SHORT REPORT

Utility of anthropometric indicators of body fat thresholds for detecting metabolic syndrome risk in North Central Nigerian youth

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ABSTRACT

The diagnostic performance of anthropometric indicators of obesity that better predicts metabolic syndrome (MetS) risk in Nigerian adolescents is not clear. This study examined the diagnostic precision of body fat indicators that would better identify the risk of MetS in north central Nigerian adolescents, aged 11 to 19 years. This cross-sectional study comprised 206 adolescent boys (101) and girls (105) from Kogi East, North Central Nigeria. Participants were evaluated for five indices of body fat, fasting blood glucose, triglycerides, high density lipoprotein cholesterol and systolic blood pressure. Receiver operating characteristic curve (ROC) analysis was used to determine the predictive capacities of the body fat proxies to detect the risk of MetS. The prevalence of MetS was 5.8% (Girls=3.4%; Boys=2.4%). Waist circumference (WC), waist-to-height ratio (WHtR) and conicity index (C-index) had significant ($p<0.001$) areas under the curve (AUC), with WC (AUC: girls=91.7%; boys=91.3%) as the best body fat indicator for identifying risk of MetS in both sexes. Relative fat (%Fat) and body mass index (BMI) had no discriminatory capacities to detect MetS risk in participants. This study has demonstrated that WC is the best tool for identifying MetS risk in Nigerian adolescents, while WHtR and C-index are reasonable second and third choices, respectively. It is recommended that public health professionals should use WC for preliminary screening for risk of MetS in Nigerian adolescents prior to referral for confirmation and medical follow-up.

Key words: abdominal obesity, adolescents, anthropometry, MetS, ROC curve

INTRODUCTION

The clustering of cardio metabolic risk factors in the same person is referred to as metabolic syndrome (MetS). These risk factors include central obesity, hypertension, hyperglycemia, hypertrigly-ceridemia and low high density lipoprotein cholesterol (HDL). The MetS has become a major public health problem globally, increasing the chances of developing cardiovascular disease (CVD), Type 2 diabetes mellitus (T2DM) and some forms of cancer in adults.[1] Although the clinical endpoints for cardio metabolic disease (CMD) rarely occur in pediatric population, the development of atherosclerotic streak has been shown to originate in childhood and adolescence and progresses into adulthood.[2] From a public health perspective, it is important and beneficial to identify youth at risk of MetS for the purpose of early prevention and thus reduction in morbidity, mortality and public health expenditure later in life.

One of the recognized predisposing factors for MetS in the pediatric population is excess adiposity.[3] In epidemiological studies, body mass index (BMI) has been the most widely used estimate of total body fat.[4,5] Waist circumference (WC), waist-to-height ratio (WHtR) and of recent, conicity index (C-index) have also been used as estimates of central fat, with potential risk for CMD in adolescents.[6,7] However, studies assessing the power of body fat indicators to identify MetS have produced conflicting results. De Oliveira and Guedes[8] reported WHtR as body fat index with the best discriminatory capacity, with WC and BMI as alternatives. Some investigators[8] found WC with the best predictive power. Yet, others[9] found BMI as the best predicator of MetS. These conflicting results call for further studies to clarify which body fat proxy best predicts MetS in adolescents.

Screening of MetS involves invasive laboratory techniques which are not only expensive and require technical expertise but are not practical in a school setting, especially in low-income countries. Therefore, more cost-effective procedures such as the use of anthropometric data to identify MetS are warranted. This becomes necessary in a resource-limited setting, like schools especially in developing countries. Although, many studies using anthropometric methods to screen for CMD have been conducted in different ethnic groups,[10,11] this may not be applicable to African adolescents due to different patterns of development. Added to this, information on the anthropometric indicator of body fat that best predicts MetS in African adolescents is scarce, hence the need for the present study.

The purpose of this study was to determine the diagnostic accuracy of five anthropometric proxies of body fat (BMI, %fat, C-index, WC & WHtR) in detecting risk of MetS in Nigerian adolescents. A secondary purpose of the study was to examine the association of body fat indicators with risk of MetS in Nigerian adolescents. The ability of each body fat proxy to distinguish between presence and absence of MetS risk among adolescence will be of public health importance.

