distance from the hollow of the knee to the rearmost point of the buttock.
6.4.8	Buttock knee length	The horizontal distance from the foremost point of the knee-cap to the rearmost point of the buttock.
6.2.12	Thigh clearance	The vertical distance from the sitting surface to the highest point on the thigh.
6.2.2	Eye height, sitting	The vertical distance from a horizontal sitting surface to the outer corner of the eye (ectocanthus).
6.2.8	Shoulder (bideltoid) breadth	The horizontal distance across the maximum lateral protrusions of the right and left deltoid muscles.
6.2.13	Knee height, sitting	The vertical distance from the floor to the highest point of the superior border of the patella (suprapatella, sitting).
6.1.1	Body mass	The total mass (weight) of the body.
6.4.6	Forearm fingertip length	The horizontal distance from olecranon (back of the elbow) to the tip of the middle finger, with the elbow bent at right angles.

Source: (Esmaeel & Order 2017).

4 RESULTS AND DISCUSSION

4.1 *Anthropometric dimension for students*

The results obtained from the four selected tertiary institutions were analysed using Minitab 17.0 statistical package, to get the mean, standard deviation, 5th, 50th, and 95th percentiles. For seat height, the 5th percentile (lower percentile) of the popliteal height of the population is usually recommended so that a larger number of the population is accommodated, thus allowing a short person to use the chair. Similarly, the 95th percentile (larger percentile) of the hip breadth is usually recommended in the design of the seat width to accommodate as many people of the population as possible, thus allowing an overweight person to use the chair. The following results, shown in Table 2, give a summary of the anthropometric measures, based on the average of the collected anthropometric data, that can be used in designing a desktop–chair for students at four selected tertiary institutions in Uasin-Gishu County, Kenya.

After analysing all the anthropometric measurements of the students at the four selected tertiary institutions, the final specification is proposed for the design of the ergonomic desktop–chair that

Table 2. Summary of anthropometric dimension for student of the selected institutions (n = 382).

Variable	Mean	St. Dev	5th Percentile	50th percentile	95th Percentile
Age (Yrs.)	20.51	1.67	18.00	20.00	23.00
Stature	168.38	7.86	155.50	168.00	182.00
Sitting height	81.01	4.01	75.00	81.80	88.00
Shoulder height	54.41	2.76	50.96	54.50	57.80
Popliteal height	44.73	2.78	40.50	44.50	49.60
Hip breadth	33.46	3.49	29.57	32.86	39.36
Elbow height	20.39	1.16	19.11	20.30	22.37
Buttock popliteal length	42.54	2.73	38.10	42.65	46.90
Buttock knee length	51.85	3.05	47.20	51.90	56.70
Thigh clearance	14.54	1.70	11.96	14.43	17.39
Eye height	67.43	3.46	62.88	68.00	72.50
Shoulder breadth	41.78	3.43	37.02	41.47	46.59
Knee height	51.96	3.29	46.80	52.10	57.30
Body mass	60.54	9.09	48.00	59.50	75.50
Forearm fingertip length	47.62	2.70	43.46	47.44	51.88

can cover the maximum number of students. Table 3 shows the recommended dimensions for a new desktop–chair with the criteria for use in four elected tertiary institutions, Uasin-Gishu County, Kenya.

4.2 *Design of the desktop–chair*

After, running the analysis of the recorded data, as shown in Table 3 there is only one type of innovative ergonomically suitable desktop–chair that was identified in the four selected tertiary institutions (the dimensions were the same in the respective institutions), as drawn in Figures 3a and 3b using 3D SolidWorks 2019 software.

Table 3. Recommended dimensions for a new desktop–chair for use in tertiary institutions, Uasin-Gishu County, Kenya.

Seat feature	Anthropometric measure	Design dimensions (cm)	Criteria/ Determinant	References
Seat height	Popliteal height	40.95	5th percentile of popliteal height + 0.45 cm shoe heel allowance	(Ismail et al. 2013)
Seat width	Hip breadth	45.26	95th percentile of hip-breadth + 15% allowance for clothing	(Musa & Ismaila 2014)
Seat depth	Buttock popliteal length	38.10	5th percentile of buttock popliteal length	(Mohamed et al. 2010)
Desktop height from seat	Elbow height	19.11	5th percentile of elbow height	(Musa et al. 2014)
Backrest height	Shoulder height	50.96	5th percentile of shoulder height	(Mohamed et al. 2010)
Desktop width	–	24.20	Literature review suggestions	(Ismaila et al. 2013)
Desktop length	Forearm fingertip length	47.44	50th percentile of forearm fingertip length	(Ismaila et al. 2013)
Backrest angle	–	109°	Literature review suggestions	(Mohamed et al. 2010)
Desk angle	–	0°	From literature review	(Ansari et al. 2018)
Seat angle	–	110°	From literature review	(Igbokwe et al. 2019)

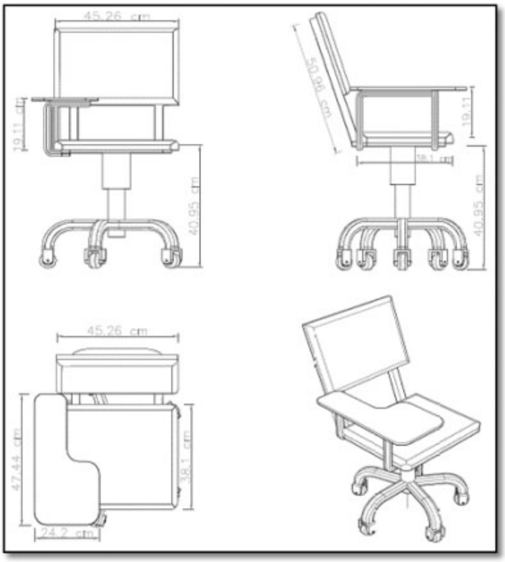

Figure 3a. Sketches of the proposed adjustable students' desktop–chair.

Figure 3b. Complete model of the proposed adjustable students' desktop–chair.

5 CONCLUSION AND RECOMMENDATIONS

5.1 *Conclusions*

From the present study, it is well expected that the determining criteria for an adjustable desktop–chair shown in Table 3 need to be used whenever designers wish to have adjustable classroom furniture (which is ergonomic design desktop–chair) in the four selected tertiary institutions, Uasin-Gishu County, Kenya. In this study, therefore, there is only one type of innovative ergonomically suitable classroom desktop–chair design that was proposed to improve the match between classroom desktop–chairs dimensions and students' anthropometric characteristics.

5.2 *Recommendation*

In this 21st century, it is highly recommended that the analysed anthropometric data set from this study be used for the design of classroom desktop–chairs for students in the four selected tertiary institutions, Uasin-Gishu County, Kenya. Achieving this will ensure safety, comfort, adaptability, suitability, and ultimately guarantee user satisfaction. The authors propose further work on seat chair design for elderly people should be carried out, with ergonomic and anthropometric consideration; this will allow seat chair design that is sustainable, safe, and comfortable as well as helping in health care.

Lastly, the goal is not to be perfect, it is just to be better than before (Pusca & Northwood 2018).

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