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Utility of Anthropometric Tools in Determining Obesity in Children

[1]Oni O.O., [2]Alaofin W. A.,[3]Sefogah P., [4]Mogre V., [5]Bamidele T., [6]Ayettey H.A.

[1]Department of Medicine, Ladoke Akintola University of Technology, Ogbomoso, [2]Department of Medicine, University of Ilorin Teaching Hospital, Ilorin, [3]Department of Obstetrics and Gynaecology,Korle Bu Teaching hospital, Accra, [4]Department of Health Professions Education and Innovative Learning, School of Medicine, University for Development Studies, Tamale, [5]Department of Public Health Sciences, Loyola University Chicago, Maywood, Illinois, [6]National Radiotherapy Oncology and Nuclear Medicine Centre, Korle Bu Teaching Hospital, Korle Bu, Accra

Corresponding Author: Dr. Opeyemi Oni;oniopeyemi64@gmail.com

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Dr. Opeyemi Oni

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ABSTRACT

Background: Measurement of excess body fat objectively requires the use of investigations like Dual Energy X-ray Absorptiometry (DEXA), Computed Tomography and Magnetic Resonance Imaging, which are generally not easily accessible, expensive and may involve exposure to radiation. Anthropometric tools have been used to evaluate Obesity with various levels of sensitivity. We therefore set out to determine the predictive ability of Body mass index (BMI), waist circumference and waist to height ratio (WHtR) in determining Obesity in children.

Methods: Students in classes 4 and 5 from four different primary schools in Kwara State, North Central Nigeria were recruited after ethical clearance was obtained from the Ethical Review Board of the State. Height, weight, and waist circumference were measured. Percentage body fat was measured using a Tanita (BC-543 model) bioimpedance scale. Statistical analysis was done using SPSS version 20.

Results: A total of 202 pupils from four randomly selected primary schools (2 private and 2 public schools) within the Ilorin metropolis, Kwara State, were recruited for the study consisting of 90 males and 112 females. Prevalence of obesity and central obesity using body fat from bioimpedance and WHtR were 4.95% and 11.4% respectively. Waist circumference, BMI and WHtR correlated well with percentage body fat in determining obesity. The area under curve was 0.853 for WHtR, 0.871 for WC and 0.930 for BMI (P value for all: <0.001)

Conclusion: WHtR, WC and BMI are very good tools for determining obesity in children and can be used as surrogates for determining excess body fat.

Key words: Forced Vital Capacity, Forced Expiratory Volume, Stroke, Spirometry, Respiratory Muscles

1. INTRODUCTION

Cardiovascular diseases are the top causes of death and morbidity globally. Obesity is one of the common causes of cardiovascular diseases that can be diagnosed early in life. In 2022, 2.5 billion adults aged 18 years and older were overweight, including over 890 million adults who were living with obesity. Over 390 million children and adolescents aged 5–19 years were overweight in 2022, including 160 million who were living with obesity[1]. Degree of adiposity has been shown to predict health outcomes[2,3]. Hydrodensitometry, Dual Energy X-ray Absorptiometry and Magnetic Resonance Imaging have been considered as Gold standards for measuring Obesity[4]. However, Bioelectric Impedance Analysis (BIA), as a tool of assessing Obesity, has been considered to be accurate and has been utilized as a yardstick for assessing adiposity of people[5,6]. Bioelectrical impedance devices are generally more expensive than simple weighing scales and stadiometers, and are relatively cumbersone to use. So, utilizing anthopometric tools that are comparable and can possibly replace Bioelectrical impedance in measuring excess body fat would be beneficial to health care workers and epidemiologists, especially those who work on the field.

Waist to height ratio (WHtR) and Body Mass Index (BMI) are anthropometric tools that have been

Table 1: Demographics and Anthropometric Characteristics of the Students With and Without Obesity (as Defined by Percentage Body Fat)

