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Mismatch between school furniture dimensions and anthropometric parameters is a risk for spinal deformities in secondary school students in Lagos, Nigeria: a cross-sectional study

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Abstract

Background A mismatch between school furniture dimensions and anthropometric parameters has been well documented in adolescents, but there is a paucity of data on the impact of these mismatches on the students' spinal health in Nigeria. This study therefore investigated the relationship of spinal deformities with selected anthropometric parameters and furniture dimensions of adolescents in secondary schools.

Methods This study involved 540 apparently healthy students between the ages of 10 and 19 years from 9 public and private secondary schools in Lagos state, Nigeria. The furniture dimensions, anthropometric parameters, and spinal curvature disorders were evaluated using standard protocol. Data was analyzed using SPSS version 20.0 with a level of significance set at $p < 0.05$.

Results Two hundred two (37%) of the participants had abnormal spinal curvatures in varying types and degrees. There was a significant association at $p \leq 0.05$ between the presence of spinal deformities and popliteal height to seat height mismatch ($X^2 = 175.67$, $p = 0.001$), hip breadth to seat width mismatch ($X^2 = 293.14$, $p = 0.00$), and shoulder height to backrest height mismatch ($X^2 = 788.16$, $p = 0.001$).

Conclusion Anthropometric parameters to furniture dimensions mismatch are significantly associated with the presence of spinal deformities among the students. The main cause of mismatch is using a homogeneous size of furniture for all students in addition to non-consideration of the students' dimensions during furniture manufacturing.

Keywords Anthropometry, Furniture mismatch, Kyphosis, Lordosis, School furniture, Scoliosis, Spinal deformities

Introduction

Secondary school students spend a greater part of their waking hours seated in school [1]; thus, school furniture plays a vital role in the environment and learning experience and is as important as equipment and other learning resources. This is more so as static posture, and prolonged sitting in a forward bending position, such as students often adopt, puts extreme strain on the muscles, the ligaments, and in particular the discs

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[2]. Proper implementation of classroom ergonomics is needed for the maintenance of good health and improvement in academic performance, learning, and motivation [3]. School children are at particular risk of the negative effects from poorly designed and ill-fitting furniture due to extended periods of sitting [4], and recent studies have shown a rising incidence of idiopathic spinal deformity among adolescents [5]. This may be attributed to school furniture-anthropometric mismatch as a recent study on 12-year-old pupils reported school furniture as a potential source of musculoskeletal pain among primary school pupils. In the study, seat height was found to be unsuitable for 90% of the pupils and desk height was unsuitable for 82% of them. The study concluded that school furniture in Slovenia is unsuitable for most pupils and recommended that anthropometric data be considered in designing new school furniture [6]. Several studies have shown that schoolchildren frequently use furniture that is not consistent with their anthropometric needs [1, 7, 8]. School furniture that allows students to sit comfortably for longer periods of time thereby resulting in better concentration during learning is an important consideration in this respect [9].

A mismatch is defined as an incompatibility between furniture dimensions and the student's body dimensions. According to Parcells et al. [4], a mismatch is said to be present when seat height is either > 95% or < 88% of the popliteal height, seat depth is either > 95% or < 80% of the thigh length, or desk is < 2 cm higher than the knee height. According to Chaffin and Anderson [10], the minimum and maximum acceptable angle of the shoulder during writing is 0–25° for shoulder flexion and 0–20° for shoulder abduction.

Incidentally, several studies have focused on the design of ergonomically suitable furniture in the workplace but the design of suitable school furniture for students is largely understudied [11]. Students are thus forced to adapt to the furniture given irrespective of their anthropometric parameters rather than being the other way around. Anthropometric measurements are therefore an important consideration in designing ergonomically appropriate furniture for school children [7].

The purpose of this study was to determine the prevalence of mismatch between anthropometric parameters and school furniture and the effect on spinal curvatures in adolescents in secondary schools in Lagos, Nigeria. This may provide a template for the development of normative anthropometric reference values for Nigerian children and adolescents.

Materials and methods

Participant selection

This was a cross-sectional analytical survey that involved 540 apparently healthy adolescents between 10 and 19 years old who attended public and private secondary schools within Lagos state, Nigeria. Excluded were students who could not stand erect independently due to disability and those who had been absent from school for more than a term before the commencement of the study.