METHODS

Study design and sample

This is a cross-sectional study comprising 206 apparently healthy secondary school girls (114) and boys (92) aged 11 to 19 years drawn from two secondary schools (private and public) in Kogi East Senatorial District, Kogi State of Nigeria. The study was cross-sectional conducted between September and November, 2019 just before the covid-19 pandemic. Participants were selected using probability sampling procedure. Specifically, the students were systematically selected from the class register in which every 4th student beginning from a particular number on the list was selected to participate in the study. Details of the sampling procedure and criteria for including or excluding participants have been previously described.[12] Written informed consent of parents and assent of minors were obtained before data collection.

Data Collection

Physical characteristics of participants were measured using standard procedures.[13] Body mass and stature were measured indoors with the aid of an electronic weighing scale (Seca digital floor scale, Sec-880; Seca, Birmingham, UK) and a potable stadiometer (Model Sec-206; Seca, UK) respectively. Participants' body mass index (BMI) was computed and expressed as weight in kilograms divided by stature in meters ($kg.m^{-2}$). Both the triceps and medial calf skinfold thickness was measured on the right side of participants' bodies with the aid of the Harpenden Skinfold Calipers (Creative Health Products, MI, USA). All measurements were taken thrice and the median of the three readings recorded. The revised regression equations of Slaughter et al, as cited[14] for black children, were used to estimate percent fat. Waist circumference (WC), an estimate of abdominal fat, was measured with a retractable metal tape (Creative Health Products, MI, USA) at the level of umbilicus and midway between the lower rib margin and the iliac crest. Readings were taken at the end of a quiet expiration to the nearest 0.1cm. Two measurements were taken and the average score recorded. The WHtR was calculated by dividing the WC in centimeters by stature in centimeters. The C-index, an estimate of central fat was obtained by the following equation:[15]

$$\text{Conicity index} = \frac{\text{waist circumference } (m)}{0.109\sqrt{\frac{\text{body weight } (kg)}{\text{height } (m)}}}$$

Twelve-hour overnight fasting blood glucose (FBG), HDL and TG were obtained through finger stick blood samples analyzed with a CardioCheck Plus Analyzer (CCPA) (PTS Diagnostics, Indianapolis, IN, USA). The CCPA is a valid and reliable instrument for analyzing blood glucose (GLU) and lipids.[16] Details of the protocol have been previously described.[12]

Resting systolic blood pressure (SBP) and diastolic blood pressure (DBP) levels were measured on each participant's right arm using appropriate cuff sizes with an oscillometric device (HEM-705 CP; Omron, Tokyo, Japan) after sitting quietly for 5 minutes. Measurements were taken three times at 2-minute intervals, and the average of the three readings recorded. Blood pressure cut-off point for hypertension (HTN) was based on the standards of the Fourth Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents 2004.[17]

Continuous metabolic risk score

A continuous MRS was computed from the following variables: GLU, SBP, HDL, and TG. Each of these variables was standardized by subtracting the mean value for each sex group from the individual's value and then dividing the product by the value of standard deviation [z = (value - mean)/SD]. The standardized HDL was inverted because it is inversely related to the MS risk. The z-scores of the individual risk factors were summed to create a clustered MRS (continuous variable) for each participant with a lower score indicating a more favorable metabolic risk profile. This approach has been previously used in the pediatric population.[18] Participants' MetS profile was determined using the criterion of MRS +1SD above the overall mean to represent increased risk of MetS.[19]

Definition of metabolic risks

The criteria used for defining the metabolic risk abnormalities were determined according to the standards of the International Diabetes Federation (IDF)[20] indicated in parentheses: GLU (≥5.6 mmol); HDL (≤ 1.04 mmol); TG (≥1.7 mmol) and WC (90th percentile for age and sex). The standard for SBP (95th percentile for age and sex) was based on the Fourth Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents 2004.[17] The cut-points used for WHtR (0.46), C-index (90th percentile for age and sex) and BMI (95th percentile for age and sex) were those recommended by Meng et al.,[21] Filgueiras et al.[22] and The Cooper Institute[14] respectively.

