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A Cross-sectional Study on Exploring Body Mass Index (BMI) as a Cause of Furniture Mismatch among Secondary School Students

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Abstract

Various factors are cause of Mismatch between furniture and body dimension. This study aim to establish Body Mass Index as one of its significance cause. This is a cross-sectional study with a sample size of 640 secondary students from private and public schools in Lagos State, Nigeria. Multistage Sampling Technique was employed with Simple Random Sampling adopted for every stage. Furniture measurement were taken using appropriate equipment and all anthropometry measurement were taken following the recommendation of International Society for the Advancement of Kinanthropometry (ISAK) using the appropriate equipment as well. The data was analysed for descriptive statistics, the frequency statistics, match and mismatch analysis, and Chi Square Test Analysis with statistical significance α set at <0.05.

The descriptive statistics highlighted the mean, median (in a case), standard deviation, minimum and maximum of anthropometry of the students as well the BMI descriptive statistics according to age groups, sex and schools. The results show that BMI of more than half of the students' participants are normal, however, there are underweight (severe malnutrition and moderate malnutrition), overweight and obese within students. Also, the results show mismatches in almost all measurements compared with furniture dimension and outright mismatch in a case. Furthermore, there is an association between most of the BMI, match and mismatches between body measurement and furniture dimension investigated.

Body Mass Index have been established among many as a cause of mismatch between body measurement and furniture dimension. Further research can be carried out to establish other cause of mismatches.

Keywords: Body Mass Index (BMI), Cross-Sectional, Match, Mismatch

Introduction

In the educational context, optimizing the organization of work and study environments for both teachers and students is essential for maximizing productivity and minimizing the risk of musculoskeletal discomfort (Rudolf and Griffith, 2009) [14]. School furniture emerges as a critical element, and the act of sitting becomes integral to the school experience. It has become important that classroom furniture be designed to suit the end users (Siy W *et al.*, 2023) [15]. Ergonomic design concepts should be employed to craft user-friendly furniture that reduces the risk of musculoskeletal pain and fosters good sitting postures (Szeto *et al.*, 2014) [16].

Furniture Mismatch: This is occurs when school furniture such as school chairs, tables, and other furniture does not fit the students' body dimension which might lead to a discomfort and have a potential negative impact on learning and health. School is the place where permanent habits of sitting are formed and settled. Considering this, it is fundamental that school furniture fulfils two fundamental variables: Furniture Form and Dimensions (De Bruin & Castellucci, 2022) [5]. Regarding School furniture dimensions, students are usually exposed to furniture with fixed dimensions, which makes it almost impossible to adjust to the "growing" anthropometrics along their school life and neither does it accommodate multidimensional

fit very well (de Bruin & Castellucci, 2022) [5]. Ergonomic designs that fit the user and reduce the discomfort of the user are based on multiple tools, including the user's anthropometric measurements (Depreli *et al*. 2024) [6]. Anthropometry, which is measurement of human is coined from two Greek word "anthropos" meaning "human" and "metrons" meaning "measure". Anthropometric measurements such as popliteal height, knee height, hip-popliteal length, and elbow height are generally required to determine furniture dimensions that will minimize ergonomic risks (Depreli *et al*. 2024) [6].

Body Mass Index (BMI): The body mass index (BMI) is the metric currently in use for defining anthropometric height/weight characteristics in adults and for classifying (categorizing) them into groups (Nuttall, 2015) [11]. Body mass index (BMI) is an index of weight-for-height for categorizing underweight, normal weight, overweight and obesity in individuals of various category (children, adolescent and adult) and genders. It is calculated as a person's weight in kilograms divided by the square of his height in meters (kg/m^2). According to World Health Organization (W.H.O), BMI can be categorized into underweight (severe malnutrition and modest malnutrition), normal weight, overweight and obese (I, II and III). WHO recommends Body Mass Index (BMI) as the most useful population level measure of underweight, overweight and obesity (Wanghi *et al*. 2021) [9]. Body Mass Index (BMI) helps to estimate the risk of underweight and obesity of examined person (Bobula, 2019) [3].

Secondary School Students: These are individuals who are receiving education after their primary or basic education.