Materials

A self-made, modified plumbline which is a metal weight attached to a rope and made to hang was used in this study to assess the alignment of the back. A Scoliometer (S.181.525, USA) was used to measure the degree of scoliosis. It is calibrated in degrees (°). From 0 to 30° from the left and right. A Flexicurve (RUR0067, China) is a plastic model of the rubber ruler brand which is usually molded to the spine in order to reproduce the back shape. This instrument consists of a flexible metal ruler covered in plastic. A flexible ruler is a low-cost, non-invasive, and valid instrument comparable with the radiological Cobb's method. The reliability and validity of this instrument for lumbar and thoracic regions have been shown in some studies, which demonstrated a significant correlation between this method and Cobb's angle method [12, 13]. For this study, it was used to measure the degree of hyperkyphosis and hyperlordosis.

Methods

A multistage sampling technique was used to select the participants for this survey. Names and numbers of secondary schools in educational district VI of Lagos state were received from the headquarters. Five (5) public schools and 5 private schools were selected using the fishbowl method, but 1 of the private schools declined in the course of the study leaving 9 schools. Sixty students (10 from each class) were randomly selected from the 9 schools. The minimum sample size for the study was determined to be 384 using the Cochrane [14] formula for the determination of the sample size in a survey of an infinite population.

Ethical consideration

Prior to the commencement of the study, ethical approval was obtained from the institutional Health Research and Ethics Committee. Informed consent was obtained from each participant and from the parents/guardians of any child less than 18 years old for the purpose of data collection. Participants were assured of the confidentiality of the information obtained. The aims and objectives of the study were carefully explained to the participants as well as the procedures to be carried out. Socio-Demographic data such as age, gender and class of the participants were taken.

Measurement of anthropometric parameters

The body mass index

The BMI of the participants was assessed using the Quatelet index which is the most widely accepted method of determining the BMI [15]. It is measured by dividing the body weight in kilograms by the square of the height in m^2 (kg/m^2). The quatelet index would predict a percentage of body fat ranging from 10 to 20% two thirds of the time [16].

Popliteal height

It is the distance in centimeters (cm), taken vertically with 90° knee flexion, from the foot-resting surface to the posterior surface of the knee or popliteal space [4]. The participant sat erect, knees flexed 90°, and thighs parallel. With tape measurement, the vertical distance from the floor to the lateral underside of the right thigh at a point contiguous to where the tendon of the biceps femoris muscle joins the lower leg was measured [17].

Buttock-popliteal length

With 90° knee flexion, the buttock-popliteal length is the horizontal distance (in cm) from the posterior surface of the buttock to the posterior surface of the knee or popliteal space [4]. The participant was asked to sit erect on an adjustable seat with knees flexed 90° and thighs parallel. With the tape measurement, the horizontal distance from the most posterior aspect of the right buttock to the posterior surface of the right knee was measured.

Elbow-seat height

This was measured with the elbow flexed at 90˚, which is the vertical distance from the bottom of the tip of the elbow (olecranon) to the participant's seated surface.

Hip breadth

This was measured as the maximum horizontal distance between the hips in the sitting position. Participants were asked to sit erect, and the distance between the two hips was measured at the back using a tape measure.

Shoulder height

It is the vertical distance from the horizontal sitting surface to the top of the shoulder at the acromion.

Measurement of furniture dimensions

Seat height

This is measured as the vertical distance from the highest point on the front of the seat to the floor.

Seat width

This is measured as the horizontal distance between the lateral edges of the seat.

Seat depth

This is measured as the horizontal distance from the back of the sitting surface of the seat to its front edge.

Desktop-seat height

This is measured as the vertical distance from the sitting surface to the upper edge of the desktop.

Backrest height

This is measured as the vertical distance from the sitting surface to the top edge of the backrest [1].

Measurement of spinal curvature

The posture of all participants was assessed with palpation, and the determined landmarks were marked. These landmarks included the tragus of the left ear, the left acromion process, the left lateral malleolar process, and the spinous process of the 7th cervical vertebra.

The assessment was first done in the sagittal plane. The participants were asked to stand laterally behind the plumb-line on the predetermined feet locations, and then, forward bending was done three times. Afterwards, they were instructed to stand in their normal, comfortable posture, arms resting by the sides, with feet shoulder-width apart and equally balanced on both feet [18] (Fig. 1).