Statistical Analysis

All analyses were conducted using the Statistical Package for the Social Sciences (Version 20, SPSS Inc, Chicago, IL, USA) at a probability level of 0.05. Data were checked for normality before analyses with the Kolmogorov Smirnov test. Complete data for all variables were available for 206 out of 217 participants, a compliance rate of 95%. Descriptive data were expressed as means ± SDs, frequencies and percentage distributions. Significant differences between adiposity categories for physical characteristics and MetS were determined using independent samples t-test. Pearson's product moment correlation coefficients were used to assess the relationships among the variables. Predictive performances of body fat proxies for risk of MetS were determined through the receiver operating characteristics curve analysis (ROC) with 95% confidence interval (95%CI). Accurate threshold values for detecting MetS risk were determined through area under curve (AUC) values and the best balance between sensitivity and specificity that maximizes the true-positive rate while maintaining the lowest possible false-positive rate. Values of AUC were interpreted using appropriate guidelines:[23] ≥0.90 =excellent, 0.80-0.89 = good, 0.70-0.79 = moderate, <0.70 = poor.

Ethical Clearance

All tests were conducted from 9 AM to 12 Noon in accordance with the principles of Helsinki Declaration after prior approval was received from the Ethical Review Committee of The College of Health Sciences (ID: COHS/02/25/2020), Kogi State University, Nigeria. The approval was obtained on the 5th of May, 2019.

RESULTS

Physical and biochemical characteristics of participants are presented in Table 1 stratified according to gender. On the average, girls were significantly heavier (p=0.016), fatter (<0.001) and had greater BMI (p<0.001). There were no significant (p>0.05) gender differences in all other variables. The general characteristics of participants stratified according to MetS risk profile were determined. With the exception of stature (p=0.968) and body fat (p=0.387), participants at risk of MetS had significantly poorer metabolic profile compared to their peers without risk as follows: BMI (p=0.002), WC (p<0.001), WHtR (p<0.001), C-index (p<0.001), SBP (p<0.001), GLU (p<0.001), HDL (p<0.001), TG (p<0.001) and MRS (p<0.001). Participants at risk of MetS were also significantly (p<0.001) older.

The overall prevalence of MetS was 5.8% (Girls=3.4; Boys=2.4). Figure 1 displays obesity prevalence rates determined by body fat proxies. As indicated, the overall prevalence rates for WHtR, WC and C-index were greater than those of BMI and relative fat, and higher in girls than boys generally.

Table1 Physical and biochemical characteristics of participants stratified by gender (n=206)

	Combined	Girls (n = 105)	Boys (n = 101)		
Variable	Mean SD	Mean SD	Mean SD	t-value	*p*
Age (y)	14.7 ±2.3	14.7 ± 2.3	14.8 ± 2.3	0.209	0.835
Body mass (kg)	53.0 ± 12.5	55.1 ± 12.1	50.9 ± 12.5	2.436	0.016
Stature (cm)	160.1 ±9.7	159.5±7.2	160.6±11.8	0.810	0.419
Body fat (%)	15.5 ± 7.0	19.6 ± 7.3	11.1 ± 2.9	11.023	<0.001
BMI (kg.m-2)	20.5 ± 3.5	21.5 ± 4.0	19.4 ± 2.6	4.507	<0.001
WC (cm)	65.8 ± 8.8	66.8 ± 9.4	64.7 ± 8.1	1.744	0.083
WHtR	0.41 ± 0.1	0.40 ± 1.0	0.40 ± 1.0	1.925	0.056
C-index	1.1 ± 0.1	1.1 ±0.1	1.1 ± 0.1	0.850	0.396
SBP (mmHg)	105.5 ± 16.6	107.1±16.8	103.9±16.3	1.379	0.169
DBP (mmHg)	69.9 ± 14.4	69.9 ±15.3	69.8 ± 13.4	0.065	0.948
GLU (mmol)	5.1 ± 0.7	5.0 ± 0.7	5.2 ± 0.7	1.282	0.201
HDL (mmol)	1.3 ± 0.4	1.3 ± 0.3	1.3 ± 0.5	0.610	0.542
TG (mmol)	1.0 ± 0.9	1.1 ±1.2	0.9 ± 0.4	0.979	0.329
MRS	-7.7 ± 2.2	-7.5 ± 2.4	-7.9 ± 2.0	1.328	0.186