Various factors contribute to the mismatch between school furniture and student body dimensions, such factors that can be internal or environmental (Omotayo *et al*. 2024) [13]. These factors can be investigated as well as it significance effect on the mismatch. The aim of the study is to establish body mass index as one of the cause of mismatch between furniture and body dimension and it significance.

Materials and Method

This is a cross-sectional of 640 students' of age 10 to 17 from selected private and government secondary schools in Lagos State Nigeria. All necessary approval was obtained and consent from the parents and students was obtained as well. The sampling technique adopted was Multistage Sampling with Simple Random Sampling at every stage. The dataset was later grouped into four age groups.

The required anthropometry measurement was carried out on all the participants and all practices follows the recommendation of International Society for the Advancement of Kinanthropometry (ISAK). Also, the measurement of the furniture design follows the standard practice. All measurement for both furniture dimensions and body anthropometry was taken using appropriate tools and instruments.

Body dimensions:

- **Body Height / Stature (cm):** The vertical distance from the floor to highest point of the head (vertex).
- **Body Weight / Mass (kg):** Body mass is the quantity of matter of the body when weighed in a standard gravitational field.
- **Popliteal height:** Vertical distance from the floor to the popliteal angle at the underside of the knee where the tendon of the biceps femoris muscle inserts into the lower leg.
- **Buttock-Popliteal Length:** 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.
- **Hip Breadth:** Horizontal distance of the body measured across the widest portions of the hips.
- **Elbow Height Sitting:** The vertical distance from a horizontal sitting surface to the lowest bony projection of the elbow bent at a right angle with the forearm horizontal.
- **Shoulder Height Sitting:** Shoulder height (sitting): The vertical distance from the horizontal sitting surface to the acronium.

Furniture dimensions:

- **Seat height:** The distance from the floor to the highest point on the front of the seat.
- **Seat depth:** The distance from the back of the seating surface of the seat to its front.
- **Seat width:** The horizontal distance across the sides of the seating surface.
- **Back rest height:** The vertical surface from the seating surface of the seat to the top edge of the back rest.
- **Seat-desk height:** The vertical distance from the seating surface of the seat to the top of the front edge of the desk.

The dataset was analysed for mismatch across age groups using the mismatch formulas. The formulas for different mismatch between furniture dimensions and body measurements are listed below:

Popliteal Height with Seat Height
$0.88\ PH \leq SH \leq 0.95\ PH$ (i)

Buttock-Popliteal Length with Seat Depth
$0.80\ BPL \leq SD \leq 0.95\ BPL$ (ii)

Hip Breadth with Seat Width $HB \leq SW$ (iii)

Backrest Height with Shoulder Sitting Height $0.6\ SHH \leq BRH \leq 0.8\ SHH$ (iv)

Elbow Height Sitting with Seat-Desk Height $EHS \leq SDH \leq EHS + 5$ (v)

The Body Mass Index (BMI) which is the ratio of the body weight/mass in *kg* over the squared body height/stature in *m*, the formula is as follow,

Body Mass Index (BMI):

$$\frac{\text{Body mass (kg)}}{[\text{Stature (m)}]^2} \quad \text{(vi)}$$

BMI was calculated and categorise, Descriptive Analysis was carried out on the BMI, Mismatch Analysis done and Chi-Square (χ^2) Analysis was used to check for association between BMI and the Mismatches, with statistical significance set to $p<0.05$. All the analysis was carried out on SPSS v25.0 and MS-Excel.

Results

In the results below, Table 1 show the frequency and percentage of students participated in the study. From the table there are 338 females and 302 males with 52.8% and 47.2% respectively. In the school category, there slightly more students from public school than private school with

fewer male in participants in public school than female and more participant male than female in private school.

Table 2 highlighted the descriptive statistics (mean, standard deviation, minimum and maximum) of the students' participants. It show the statistics based on sex and school categories. Female student participants have higher average value in all body dimensions in all school, however, the average age value is slightly different among others.

