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DESIGN OF ERGONOMICALLY COMPLIANT DESKS AND CHAIRS FOR PRIMARY PUPILS IN IBADAN, NIGERIA

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Abstract

Selected anthropometric measures of two hundred primary school pupils in Ibadan North Local Government Area of Oyo State were used to design classroom desks and tables. The relevant anthropometric measures were popliteal height, buttock-popliteal length, elbow rest height, hip breadth, shoulder height and elbow-hand grip. The pupils with age range from 5 to 14 years (mean = 9.8 years, SD = 2.9 years) were grouped into three age groups of 5-8 years, 9-12 years and 13-14 years. From the data obtained; 5th, 10th, 50th, 75th, 90th and 95th percentiles were computed. In addition, 2-Tail Paired samples T-Test was conducted for the measurements of the male and female pupils for the three- age groups at 0.05 level of significance. Based on the anthropometric data obtained, this paper proposes furniture design dimensions for seat height (32.0 cm, 37.3 cm and 40.3 cm for 5-8 years, 9 to 12 years and 13-14 years respectively). It proposes seat depth (33.0 cm, 38.0 cm and 41.0 cm for 5-8 years, 9 to 12 years and 13-14 years respectively) and seat width (30.0 cm, 31.0 cm and 31.0 cm for 5-8 years, 9 to 12 years and 13-14 years respectively). Moreover, it proposes backrest height (upper) (39.0 cm, 43.0 cm and 44.0 cm for 5-8 years, 9 to 12 years and 13-14 years respectively) and arm rest (12.0 cm, 13.0 cm and 15.0 cm for 5-8 years, 9 to 12 years and 13-14 years respectively). It also proposes desk height (42.0 cm, 49.0 cm and 53.3 cm for 5-8 years, 9 to 12 years and 13-14 years respectively.

Keywords: Anthropometry, School furniture, Ergonomics, Sitting posture, Nigeria.

Abbreviations

BPL	Buttock- popliteal length (Sitting)
EHG	Elbow- hand grip
ERH	Elbow rest height (Sitting)
HPB	Hip breadth (Sitting)
KH	Knee height (Sitting)
POH	Popliteal height (Sitting)
SDH	Shoulder height (Sitting)
STH	Standing height (Stature)

1. Introduction

Pupils are required to sit for long period in schools [1] and yet the effect of the design of school furniture on their behaviour and health has received comparatively little attention compared to their adult counterparts. At this stage of development, there may be changes to their spinal column due to wrong sitting posture because of use of incompatible school furniture.

Molenbroek et al. [2] reported that prolonged sitting by students for educational purposes might result in headache, neck pain and back pain particularly if there is a mismatch between the students and school furniture. Lin and Kang [3]; Parcells et al. [4] and Troussier et al. [5] established that mismatch between school furniture and body size is a causative factor for low back pain or musculo-skeletal disorders among school students. Moreover, poor sitting postures over a long period can result in back pain [6].Thus chairs and desks must be designed for the user population taking into consideration their anthropometric parameters.

For the Nigerian population, there seems to be very few reported anthropometric data on which the design of ergonomically compliant chairs and desks could be based. The few reported anthropometric data includes that of Igboanugo et al. [7] on anthropometric data of Nigerian adult working class to serve as a data base for designers of domestic and industrial population; Ayodeji et al. [8] on anthropometric data of Nigerian paraplegics and Ismaila [9] on anthropometric data of the foot of Nigerian University students. Others are Ismaila [10] on the anthropometric data of hand, foot and ear of University Students in Nigeria and Ismaila et al. [11] on Anthropometric survey and Appraisal of Furniture for Nigerian Primary School Pupils. Ismaila et al. [11] concluded that chairs and desks in use in the primary schools by pupils were probably designed using the anthropometric dimensions of the British or none at all because some of the dimensions were low while others were high for the pupils. Thus, there seems to be no reported ergonomically compliant design of the chairs and desks for use by the primary school pupils in Nigeria.