Figures 2 and 3 display the AUC for the body fat indices in girls and boys respectively. Gender-specific ROC analyses are presented in Table 2. In girls, WC demonstrated the best discriminatory capacity in distinguishing adolescents with risk of MetS from those without [AUC = 91.7% (95%CI=86.6%-96.7%)]. This was followed by WHtR [AUC = 89.3% (95%CI=82.6%-96.0%)] and C index [AUC = 81.2% (95%CI=72.5%-89.8%)]. The optimal thresholds for WC, WHtR and C-index in girls were 60.5cm, 0.40 and 0.90 respectively. In boys, WC again demonstrated the best discriminatory power for diagnosing MetS risk [AUC = 91.3% (95%CI=85.9%-96.8%)]. Next were WHtR with an AUC of 90.3% (95%CI=84.2%-96.5%] and C-index with an AUC of 86.2% (95%CI=77.9%-94.5%). The optimal thresholds for the three body fat proxies with best discriminatory powers in boys were 59.3, 0.37 and 1.0 respectively. Performance of BMI and Body fat were poor in both genders. Indeed, none was significant (>0.05) in boys. For all the three parameters (in girls and boys), sensitivity was high while specificity was moderate. This implied that the test were good at identifying most of the adolescents at risk of MetS, but also missing out a few participants at risk.

Table 2 ROC curve analysis for risk of metabolic syndrome stratified by gender (n=206)

Group	Variable	AUC	95%CI	Cut-point	Sensitivity	Specificity	p-value
Girls	BMI	0.690	.587-.792	21.2	0.723	0.397	0.001
	% Fat	0.603	.494-.712	18.5	0.596	0.431	0.071
	C- index	0.812	.725-.898	0.90	0.830	0.672	<0.001
	WC	0.917	.866-.967	60.5	0.936	0.414	<0.001
	WHtR	0.893	.826-.960	0.40	0.915	0.310	<0.001
Boys	BMI	0.592	.478-.706	18.6	0.591	0.544	0.115
	% Fat	0.500	.387-.614	10.6	0.523	0.456	0.997
	C- index	0.862	.779-.945	1.00	0.864	0.386	<0.001
	WC	0.913	.859-.968	59.3	0.909	0.439	<0.001
	WHtR	0.903	.842-.965	0.37	0.932	0.439	<0.001

The correlations between MRS and the independent variables adjusted for age were generally moderate, particularly with the WC (r=0.714, p<0.001), WHtR (r=0.683, p<0.001) and C-index (r=0.530, p<0.001) in girls, and also in boys [WC (r=0.752, p<0.001); WHtR (r=0.703, p<0.001); C-index (r=0.667, p<0.0005)]. Body fat and BMI were weakly related to the dependent variable.