Variables	Obese n=10	Not Obese n=192	P- Value
Age	8.6±1	10.3±2.3	0.025
School Type			
Public	1(0.97)	102(99.03)	0.009
Private	9(9.1)	90(90.9)	
Schools			
Public School 1	1(1.96)	50(98.0)	0.030
Public School 2	0(0)	52(100)	
Private School 1	6(10.9)	49(89.1)	
Private School 2	3(6.8)	41(93,2)	
Sex			
Male	6(6.6)	84(93.3)	0.313
Female	4(3.6)	108(96.4)	
Waist to Height Ratio			
Obese	6(26.1)	17(73.9)	<0.001
Not Obese	4(2.2)	175(97.8)	
Weight (kg)	45.5±10.5	31.4±6.4	<0.001
Height (cm)	141.3±10.3	138.9±9.5	0.433
Body Fat %	33.7±5.7	15.1±5.2	<0.001
Waist Circumference(inches)	31±4.4	25.2±2.3	<0.001
Waist to Height Ratio	0.55±0.08	0.45±0.04	<0.001
Body Mass Index (kg/m^2)	22.8±4.8	16.2±2.2	<0.001

Table 2: Demographics of the Students Used for the Study-Central Obesity Defined by Waist to Height Ratio (WHtR≥0.5)

Variables	Central Obesity n=23	No Central Obesity n=179	P- Value
Age	8.9±1.0	10.3±2.3	0.005
School type			
Public	4(3.9)	99(96.1)	0.001
Private	19(19.2)	80(80.8)	
Sex			
Male	10(11.1)	80(88.9)	0.912
Female	13(11.6)	99(88.4)	
Percentage Body Fat			
Obese	6(60)	4(40)	<0.001
Not Obese	17(8.9)	175(91.1)	
The Schools			
Public School 1	4(7.8)	47(92.2)	0.003
Public School 2	0(0)	52(100)	
Private School 1	11(20)	44(80)	
Private School 2	8(18.2)	36(81.8)	
Weight Parametres			
Weight (Kg)	36.4±11.4	31.5±6.7	0.003
Height (cm)	135.5±7.1	139.4±9.7	0.060
Body Fat%	25.2±8.5	14.8±5.3	<0.001
Waist Circumference (inches)	29.6±3.3	24.9±2.1	<0.001
Waist to Height Ratio	0.55±0.05	0.45±0.03	<0.001
Body Mass Index (kg/m^2)	19.6±5.0	16.1±2.2	<0.001

shown to not be gender biased in assessing adiposity, unlike Waist circumference, Waist-Hip Ratio and Waist-Thigh Ratio[7,8]. Both tools are easy to measure both in clinic settings and public health settings. The body mass index has been widely used and accepted in both clinical and public health settings as tools for assessing excess or inadequate body weight. However, the 2025 NICE guideline stated that BMI should be used as a measure of overweight in adults but must be interpreted with caution because it is not a direct measure of adiposity[9]. The waist to height ratio, on the other hand, appears to be a measure of central obesity. However, the accuracy of one over the other has not been well elucidated. Body mass index is the most commonly used index for screening and detecting obesity and being overweight in both hospital and public health settings, being relatively easy to compute from just two variables. There are several reference data sets available as BMI cut-off values in children and adolescents, three of the most widely used are as follows:

World Health Organization (WHO) using Z score and standard deviation based on multicenter data collected globally and designed for two age ranges; 0–5 and 5–19 years old[10].

United States Center for Disease Control and Prevention (CDC) based on age-gender specified BMI percentiles in North America.[11]

International Obesity Task Force (IOTF), which defined BMI cut-off points based on data from six different countries by matching childhood BMI percentiles to adult cut-off values of 25 and 30 kg/m2 at the age of 18, using the Lambda-Mu-Sigma (LMS) method[12].

Although studies have shown discordance in reported prevalence of obesity between BMI definition systems[13,14], there is no consensus on which system is the most accurate[15]. The objectives of this study was to determine the utility of common anthropometric tools in evaluating obesity.

2. MATERIALS AND METHODS

The study was a community-based multicenter, cluster cross-sectional study that was conducted in September 2021 in two private and two public primary schools. A list of both public and private schools was obtained from the Ministry of Education and entered into a computer for randomization. School-age children in primary 4 and 5 from the selected schools across urban settings in Ilorin, Nigeria were recruited. The inclusion criteria were that the schools must have at least 50 students in Primary 4 and 5, and informed consent must be obtained from their parents. All children in primary 4 and 5 in the selected schools who met the inclusion criteria were enrolled into the study. The researchers, with the help of research assistants, visited the schools for recruitment, data collection and follow-up purposes. Written informed consent(given by their parents/guardians) was obtained from all subjects. Specific permissions were obtained from the headmasters and headmistresses of the schools to access the teachers and the students. The children were informed about the study through their teachers. Those who agreed to participate gave written assent. The parents of the pupils that participated gave informed consent. Participants were assured that their participation was voluntary, and confidentiality of their data was ensured.