The current study is to propose an ergonomically compliant desks and tables for pupils in primary schools in Ibadan, Oyo State, Nigeria.

2. Methodology

A sample size of 200 children without any noticeable physical disability that were randomly selected from a population of 2180 pupils in four public primary

schools that were also randomly selected in Ibadan Local Government Area of Oyo State was used. The age of range of the children was from 5 to 14 years (mean = 9.8 years, SD = ± 2.9 years). The sample comprised of equal number of males and females. The consent of the parents and the teachers of the pupils were obtained before the commencement of the measurements.

Eight anthropometric dimensions namely STH, BPL, SDH, POH, KH, ERH, HPB and EHG as defined in Table 1 and shown in Fig. 1 were measured with the use of Vernier Calliper, Stadiometer and measuring tape. The measurements were taken three times to ensure the correctness. The data obtained from the recorded measurements on prepared forms were combined into a file from which 5^{th}, 10^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} percentiles were computed using Microsoft Excel Package. Also, 2-Tail Paired samples T-Test was conducted for the measurements of the male and female pupils for the three- age groups at 0.05 level of significance using SPSS 16.0 statistical package. The dimensions of the chairs and tables measured are shown in Table 2.

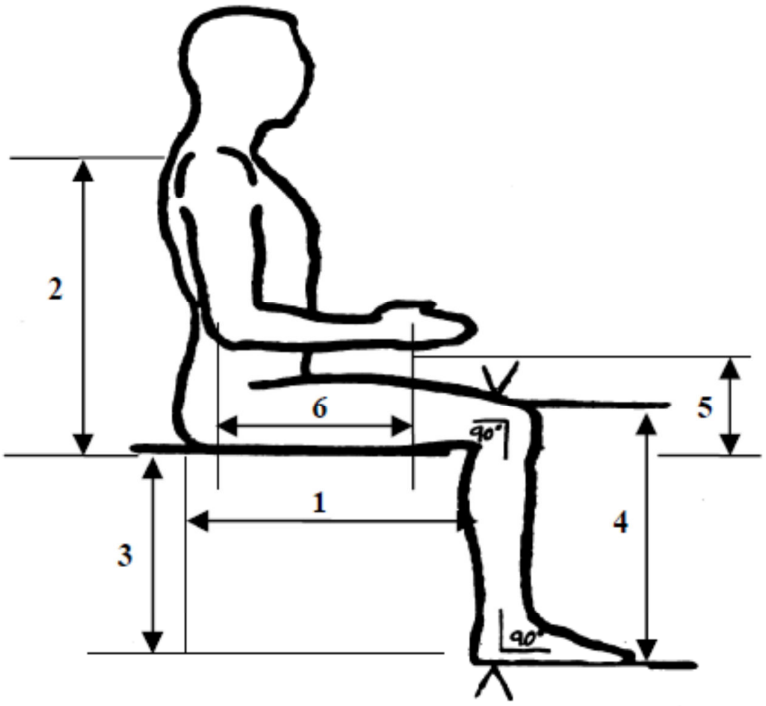

Fig. 1. Measured anthropometric data.

Legend

1- Buttock-Popliteal Length (BPL)
2- Shoulder Height (SDH)
3- Popliteal Height (POH)
4-Knee height (KH)
5-Elbow Rest Height (ERH)
6- Elbow- Hand Grip

Table 1. Definitions of anthropometric dimensions measured.

Anthropometric dimension	Definition
STH	Vertical distance from floor to crown of head.
BPL	Horizontal distance from the back of the uncompressed buttocks to the popliteal angle, at the back of the knee, where the back of the lower legs meets the underside of the thigh.
SDH	Vertical distance from the seat surface to the bony tip of the shoulder.
POH	Vertical distance from the floor to the underside of the thigh immediately behind the knee.
KH	Vertical distance from the floor to the uppermost point on the knee.
ERH	Vertical distance from the sitting surface to the bottom of the right elbow.
HPB	Maximum horizontal distance across the hips in the sitting position.
EHG	Horizontal distance from the elbow to the middle of the hand.