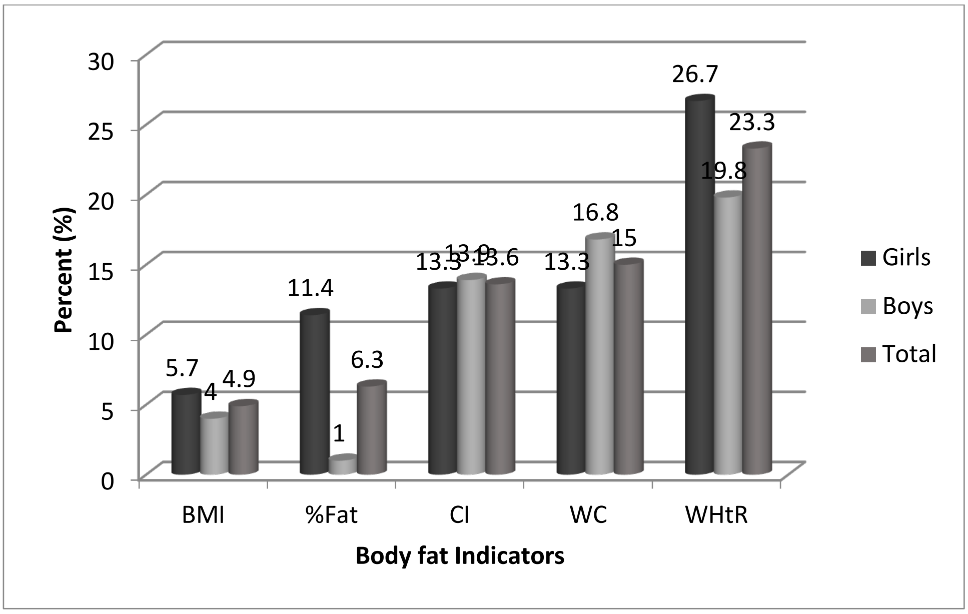

Figure 1 Prevalence of obesity determined by body fat indicators

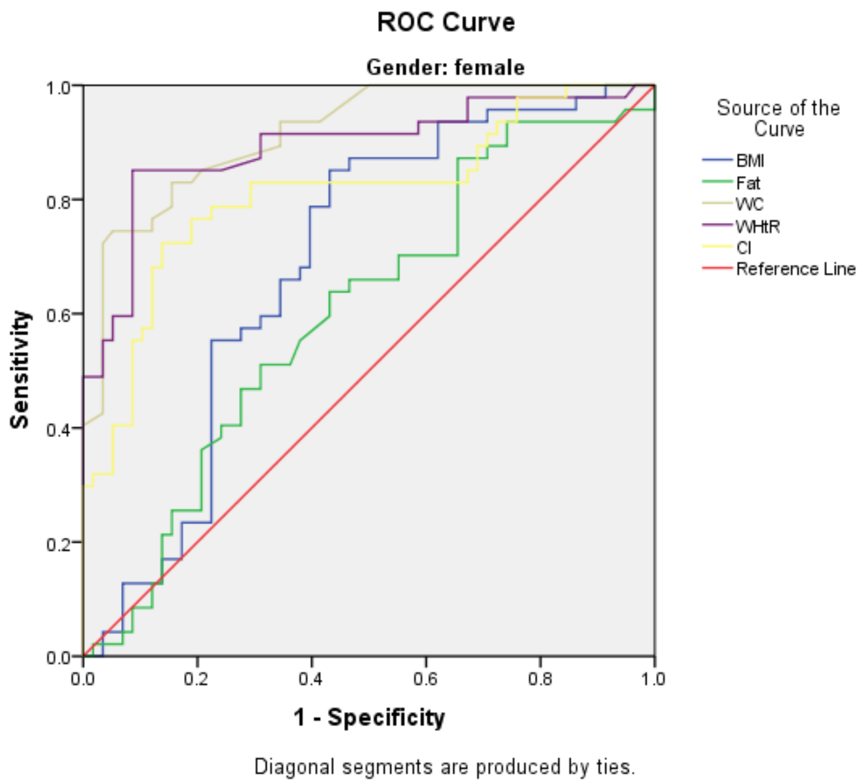

Figure 2 Areas under the curve for the body fat indicators in girls

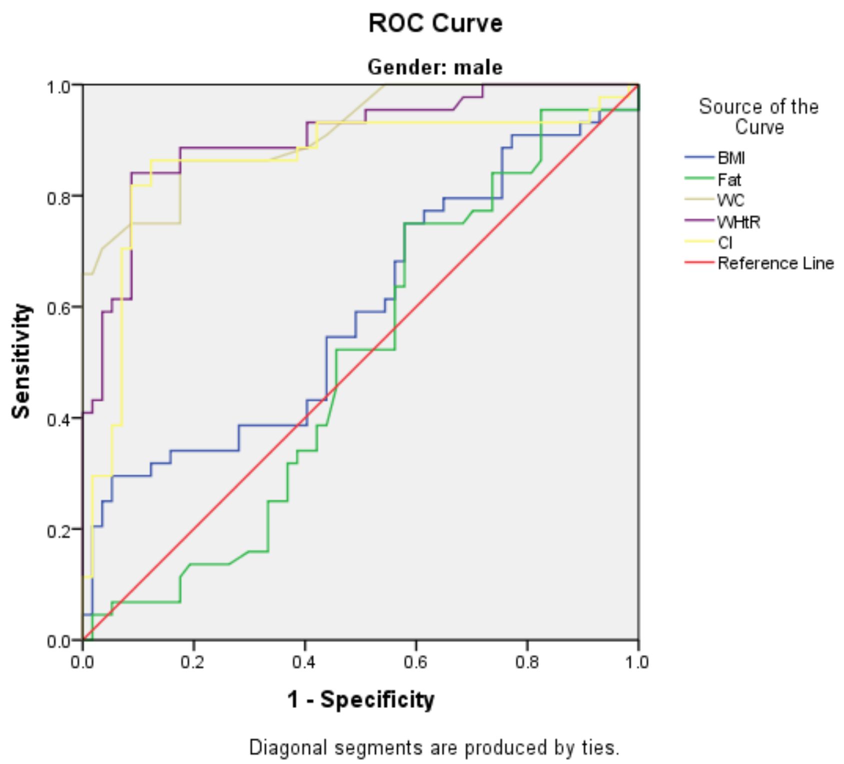

Figure 3 Areas under the curve for the body fat indicators in boys

DISCUSSION

In this study, the MetS prevalence of 5.8% is comparable with the 5.9% reported for South African adolescents[24] and 5% observed in Iranian adolescents,[25] but lower than the American adolescent average of 8.6%[26] The prevalence of obesity determined by body fat proxies is highest for WHtR, followed by WC. This result clearly showed that central fat deposits have become a health problem at this early stage of life. These differences in prevalence rates of MetS may be due to several factors, including physical development, especially the growth spurt which results in higher deposition of fat in girls than boys and ethnicity during this stage of development. Both physical development and ethnicity influence body fat and individual components of MetS during adolescence[20]

Findings from the present study showed that WC with a cut-off point of 60.5 cm in girls and 59.3 cm in boys was the body fat indicator with the best discriminatory capacity for MetS. These results are consistent with those of Iranian youth,[7] but at variance with the findings of de Oliveira and Guedes[8] and Jung et al who found WHtR and BMI respectively to have the best discriminatory power for detecting MetS in adolescents. Regardless of sex, this study indicated that the three measures of android fat, that is, WC, WHtR and C index were able to discriminate between adolescents with and without MetS risk. Several studies in adolescents have reported similar findings.[27,28] Waist circumference demonstrated excellent capacity while WHtR and C-index displayed good capacity to detect MetS risk in this cohort of adolescents. This study clearly indicated that %fat and BMI were the worst body fat indices in detecting MetS risk in Nigerian adolescents. This clearly indicates that total fat is not as important as central fat in predicting MetS risk in