According to the definition of Kendall and Kendall [19], lateral posture is considered normal, if the plumb-line passes through the tragus of the ear, C_7 spinous process, the acromion process, the greater trochanter, just anterior to the midline of the knee, and slightly anterior to the lateral malleolus. Therefore, forward displacement of the tragus and acromion compared to plumb-line in lateral view was considered as forward head posture and rounded shoulder posture, respectively.

For the coronal plane, the participants were requested to stand back from the plumbline. Scoliosis was investigated in the form of any deviation of the spine. If there is any suspicion of scoliosis, the participants were asked to perform Adam's forward bending for further assessment of the condition. A scoliometer was then used in Adam's forward bending position to measure the degree

Fig. 1 Plumbline assessment in coronal plane

Fig. 2 Measurement of scoliosis using a scoliometer

of scoliosis. In the assessment session, all of the procedures were repeated three times one after another by the same examiner and results were recorded [18] (Fig. 2).

To assess hyperkyphosis and hyperlordosis, a flexible 32-in. ruler (flexi curve) was used. To measure the thoracic curve, participants were asked to swing their hands three times and stand in a straight-line position with habitual body posture. The flexible ruler was molded along the contour of the spine, and the C_7, T_1, and T_{12} spinous processes were recorded using the metric scale incorporated in the device. Then, the ruler was removed carefully and the internal curve (the side of the ruler in contact with the skin) was drawn onto graph paper. Thereafter, it was straightened again and the procedure was repeated three times by the same examiner.

In the next stage, the flexible ruler was molded along the contour of the lumbar spine and the L_1 and S_1 spinous processes were recorded. Drawing the lumbar curve onto paper and repeating the procedure was also done similarly to the previous process. Later, kyphosis and lordosis angles were calculated and converted to Cobb's angle equivalents, using the following method:

After tracing the curvatures, thoracic length (L_1) was drawn by connecting the T_1 mark (most superior point) to the T_{12} (most inferior point). Thoracic width (H_1) was considered as the greatest width from the thoracic curve to the vertical line. For each trial, kyphosis angle (KA) was calculated according to the following formula [20]:

$$\text{Kyphosis angle} = 2\text{Arctang}\,(2\text{H1}/\text{L1})$$

Then, Cobb's angle for the thoracic curve was determined, using the subsequent:

$$\text{CA}_\text{T} = 0.8587\text{FA}_\text{T} + 6.9064$$

(CAT, Cobb's angle for thoracic curve; FAT, flexible ruler angle for kyphosis) [12]

Lordosis angle (LA) was calculated according to the following formula:

$$\text{Lordosis angle} = 4\text{Arctang}\,(2\text{H}_2/\text{L}_2)$$

In the equation, lumbar length (L_2) is the distance from the L_1 to the S_1 mark and lumbar width (H_2) is the greatest width from the lumbar curve to the vertical line. For conversion of this angle to the Cobb's equivalent, the correction with the linear transformation formula was done:

$$\text{CA}_\text{L} = 0.7702\text{FA}_\text{L} + 9.6924$$

(CA_L, cobb's angle for lordosis; FA_L, flexible ruler angle for lordosis) [12].

Again, the average of three lordosis angles was used [18].

Data analysis

All statistical analyses were carried out using Statistical Package for Social Sciences (SPSS) 20.0. Data was summarized using the descriptive statistics of mean, standard deviation percentages, and frequency distribution. They were presented in the form of tables and charts.

Table 1 Socio-demographic characteristics of the participants

Variables	Frequency (*n*)	Percentage (%)
Age		
0–12	111	20.6
13–16	363	67.3
17–19	66	12.3
Sex of participants		
Male	233	43.1
Female	307	56.9
Type of school of participants		
Public	300	55.6
Private	240	44.4
Class of participants		
JSS1	90	16.7
JSS2	90	16.7
JSS3	90	16.7
SSS1	90	16.7
SSS2	90	16.7
SSS3	90	16.7

JSS Junior Secondary School, *SSS* Senior Secondary School

Table 2 Anthropometric profile of participants

Variables	Mean	Standard deviation
Height (m)	1.60	0.09
Weight (kg)	47.75	9.48
Body mass index (kg/m^2)	18.61	2.64
Popliteal height (cm)	43.53	3.14
Shoulder height (cm)	50.30	4.19
Hip breadth (cm)	40.18	7.05
Elbow-seat height (cm)	17.76	2.92
Buttock-popliteal length (cm)	51.18	4.78

Inferential statistics of biserial correlation were used to determine the relationships between spinal deformity and body mass index. Chi-square test and Fisher's exact test were used to determine the association of spinal deformity with mismatch anthropometric variables. All statistical tests were performed at the 0.05 level of significance (i.e., $p<0.05$).