Table 2. Description of dimensions of the existing school furniture.

Parameter	Description
1. Chair Height	Vertical distance from the floor to the topmost part of the Chair.
2. Seat Height	Vertical distance from the floor to the highest point on the front of seat.
3. Seat Depth	Horizontal distance of the sitting surface from the back of the seat to the front of the seat.
4. Desk Height	Vertical distance from the floor to the top of the front edge of the desk.
5. Desk Depth	Horizontal distance from the front of the desk to the back at the top of the front edge of the shelf under the writing surface.

3. Results and Discussion

The anthropometric data for the female and male pupils are presented in Tables 3, 5 and 7. As can be inferred from Table 3, the standing height of male pupils with ages between 5 and 8 years differed significantly ($t = -2.529$, $p = 0.016$) from those of the female pupils and were consistently higher. This is at variance with the finding of [12], which showed that in the Korean population, girls exhibited higher mean heights but is in agreement with the finding of [12] for the British pupils. In addition, the elbow rest height of the male pupils in the age range differed significantly ($t=-2.508$, $p=0.016$) and were consistently higher than those of the female pupils. This finding differed from that of [13], which noted that, the elbow height of the Iranian primary school girls were significantly higher than the boys were. However, buttock-popliteal length, shoulder height, popliteal height, knee height, hip breadth and elbow-hand grip dimensions of the male pupils did

not differ significantly (t=-0.187, p= 0.853; t=-1.148, p= 0.258; t=-1.756; t=0.000, p= 1.00; t=0.272, p=0.787; t=-0.681, p= 0.50; t=0.754, p=0.455 and t=-1.070, p = 0.291 respectively) from those of the female pupils.

Table 3. Anthropometric dimensions of pupils with ages between 5 and 8 years for chair and desk design in cm (male: mean = 6.5 years, *n* = 40; female: mean = 6.5 years, *n*= 40, SD = ± 1.20).

Gender	Dimension	5th percentile	10th percentile	25th percentile	50th percentile	75th percentile	90th percentile	95th percentile
Male	STH	106.0	107.0	114.0	120.0	123.0	124.1	125.1
Female		101.0	101.9	112.8	118.0	122.0	123.1	124.1
Male	BPL	27.0	27.0	28.0	32.0	33.0	34.0	35.0
Female		28.0	28.0	29.0	30.5	32.0	33.0	33.1
Male	SDH	34.0	35.0	36.8	38.0	40.0	41.0	41.0
Female		33.0	34.0	35.0	37.0	39.0	41.0	41.1
Male	ERH	12.0	13.0	13.0	15.0	17.0	18.0	18.0
Female		12.0	12.9	13.0	14.0	15.0	17.0	17.1
Male	POH	27.0	27.0	28.8	30.5	32.0	33.0	33.0
Female		27.0	27.0	29.0	30.0	32.0	33.1	34.0
Male	KH	32.0	32.9	35.0	39.0	40.0	41.0	41.1
Female		34.0	34.0	36.0	37.5	40.0	42.0	42.0
Male	HPB	19.0	19.0	21.0	23.0	24.0	25.0	25.0
Female		20.0	20.9	21.0	22.0	25.0	26.0	28.0
Male	EHG	33.0	34.0	34.0	34.0	35.0	36.0	36.0
Female		32.9	33.0	33.5	34.0	35.0	36.0	36.0

The design of the chair and table for use by pupils in the selected primary schools was based on the following criteria and 'one size fits all' for each age group:

- ***Seat height***

The popliteal height should be considered in the design of seat height. The seat height was designed using the 75th percentile of the popliteal height which was 32 cm. Parcells et al. [4] defined a mismatch to occur when the seat height was either >95% or < 88% of the popliteal height but the percentile of the popliteal to use was not defined.