Table 1: Frequency table of students based on gender and school category

		Frequency	*Percent*
Sex	Male	302	47.2
	Female	338	52.8
Private School	Male	175	55.0
	Female	143	45.0
	Sub-Total	318	100.0
Public School	Male	127	39.4
	Female	195	60.6
	Sub-Total	322	100.0
Total		**640**	**100.0**

Table 2: Descriptive Statistics of students' participants based on school category and sex

	Male						**Female**					
	Private School			**Public School**			**Private School**			**Public School**		
	Mean ± Std. Dev.	*Min.*	*Max.*	*Mean ± Std. Dev.*	*Min.*	*Max.*	*Mean ± Std. Dev.*	*Min.*	*Max.*	*Mean ± Std. Dev.*	*Min.*	*Max.*
Age	13.46 ± 2.34	10	17	13.57 ±2.3	10	17	13.62 ±2.24	10	17	13.42 ±2.23	10	17
Weight (*kg*)	28.58 ± 4.90	20.2	39.7	29.42 ±5.24	20	39.9	37.65 ±6.13	26.7	49.8	38.31 ±6.48	28.2	49.9
Height (*cm*)	130.31 ± 4.81	120.1	140	130.15 ±4.05	120.4	139.5	135.09 ±9.46	111.7	149.8	135.82 ±10.49	110.1	150
BMI	18.41 ± 3.44	10.4	25.8	18.7 ±3.68	11.1	28.9	19.09 ±3.9	10.3	28.8	18.25 ±3.57	10.7	28.5
SHS (*cm*)	55.41 ± 10.52	37	74.6	56.83 ±9.94	39.6	74.7	67.58 ±5.28	55.5	77	68.37 ±4.99	60	77
EHS (*cm*)	32.89 ± 2.73	28.08	38	32.84 ±2.89	28.07	37.74	36.92 ±2.14	28.04	40	37.47 ±1.46	35.03	40
BPL (*cm*)	33.05 ± 3.54	27	39	33.17 ±3.61	27.3	38.8	37.12 ±4.15	27.1	43.9	37.04 ±3.72	31	43.9
HB (*cm*)	33.97 ± 2.28	30	37.9	34.25 ±2.26	30	37.9	38.01 ±2.57	30.2	42	38.53 ±2.05	35	42
PH (*cm*)	38.32 ± 1.68	35	41.8	38.68 ±1.66	35.1	42	42.06 ±1.75	37.4	45	42.58 ±1.5	40	45

(*PH= Popliteal Height, HB=Hip Breadth, BPL=Buttock Popliteal Length, SHS=Shoulder Height Sitting, EHS=Elbow Height Sitting, BMI=Body Mass Index*)

Table 3 shows the descriptive statistics of Body Mass Index (BMI) of students in age groups, sex and schools. It display the mean (± standard deviation), median, minimum and maximum values of the BMI of the participants. There are slight differences in average values and median in each age groups, sex and schools.

Table 4 highlight the frequency and percentage of BMI categories of the students according to schools. From the table, severe and moderate malnutrition is present in both private and public schools as well as overweight, however a small percentage are obese 1.3% and 1.2% in private and public school respectively.

Table 5 show the frequency of BMI categories of participants as well as the age groups of the participants based on schools and sex. It highlight the BMI categories based on sex of the students' participants in both private and public school. It also shows the students' participant composition based on age group.

Table 6 highlight the frequency of match and mismatch and the dimension compared based on schools. It show the frequency and the percentage of the match and mismatches (low mismatch and high mismatch).

Table 3: Descriptive Statistics of Body Mass Index of students based on school category, age groups and sex

		Body Mass Index							
		Private School				**Public School**			
	Age Group	*Mean ± Std. Dev.*	*Median*	*Min.*	*Max.*	*Mean ± Std. Dev.*	*Median*	*Min.*	*Max.*
Male	10-11	15.38 ± 2.39	15.5	10.4	21.3	15.42 ± 2.48	15.8	11.1	19.6
	12-13	19.18 ± 2.82	19.0	14.1	24.6	20.13 ± 2.38	20.0	15.0	24.7
	14-15	20.83 ± 2.75	20.7	16.1	25.8	20.90 ± 3.52	20.4	15.3	28.9
	16-17	18.87 ± 3.20	18.6	13.1	24.9	18.17 ± 3.62	17.6	12.9	25.5
Female	10-11	15.40 ± 2.26	15.8	10.3	19.5	15.27 ± 2.49	15.1	10.7	20.0
	12-13	19.35 ± 2.73	19.4	14.8	24.9	18.63 ± 2.94	17.9	13.9	24.9
	14-15	21.52 ± 4.18	21.5	13.8	28.8	20.27 ± 3.54	19.95	13.0	28.5
	16-17	19.41 ± 3.47	20.1	13.8	25.3	18.93 ± 3.21	18.75	13.5	26.4