Results

Five hundred forty secondary school students participated in this study which comprises 90 (16.7%) students from each of the six levels of study in secondary school (JSS1 to SSS3). The socio-demographic and anthropometric parameters are seen in Tables 1 and 2. Figure 3 shows that 202 (37.4%) of the participants had one or more deformities while 338 (62.6%) had no deformity. Table 3 shows the spinal deformity profile of the participants, and it is seen that the majority (136, 67.3%) had scoliosis deformity only. The associations between anthropometric mismatch and the presence of spinal deformity are presented in Table 4. Four hundred twenty-four (78.5%) of the total participants had popliteal height-to-seat height mismatch, and there is a significant association between the presence of spinal deformity and popliteal height-to-seat height mismatch ($X^2=175.67$, $p<0.01$). Also, 319 (59.1%) of the participants had hip breadth-to-seat width mismatch and there is a significant association between the presence of spinal deformity and hip breadth-to-seat width mismatch ($X^2=293.14$, $p<0.01$). Similarly, 463 (85.8%) of the participants had a buttock-popliteal length-to-seat depth mismatch and there is a significant association between the mismatch and the presence of spinal deformity ($X^2=678.74$, $p<0.01$).

The table also shows that most participants 506 (93.7%) had elbow-seat height to desktop-seat height mismatch,

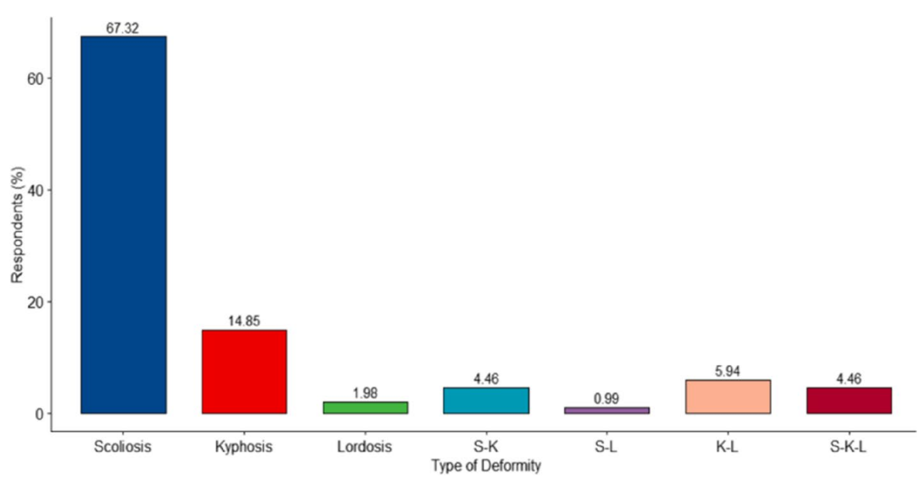

Fig. 3 Spinal deformity profile of the participants ($N=202$)

Table 3 Profile of participants' pattern and severity of spinal deformity

Variables	Frequency (*n*)	Percentage (%) of total	Overall prevalence (%)
Scoliosis	**156**		28.88
1–9° minor asymmetry			
10–24° minor scoliosis			
3–6°	98	62.8	18.14
7–10°	52	33.3	9.62
11–13°	6	3.85	1.11
Kyphosis	**60**		11.11
Normal: 20–40°			
30.00–34.99°	8	13.3	1.48
35.00–39.99°	15	25.0	2.78
40.00–44.99°	12	20.0	2.22
45.00–49.99°	20	33.3	3.70
50.00–54.99°	5	8.33	0.92
Lordosis	**27**		5.00
Normal: 40–60°			
40.00–49.99°	2	7.40	0.37
50.00–59.99°	0	0	0.00
60.00–69.99°	7	25.92	1.30
70.00–79.99°	14	51.85	2.60
80.00–89.99°	1	3.70	0.18
90.00–99.99°	3	11.11	0.55

and it is significantly associated with the presence of deformity ($X^2 = 412.56$, $p < 0.01$). Meanwhile, the least number of participants 137 (25.4%) had shoulder height to backrest height mismatch although there is a significant association between the presence of spinal deformity and the shoulder height to backrest height mismatch.