- ***Seat depth***

The anthropometric dimension to consider in the design of the seat depth was the buttock-popliteal length and for the 75th percentile of the male BPL was considered. From Table 3, this dimension is 33.00 cm.

- ***Seat width***

The dimension of the seat width should be determined using the hip breadth and an extreme design was selected for the seat width (95th percentile of the female hip breadth) with an allowance of 2 cm for clothing. The value of this dimension is 30 cm.

- ***Arm rest height***

The elbow rest height (sitting) is a determinant in the design of armrest height. Since if the lowest value is accommodated, the others could also be

accommodated, the 5th percentile of the elbow rest height was considered in the design. From Table 3, this value is 12 cm.

- ***Seat back rest height (upper)***

For the design of the upper part of the backrest, the shoulder height (sitting) was considered and the 75th percentile for the male was adopted. The 75th percentile of SDH for male (highest in the category) from Table 3 is 39 cm. This is to take care of the larger dimensions as well as accommodating the lower dimensions as reported by [14]

- ***Desk surface height***

The desk surface height is function of the knee height. In the determination of the desk height, the 75th percentile of knee height in addition to a clearance of 2 cm [15, 16] was used. From Table 3, the 75th percentile of knee height is 40 cm and an addition of 2 cm would give 42 cm.

- ***Desk surface width***

The desk surface width and the seat width are expected to be of the same dimensions. Thus, the desk width is 30 cm.

- ***Desk surface depth***

The distance between the elbow and the hand should be a deciding dimension in the determination of the desk depth. The 50th percentile of the elbow-hand grip was used for the design of desk surface depth and this value from Table 3 is 34 cm. The recommended dimensions for the chair and table for pupils with ages between 5 and 8 years are presented in Table 4.

Table 4. Recommended dimensions for chairs and desks for pupils in primary school with ages between 5 and 8 years.

Features	Anthropometric Measurements	Deciding Factors	Recommended Dimensions
Seat surface height	POH	75th percentile of POH	32.0 cm
Seat surface depth	BPL	75th percentile of BPL (male)	33.0 cm
Seat surface width	HPB	95th percentile of HPB+ 2 cm	30.0 cm
Armrest height	ERH	5th percentile of ERH	12.0 cm
Upper seat back rest height	SDH	75th percentile of SDH	39.0 cm
Desk surface height	KH	75th percentile of KH + 2 cm	42.0 cm
Desk surface width	HPB	95th percentile of HPB+ 2 cm	30.0 cm
Desk surface depth	EHG	50th percentile of EHG	34.0 cm

For the pupils between 9 and 12 years old, the standing height; buttock-popliteal length; shoulder height; knee height and elbow hand-grip differed significantly ($t = -2.781$, $p = 0.008$; $t = -2.235$, $p = 0.031$; $t = -2.781$, $p = 0.008$; $t = -2.973$, $p = 0.005$ and $t = -3.147$, $p = 0.003$ respectively) between the dimensions of the male and female pupils. However, there were no significant differences between the values of the male and female pupils with respect to elbow rest height ($t = -0.110$, $p = 0.913$), popliteal height ($t = 1.943$, $p = 0.059$) and hip breadth ($t = 0.723$, $p = 0.474$).

Table 5. Anthropometric data of pupils with ages between 9 and 12 years for chair and desk design in cm (male: mean = 10.5 years, *n* = 40; female: mean = 11.5 years, *n*= 40, SD = ± 1.21).