2.1 Sample Size Determination

Using Leslie Kish formula, a minimum sample size of 93 was estimated for the study. Prevalence of obesity (5.8%) in a previous study was used[16]. Tolerable margin of error was set at 5% and a non-response rate of 10% was envisaged among the respondents and corrected for.

2.2 Anthropometric Measurements

Weight and height of the children were measured using an electronic scale according to standard procedures. The weight and percentage body fat of the children were measured using a bio-impedance body monitor manufactured by Tanita (BC-543 model), a bipolar single-frequency (50 kHz) foot-to-foot instrument which has an accuracy of ± 2-3% of DEXA for % body fat and 0.1Kg

Table 3: Correlation of Demographics and Anthropometric Variables With Obesity as Defined by Percentage Body Fat

Variables	Pearson Correlation Coefficient	P value
Age	-0.157	0.025
Body Mass Index	0.534	<0.001
Waist to Height	0.473	<0.001
Waist Circumference	0.458	<0.001

for body weight. Participants were instructed to stand barefoot with heel and forefoot placed on the four metal electrodes. Their height was measured using a stadiometer. Using percentage body fat, values ≥25% in males and ≥ 30% in females was defined as Obesity[17]. Central Obesity was defined as WHtR ≥0.5.

2.3 Statistical Analysis

All data obtained were entered into a standard proforma. Continuous variables were expressed as mean ± standard deviation [SD] while categorical variables were expressed as frequency (percentages). The values of continuous variables (anthropometry, and body composition) were compared using Student's independent t-test. Correlation of percentage body fat was determined using Pearson's correlation coefficient. The area under curve was determined for WHtR, WC and BMI, using the percentage body fat as reference point for obesity. The level of significance was set as P≤ 0.05. SPSS version 20.0 was used for data analysis.

2.4 Data Availability Statement

The data that support the findings of this study are available at https://zenodo.org/records/14066317

3. RESULT

A total of 202 pupils from the four randomly selected primary schools (2 private and 2 public schools) within the Ilorin metropolis were recruited for the study consisting of 90(44.6%) males and 112(55.4%) females. Prevalence of obesity using percentage body fat from bioelectrical impedance analysis was 4.95%. The male: female ratio among those who were obese was 3:2. Ninety percent (90%) of the obese subjects were from Private schools. Waist circumference was increased in those who were obese. A waist circumference ≥ 31 inches has a 60% sensitivity and 98.4% specificity of detecting obesity in this study. Other details are seen in Table 1.

The prevalence of central obesity (as defined by WHtR ratio) was 11.4%. Most of them (82.6%) were from private schools, with a female-male ratio of 1.3:1. Though those with central obesity were younger, it was not statistically significant. Details are seen in Table 2.

Percentage body fat correlated directly with BMI, Waist-to-Height, and WC. It correlates inversely with age. Details are seen in Table 3.

When age and anthropometric measures were correlated with obesity as define by WHtR, age retained its inverse correlation with obesity. Body mass index, Waist to height ratio and waist circumference all correlate strongly with being centrally obese. Details are seen in Table 4

The area under curve was 0.853 for WHtR, 0.871 for WC and 0.930 for BMI (P value for all: <0.001). Details are seen in both Figure 1 and table 5.

Table 4: Correlation of Demographics and Anthropometric Variables With Central Obesity as Defined by Waist to Height Ratio

Variables	Pearson Correlation Coefficient	P value
Age	-0.198	0.005
Body Mass Index	0.393	<0.001
Waist to Height	0.709	<0.001
Waist Circumference	0.538	<0.001

4. DISCUSSION

The prevalence of childhood obesity in this study, using the percentage of body fat, is 4.95%. This is similar to the African prevalence of Obesity in children and adolescents, which was 4.9% in 2018, largely determined by WHO growth reference chart.[18] However, the prevalence as determined by the WHtR cutoff of ≥0.5, is 11.4%, is higher than the African prevalence. The prevalence quoted by various studies vary widely, as various tools like percentage body fat, BMI, DEXA and MRI have been used. Excess body fat has been shown to be deleterious to health. The distribution of excess fat has also been shown to be important, being closely linked to cardiovascular diseases like Diabetes Mellitus, Hypertension and Dyslipidaemia.[19]