The biserial correlation coefficient computed to investigate the relationship between body mass index and the presence of spinal deformity shows that there was no significant relationship between body mass index and the presence of spinal deformity among participants ($r = 0.01$, $p = 0.75$).

Discussion

Recent findings show a rising incidence of spinal deformity among adolescents, especially the idiopathic type [5] which may be attributed to a mismatch between school furniture and anthropometric measures as a recent study on 12-year-old pupils reported school furniture as a potential source of musculoskeletal pain among primary school pupils [6]. Schoolchildren spend most of their waking hours at school, mainly in the seated position; hence, their posture while carrying out daily activities in school is very important to their overall spine health [1]. Contrary to the general belief that sitting is just about relaxation, it actually puts a lot of strain on the back because the full weight of the upper body is transferred onto the buttocks and thighs [21]. Static posture and prolonged sitting in a forward bending position, as students often do, put extreme strain on the muscles, the ligaments, and particularly the discs [2]. Anthropometric parameters are therefore an important consideration in designing ergonomically appropriate furniture for school children [7]. Considering the amount of time they spend in sedentary activities, students are at particular risk of suffering from the negative effects of poorly designed furniture. The use of ill-fitted furniture may increase the risk of developing musculoskeletal disorders. Furniture well designed to accommodate the anthropometric measures of students promotes correct sitting posture and reduces the incidence of

Table 4 Association between anthropometric mismatches and the presence of spinal deformity

Variables		Overall ($n = 540$)	Spinal deformity		*p* value
			No ($n = 338$)	Yes ($n = 202$)	
Popliteal height to seat height	Match	116 (21.5%)	93 (27.6%)	23 (11.4%)	**< 0.001**^{C*}
	Mismatch	424 (78.5%)	245 (72.4%)	179 (88.5%)	
Hip breath to seat width	Match	221 (40.9%)	175 (51.8%)	46 (22.8%)	**< 0.001**^{C*}
	Mismatch	319 (59.1%)	163 (48.2%)	156 (77.2%)	
Buttock-popliteal length to seat depth	Match	77 (14.3%)	76 (22.5%)	1 (0.5%)	**< 0.001**^{F*}
	Mismatch	463 (85.7%)	262 (77.5%)	201 (99.5%)	
Elbow-seat height to desktop-seat height	Match	31 (6.3%)	32 (9.4%)	2 (1.0%)	**< 0.001**^{F*}
	Mismatch	506 (93.7%)	306 (90.6%)	200 (99.0%)	
Shoulder height to backrest height	Match	403 (74.6%)	272 (80.5%)	131 (64.9%)	**< 0.001**^{C*}
	Mismatch	137 (25.4%)	66 (19.5%)	71 (35.1%)	

*Significant at $p \leq 0.05$. *C* chi-squared test, F Fisher's exact test musculoskeletal disorders [22]. Several studies have reported high mismatch percentages between furniture and students' anthropometry [1, 8, 22, 23].

The aim of this study was to determine the relationship of abnormal spinal curvatures with a mismatch of selected anthropometric parameters to furniture dimensions in adolescents in secondary schools. When the anthropometric indices and the dimensions of the school furniture were assessed, there was a high percentage of body anthropometric-furniture mismatches which according to a prior study can affect classroom activities such as writing, reading and typing, and causing pain in the back, shoulders, neck, legs, and eyes [24].