Gender	Dimension	5th percentile	10th percentile	25th percentile	50th percentile	75th percentile	90th percentile	95th percentile
Male	STH	120.8	121.9	127	134.0	140.3	151.2	156.1
Female		117.0	120.8	126.0	130.0	135.3	140.2	145.1
Male	BPL	32.0	33.0	34.0	36.0	38.0	41.0	42.0
Female		32.0	32.0	33.0	35.0	37.0	38.0	39.0
Male	SDH	38.0	39.0	40.8	43.0	45.0	47.1	48.1
Female		38.0	38.0	39.0	42.0	43.0	44.1	47.2
Male	ERH	13.0	13.9	14.0	15.0	17.0	18.1	19.0
Female		13.0	13.0	14.0	15.0	17.0	18.0	19.0
Male	POH	32.0	32.0	33.0	35.0	37.3	38.0	38.1
Female		31.0	31.9	33.0	34.0	35.3	37.0	37.1
Male	KH	38.0	38.9	41.8	43.0	47.0	49.1	51.0
Female		37.0	38.0	40.0	41.0	43.0	46.0	46.1
Male	HPB	22.0	23.0	24.0	27.0	28.0	29.1	30.1
Female		24.0	24.0	24.8	26.0	28.0	29.0	29.0
Male	EHG	35.0	35.0	35.0	36.0	38.0	40.0	40.0
Female		33.0	34.0	35.0	36.0	37.0	37.0	37.0

Using the same criteria as used for the pupils with ages between 5 and 8 years, the dimensions of the chairs and desks for pupils with ages between 9 and 12 years is as stated in Table 6.

Table 6. Recommended dimensions for chairs and desks for pupils in primary school with ages between 9 and 12 years.

Features	Anthropometric Measurements	Deciding Factors	Recommended Dimensions
Seat surface height	POH	75th percentile of POH	37.3 cm
Seat surface depth	BPL	75th percentile of BPL	38.0 cm
Seat surface width	HPB	95th percentile of HPB+ 2 cm	31.0 cm
Armrest height	ERH	5th percentile of ERH	13.0 cm
Upper seat back rest height	SDH	50th percentile of SDH	43.0 cm
Desk surface height	KH	75th percentile of KH + 2 cm	49.0 cm
Desk surface width	HPB	95th percentile of HPB	31.0 cm
Desk surface depth	EHG	50th percentile of EHG	36.0 cm

An analysis of the dimensions of the male and female pupils with ages between 13 and 14 years show that there were significant differences between the dimensions of the male pupils and those of the female pupils in respect of standing height (t=2.205, p=0.040) and elbow-hand grip (t = 4.723, p= 0.000). However, there were no significant differences in buttock-popliteal length (t = 1.930, p=0.069), shoulder height (t=1.325, p = 0.201), elbow rest height (t = 2.032, p= 0.056), popliteal height (t = 1.165, p = 0. 258), knee height (t = 2.036, p = 0.056) and hip breadth (t = 1.652, p = 0.115) of the male pupils and those of the female pupils. Using the same criteria as used for the pupils with ages between 9 and 12 years, the dimensions of the chairs and desks for pupils with ages between 13 and 14 years are as stated in Table 8.

Table 7. Anthropometric data of pupils with ages between 13 and 14 years for chair and desk design (male: mean = 13.5 years, *n* = 20; female: mean = 13.5 years, *n*=20, SD = ± 0.513 years).

Gender	Dimension	5th percentile	10th percentile	25th percentile	50th percentile	75th percentile	90th percentile	95th percentile
Male	STH	133.7	134.9	138.3	144.5	155.3	162.0	162.1
Female		120.0	124.5	131.8	141.0	147.0	153.0	153.4
Male	BPL	34.0	34.9	35.8	37.5	41.0	43.1	44.0
Female		31.0	31.9	34.0	36.5	38.3	40.0	40.2
Male	SDH	29.0	29.9	30.0	36.0	44.0	47.1	48.0
Female		27.0	27.0	30.0	35.0	44.3	47.1	48.0
Male	ERH	15.0	15.0	15.0	16.0	16.0	17.0	17.0
Female		14.0	14.0	15.0	15.5	16.0	16.0	16.1
Male	POH	37.0	37.9	38.8	40.0	40.3	42.0	42.1
Female		35.0	35.9	38.8	39.5	40.1	41.0	41.2
Male	KH	44.9	45.0	46.8	49.0	51.3	53.0	53.1
Female		38.9	39.0	43.0	47.5	50.0	52.0	52.1
Male	HPB	23.0	23.0	23.8	24.0	26.3	28.1	29.0
Female		20.0	20.9	22.8	24.0	25.3	29.0	29.0
Male	EHG	37.0	37.0	37.0	38.0	38.3	39.0	39.
Female		36.0	36.0	36.8	37.0	37.3	38.0	38.1