Nigerian adolescents. When compared to the reference standards, the cut-off points for identifying risk of MetS observed in the present study are generally lower. Thus, these international standards are not suitable for Nigerian adolescents. A possible reason for this may be exclusive use of foreign samples for developing these standards which did not include African sample most of the time.

This study showed that the android fat indicators were moderately related to MetS risk while the total fat indicators were weakly related to MetS risk. In all cases, the relationships were stronger in boys than girls. This implies that the adverse effect of these fat indicators may be more in boys.

The cross-sectional design which precludes causal attributions is a major limitation of this study. Nevertheless, a major strength of this study is the use of ROC which provided population-specific cut-off points for the anthropometric body fat proxies for identifying MetS risk. The recommended cut-off point of 90th percentile for age and sex for C-index in epidemiological research involving children is another strength as there was none before this time.

CONCLUSION

The results of this study suggest that waist circumference is the most effective tool for identifying risk of metabolic syndrome in Nigerian adolescent regardless of sex. Waist-to-height ratio and C-index are useful alternatives in both sexes. Waist circumference demonstrated excellent capacity while WHtR and C-index displayed good capacity to detect MetS risk in this cohort of adolescents.

RECOMMENDATIONS

Based on the findings of this study, it is recommended that Health care and Public Health professionals should use WC in the physical examination program to screen and monitor MetS risk in adolescents for the purpose of prevention and health promotion.

Waist circumference should be used in the preliminary screening for MetS in north central Nigerian adolescents before referral for confirmation and medical follow-up.

A population-based study on this problem is needed in order to extrapolate the findings to a wider population of Nigerian adolescents.

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