Table 4: BMI category of students based on school

	Private School		**Public School**	
BMI Category	*Frequency*	*%*	*Frequency*	*%*
Severe Malnutrition	18	5.7	26	8.1
Moderate Malnutrition	24	7.5	29	9.0
Normal	209	65.7	213	66.1
Overweight	63	19.8	50	15.5
Obese	4	1.3	4	1.2
Total	318	100.0	322	100.0

Table 5: Frequency of students BMI category based on schools and sex

		Sex		Total
Schools	**BMI Category**	Male	Female	
Private School	Severe Malnutrition	14	4	18
	Moderate Malnutrition	11	13	24
	Normal	112	97	209
	Overweight	38	25	63
	Obese	0	4	4
	Total	**175**	**143**	**318**
Public School	Severe Malnutrition	16	10	26
	Moderate Malnutrition	12	17	29
	Normal	71	142	213
	Overweight	26	24	50
	Obese	2	2	4
	Total	**127**	**195**	**322**

Table 6: Frequency of mismatch of dimensioned compared based on school categories

		PH and SH		**HB and SW**		**BPL and SD**		**SHS and BRH**	
School Category		*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*
Private School	LM	0	0.0	121	38.1	103	32.4	27	8.5
	M	157	49.4	24	7.5	148	46.5	285	89.6
	HM	161	50.6	173	54.4	67	21.1	6	1.9
	Total	**318**	**100.0**	**318**	**100.0**	**318**	**100.0**	**318**	**100.0**
Public School	LM	3	0.9	141	43.8	127	39.4	30	9.3
	M	204	63.4	32	9.9	141	43.8	282	87.6
	HM	115	35.7	149	46.3	54	16.8	10	3.1
	Total	**322**	**100.0**	**322**	**100.0**	**322**	**100.0**	**322**	**100.0**

(PH= Popliteal Height, SH=Seat Height, HB=Hip Breadth, SW=Seat Width, BPL=Buttock Popliteal Length, SD=Seat Depth, SHS=Shoulder Height Sitting, BRH=Backrest Height, LM=Low Mismatch, M=Match, HM=High Mismatch)

Table 7 show the frequency and percentage of mismatch of elbow height sitting and seat-desk height for both public and private schools.

Table 7: Mismatch of elbow height sitting and seat-desk height

		EHS and SDH	
School Category		*Frequency*	*%*
Private School	HM	318	100.0
Public School	HM	322	100.0

(EHS=Elbow Height Sitting, SDH=Seat-Desk Height, HM=High Mismatch)

Table 8 show the association between the mismatches results and Body Mass Index (BMI). The chi value (value), degree of freedom (df) and the p-value were shown in the table. With same degree of freedom (df) for all, there are difference in the chi values across all and the p-value shown significance in all except at Shoulder Height vs. Backrest Height Mismatch Result and BMI.

Table 8: Chi-Square (χ^2) Analysis between mismatch results and BMI

	Chi-Square (χ^2) Analysis Table		
Match Results and BMI	*Value*	*df*	*p-value*
Popliteal vs. Seat Height Result and BMI	19.52	8	0.012
Hip Breadth vs. Seat Width Result and BMI	20.80	8	0.008
Buttock Popliteal Length vs. Seat Depth Result and BMI	15.84	8	0.045
Shoulder Height vs. Backrest Height Result and BMI	9.52	8	0.300

Discussion

This study was aimed to identify Body Mass Index as a cause of match and mismatch between furniture and body dimension and the significance. Table 1 highlight the frequency and percentage of students' participant based on schools and sex. In total, there are 52.8% female participants while 47.2% is male participants. In school category, there are 318 and 322 students participants from private and public school respectively while male students are 55% and female students are 45% of participants from private school, female students' are 60.6% and male student students are 39.4% of participants from public school. This indicated that more female students participated in the public school than their male counterpart and it is otherwise for the private school students' participant.

Table 2 show the descriptive statistics of the age and anthropometry variable according to schools and sex. The average weight and height of female student participants is higher than that of male participants across schools. There are slight differences between the average BMI values for both sex based on schools. Other anthropometric measurement averages are higher for female student participants than male across schools.