Waist to height ratio has been postulated to be a determinant of central obesity and should be a better predictor/estimator of cardiovascular risk than the BMI.[8] It has three advantages over the BMI- it takes the central obesity into account, is cheaper to measure, and is largely independent of age[20,21]. Indeed, studies have shown that WHtR is a predictor/correlate of hypertension and diabetes mellitus in adults.[22] Waist to height ratio also has been shown to be an independent predictor of nonalcoholic fatty liver disease by Ozhan et. al.[23]

Waist to Height ratio was shown to be better than BMI in identifying metabolic risk, including hypertriglyceridaemia, hypercholesterolaemia and hyperglycaemia, in Mexican school children.[24] Still in Mexico, WHtR was found to be better than other anthropometric measures in determining elevated low density lipoprotein only- it was not better at detecting other lipid fractions.[25] However, BMI of children and adolescents has been shown to outperform WHtR in predicting insulin resistance and fasting plasma glucose, independent of age and gender.[26] A meta-analysis showed neither WHtR nor BMI is superior to each other in measuring excess body fat.[27]

In our study, waist circumference had the second largest area under curve in determining obesity. Waist circumference outperformed Waist-hip ratio, WHtR and BMI in predicting Metabolic

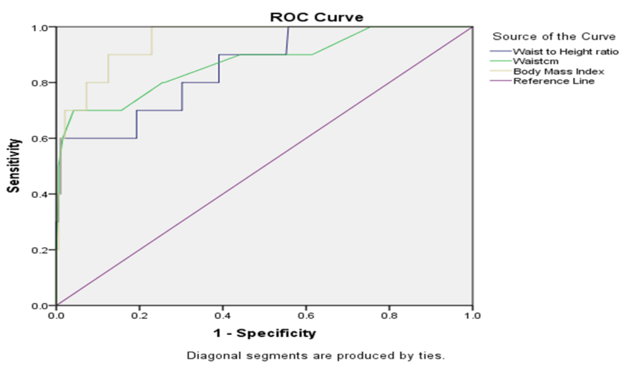

Figure 1: Area Under Curve for Predicting Obesity using Bioimpedance– Determined Excess Body Fat

Table 5: Area Under Curve (AUC) Values for Predicting Obesity Using Percentage Body Fat

Variables	Area	P value	Confidence Interval
Waist to Height Ratio	0.853	<0.001	0.731-0.976
Body Mass Index	0.952	<0.001	0.904-1.000
Waist Circumference	0.871	<0.001	0.734-1.000

syndrome among adults in Qatar.[28] Bluher et al also showed that waist circumference was the best(as compared to BMI and WHtR) in predicting elevated liver transaminases, serum lipids and uric acid.[26] However, waist circumference cut off points for determining Obesity in children has not been well defined, unlike in adults. Waist circumference values ≥31inches in children > 5years showed excellent specificity in this study, but only fair sensitivity, making it a poor screening tool in the general populace, but good in confirming obesity in suspected cases.

Most of the subjects with Obesity were from private schools, which is not a surprise, as the elite of the society usually send their children to private schools where the Teacher-student ratio is standard and the quality of the teaching is supposed to be better than the public schools. Mushtaq et al also found that Obesity correlated with higher social economic status, higher parental education, schooling in urban areas, higher school grade or class and living in high income neighbourhoods.[29]

4.1 Conclusion

The high area under curve values of WHtR, BMI and WC suggest that they are all very good tools for estimating obesity. Therefore, they can be used as surrogates for estimating body fat in the place of bioelectric impedance, which is more expensive and cumbersome to measure. Reference values for determining obesity using waist circumference should be determined in larger studies

Limitation

Bioelectrical impedance analysis has been shown to underestimate percentage body fat in comparison with DEXA.[30]

Author Contribution

All authors were involved in the conceptualization of the study. OOO and WA conducted the emperical research. OOO wrote the initial draft, cured the data analyzed the data. HA and BT helped acquire funding, validated and supervised this work. Writing-Review and Editing was done by OOO, HA and BT

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