Table 8. Recommended dimensions for chairs and desks for pupils in primary school with ages between 13 and 14 years.

Features	Anthropometric Measurements	Deciding Factors	Recommended Dimensions
Seat surface height	POH	75th percentile of POH	40.3 cm
Seat surface depth	BPL	75th percentile of BPL	41.0 cm
Seat surface width	HPB	95th percentile of HPB+ 2 cm	31.0 cm
Armrest height	ERH	5th percentile of ERH	15.0 cm
Upper seat back rest height	SDH	75th percentile of SDH	44.0 cm
Desk surface height	KH	75th percentile of KH + 2 cm	53.3 cm
Desk surface width	HB	95th percentile of HPB + 2 cm	31.0 cm
Desk surface depth	EHG	50th percentile of EHG	38.0 cm

The sketch and dimensions for the proposed desk and chair are shown in Figs. 2 and 3 respectively.

Table 9. Comparison between the dimensions of existing furniture and the recommended dimensions (cm).

Features	Pupil Furniture (5-8 years)	Pupil Furniture (9-12 years)	Pupil Furniture (13-14 years)	Existing Furniture
Seat surface height (A)	32.0 cm	37.3 cm	40.3 cm	35 cm
Seat surface depth (B)	33.0 cm	38.0 cm	41.0 cm	31 cm
Seat surface width (C)	30.0 cm	31.0 cm	31.0 cm	90 cm
Armrest height (D)	12.0 cm	13.0 cm	15.0 cm	
Upper seat back rest height (E)	39.0 cm	43.0 cm	44.0 cm	38 cm
Desk surface height (F)	42.0 cm	49.0 cm	53.3 cm	62 cm
Desk surface width (G)	30.0 cm	31.0 cm	31.0 cm	90 cm
Desk surface depth (H)	34.0 cm	36.0 cm	38.0 cm	28 cm

Based on the current study, the seat height as shown in Table 9 should be 32 cm, 37.3 cm and 40.3 cm for pupils from 5 to 8, 9 to 12 and 13 to 14 years respectively. The seat height of the existing chair is 35 cm, which is high for 5-8 year old pupils but short for pupils who are older. The proposed dimension of the seat surface height is higher than 25.83 to 32.23 cm that was proposed by [15] for an adjustable seat height for 6-7 year old primary school pupils in United States of America. Habibi et al. [17] proposed 36.5 and 40.3 cm as seat surface heights for two types of seat for use in primary schools (ages between 6 and 12 years) in Iran. As noted by Chaffin [18] when the seat height is very low, the bending angle of the knee becomes sharp thus the weight of the trunk would be transferred to the seat through the back of the thigh making the sitting to become uncomfortable.

The proposed seat depths are 33, 38 and 41 cm for 5 to 8, 9 to 12 and 13 to 14 year-old pupils respectively. This is comparable with 34 and 37.4 cm proposed by Habibi et al. [17] for two variants of chairs. The seat depth of the existing furniture of 31 cm is therefore shallow for the pupils. Too shallow a seat may cause the user to have sensation of falling off and may result in lack of support of the lower thighs [19].