Table 3 also the descriptive statistics (mean, standard deviation, median, minimum and maximum) of students' participants in age groups, sex and schools. However, there are slight difference in the values of averages and median in each age groups, sex and schools.

Body Mass Index (BMI)

The Body mass index allows to determine the state of nutrition through mathematical calculations obtained on the basis of anthropometric measurements of height and body weight (Bobula, 2019) [3]. World Health Organization (W.H.O) recommends Body Mass Index (B.M.I) as the most useful level measure of underweight, overweight and obesity (Wanghi *et al*. 2021) [9]. Table 4 show the BMI category of students' participants based on school. At both

private school and public school majority of the students' participants are normal weight 65.7% and 66.1% at frequency 209 and 213 respectively for both schools. Severe and moderate malnutrition account for 12.12% and 17.1% for public school and private school with cumulative frequency of 42 and 55 for both school. Overweight and Obese is 19.8% and 1.3% for private school with frequency of 63 and 4 for both category. For public school, overweight and obese is 15.5% and 1.2% with frequency of 50 and 4 for both category as well. This point to the fact that majority of the students' participant are normal weight in consistent with Atikovi *et al*. 2014, however there is presence of severe and moderate malnutrition among students. Furthermore, there is more overweight and obese students among students' participants than underweight (severe and moderate malnutrition). In continuation, Table 4 was subjected to further explanation for sex, as shown in Table 5. In private school, males have higher frequency in all BMI category than female except at obese where all students' who are obese and moderate malnutrition. In contrast to private school, female students in public school have more frequency in moderate malnutrition and normal weight, while male are more in severe malnutrition and overweight, however both are same in obese. The results indicated a relationship between gender and BMI in consistent with Gaylis *et al*. 2019.

Match and Mismatch

Anthropometric measurements were analysed using established criterion equations and compared with furniture dimensions to identify potential mismatches. A match implies compatibility, and a mismatch indicates incompatibility between furniture and user dimensions (Odunaiya *et al.*, 2014) [12]. The match and mismatch (low and high) of body measurements and were calculated and was referenced with the acceptable range, Table 6 and 7 show the low mismatch, match and high mismatch of the furniture dimension and body measurements for both schools. In PH and SH, there is 50.6% mismatch in private school and cumulative 36.6% mismatch in public school. Cumulative 92.5% is mismatched between HB and SW for private school while 90.1% is mismatched for public school. There is cumulative 53.5% mismatch in BPL and SD in private school, while cumulative 56.2% mismatch in public school. While there is significant match in SHS and BRH for both private schools 89.6% and public school 87.6%, there is outright mismatch for both private school and public school in EHS and SDH, in consistent with Aiyegbusi *et al*. 2023.

Chi-Square Analysis on Association

Chi-Square (χ^2) was carried out to check the association between BMI and the Match and Mismatches outcome as shown in Table 8. From Table 8, there is same degree of freedom (df) 8 for all. The chi value of Popliteal Height vs. Seat Height Result and BMI is 19.52 with p-value 0.012 which is lesser than 0.05. The chi value of Hip Breadth vs. Seat Width Result and BMI is 20.80 with p-value 0.008 which is lesser than 0.05. The chi value of Buttock Popliteal Length and Seat Depth Result and BMI is 15.84 with p-value 0.045 which is lesser than 0.05. However, the p-value of Shoulder Height and Backrest Height Result and BMI is 0.30 greater than 0.05 with chi value 9.52.

This implies that, for the first three, there was an association which is statistically significant. This indicated that body measurements of the student is the reason of match and mismatch with the furniture dimensions.

Conclusion

This study is to identify BMI as a significant cause of match and mismatch between body measurements and furniture dimensions in secondary schools. Students spend close to 40% of their day at school, with most time sitting. However, furniture provided are fixed and does not go along with the student body dimensions. As shown in the results, more than half of the students are normal weight, while there exist underweight and overweight as well. The furniture dimensions provided by school for the students are largely mismatch with their various body measurements. BMI have been identified as one of the cause of the mismatch and its significance have been establish. In view of the above, students anthropometry measurement must be put into consideration before making furniture at school. Policy should be make toward data availability on students' anthropometry measurement. Flexible and adjustable furniture should be provided for students' in accordance with their body measurements.

Conflict of Interest

Conflicting interest not declared by authors.

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