The mismatch was highest in elbow-seat height to desktop-seat height (93.7%), and there was a significant association between this mismatch and the presence of spinal deformities. This implies that most students are required to use seats either too high or too low for them, and this will likely lead to them having to either lift their arms up while writing, causing increased muscular load and discomfort [1, 4], or bending their trunk forward, increasing spinal load and putting them at risk of kyphosis deformity [25]. This high rate of elbow-seat height to desktop-seat height mismatch agrees with findings from several studies [1, 4, 22, 23]. Likewise, there was a high rate of buttock-popliteal length-to-seat depth mismatch (85.8%); thus, when the seat is too deep, it may cause increased pressure on the thighs and affect the effective use of the backrest [1, 26] while when too shallow, the thigh would not be supported, leading to discomfort and instability [26, 27]. All these uncomfortable sitting positions may precipitate the spines into abnormal curvatures. This finding corroborates that of Gouvali and Boudulus [27] who in their study found that the seat depth was only appropriate for 15.3% of boys and 20.8% of girls aged between 12 and 18 years. It is however contrary to the findings of Dianat et al. [1] who recorded only a 25.9% mismatch. This disparity might be attributed to the fact that this study had participants within the close age range of 15–18 years with them having relatively closed values of anthropometric variables and their seat depth needs of almost close range. However, the fact that there is a significant association between buttock-popliteal length to seat depth and the presence of spinal deformity also calls for the need for school furniture designers to take into account the anthropometric dimensions of Nigerian children and adolescents. The popliteal height-to-seat height mismatch was found in this study to be 78.5%. When students' seats are too high, their feet cannot be supported on the floor and there is increased tissue pressure on the posterior knee thereby leading to discomfort [28]. This rate of mismatch is in tandem with several studies [1, 4, 8, 29]. The mismatch showed a significant association with the presence of abnormal spinal curvatures.

The results of this study also showed that hip breadth to seat width mismatch was present in 59.1% of the participants. Too narrow seats have been reported to cause discomfort, unsteadiness, and mobility constraints leading to wrong posture [1]. The hip breadth to seat width mismatch showed a significant association with the presence of spinal deformities. It has been suggested that upper back pain might be associated with unsuitable backrest [6]; however, in our study, shoulder height to backrest mismatch had the lowest value of 25.4% which indicates that most students had the right backrest height for their seats in support of the study by Dianat et al. [1]. It is important that the issue of mismatch is addressed in order to forestall a situation where children develop a deformity and discomfort in their adult life. It has been suggested for instance that people who had scoliosis as children may be more likely to have chronic back pain as adults, especially if their curves are large and not managed [30]. Our results showed that most of the children had mild scoliosis; however, it has been established that most cases of scoliosis are mild but some curves worsen as children grow since scoliosis is a progressive condition that tends to worsen with age with an estimated increase in curvature of approximately 0.82° per year [31].

It may thus be suggested that if these mismatches are addressed, there will be a reduction in the prevalence of spinal deformities which will have positive effects on school performance as well as the motor skills of school-age adolescents [32]. The main cause of mismatch is using a homogeneous size of furniture for all students coupled with non-consideration of the students' anthropometric dimensions during furniture manufacturing.

Conclusion

There is a high prevalence of spinal deformity, especially scoliosis among the students which can be attributed to the widespread mismatch between the furniture used by the school students and their anthropometric characteristics. This may be responsible for the increasing occurrence of spinal deformities among adolescents. Our findings underscore the need for consideration of students' anthropometric parameters in allocating and designing school furniture. Therefore, there is an urgent need to document the normative values of anthropometrics variables of Nigerian children and adolescents which will form the references for the construction of furniture for school use.

Limitation of study

The fact that the observed spinal deformities could be due to some other factors was not ascertained so it was assumed that the discomfort experienced by the students was due to the effect of the furniture/anthropometry mismatch.

Abbreviations

BMI	Basic metabolic index
CA_L	Cobb's angle for lordosis
CAT	Cobb's angle for thoracic curve
FA_L	Flexible ruler angle for lordosis
FAT	Flexible ruler angle for kyphosis
KA	Kyphosis angle
LA	Lordosis angle

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Authors' contributions
AIA, CAG, and TOO designed the concept of the study, including the data collection. OJB did the data analysis and statistical analysis, and TOO and AIA did the literature search, manuscript preparation, and editing. All authors reviewed and approved the manuscript. AIA is the "guarantor" for this study.

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Availability of data and materials
The data for this study are available on request.

Declarations

Ethics approval and consent to participate
Ethical approval for this study was obtained from the Institutional Research Ethics Committee of the College of Medicine, University of Lagos, before the commencement of the study, and informed consent was sought from all participants.

Consent for publication
All authors reviewed and approved the manuscript for publication.

Competing interests
The authors declare that they have no competing interests.

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