The seat width of the existing furniture of 90 cm is adequate for three pupils but it is better to design a seat for each pupil. The seat width of 30 cm proposed in the current study for 5-8 year old pupils is also more than the proposed dimensions for adjustable seat width of 17.91 to 23.29 cm as proposed by Oyewole et al. [16]. The proposed dimension of upper backrest of 39 cm for 5-8 year old, 43 cm for 8-11 year old and 44 cm for the 11-14 year old pupils is higher than the existing furniture of 38 cm and may not allow for proper use of the backrest. For the 5-6 year old pupils in United States as reported by Oyewole et al. [16], the upper back rest should be between 35.64 and 44.37 cm while for

Iranian pupils it should be 37.7 and 39.2 cm for the two variants of chairs proposed by [16].

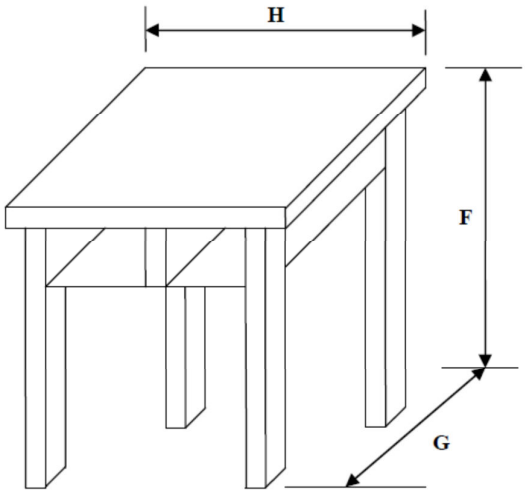

Fig. 2. The proposed desk.

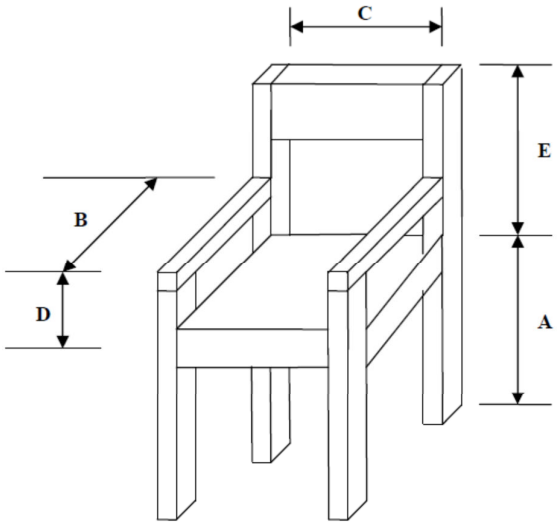

Fig. 3. The proposed chair.

A, B, C, D, E, F, G and H are as defined in Table 9.

The desk heights obtained in the present study are lower in all the three cases (42, 49 and 53.3 cm) than the height of the existing desk of 62 cm and those of [16] with 66.6 and 69.2 cm but higher than 30.12 cm and 37.85 cm reported by [15]. The desk height of 62 cm makes the desk too high for the pupils; the pupils may therefore find it convenient to stand while writing. The desk depth of 28 cm of the existing furniture is too shallow for the pupils. The anthropometric

characteristics of the users are essential for the accomplishment of various tasks safely and economically. If mismatches exist between the human anthropometric data and equipment, tools and furniture, it may result in 'decreased productivity, discomfort, accidents, biomechanical stresses, fatigue, injuries, and cumulative traumas' [20]. It may therefore not be a surprise if a higher percentage of the students complain of neck and low back pain. In fact, Musa et al. [21] confirmed that 93.75% of students in three selected tertiary institutions in Abeokuta, Nigeria complained of neck, shoulder, upper and lower back pains that they attributed to the furniture they used.

4. Conclusions

The results of this study show that the anthropometric data of pupils in primary schools were probably not used when designing the furniture currently in use. While some of the dimensions were low, others were high for the primary school pupils. It is important that if products are to be designed, they should be based on the anthropometric dimensions of the user population to reduce negative effects on the muscle due to poor sitting postures and also reduce neck, shoulder and back pain that may result. The study also provides some additional anthropometric data that may be useful in the design of other products for pupils in primary schools.

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