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Comparative Analysis of the Diagnostic Ability of Novel and Conventional Anthropometric Indicators for Metabolic Syndrome and its Components Among Lean and Overweight/Obese Adolescents in Nigeria

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Abstract

Introduction: The risk of atherosclerosis and other cardiovascular diseases is heightened by affliction with Metabolic Syndrome (MetS), a conglomeration of conditions which consist of diabetes mellitus, dyslipidemia and hypertension, in the presence of overweight or obesity. Conventional method of screening those who appear to be healthy but are in a relatively high risk of MetS are through the instrument of BMI or Waist circumference, which are no longer effective. Thus, this study sought to evaluate other novel instruments with strongest diagnostic accuracy for MetS in a sample of apparently healthy adolescent secondary school students.

Materials and Methods: This cross-sectional, prospective study was conducted in which sociodemographic, anthropometric and biochemical data were collected from 624 boys and girls, aged 10-19 years, at various secondary schools in Lagos Nigeria. Simple random sampling, probability proportion to size and systematic sampling technique were used to recruit the subjects. A body shape index (ABSI), Waist-to-height ratio (WHtR), body roundness index (BRI), weight-adjusted-waist index (WWI) and abdominal volume index (AVI) were evaluated. Correlation between anthropometric indices and MetS was clarified using partial correlation analysis. The association between anthropometric indices and Mets and its components was assessed using binary logistic regression analysis. To identify the predictive ability of anthropometric indices for MetS and its components, the study applied the Receiver-operating characteristic (ROC) curve, comparing the area under curve (AUC) difference between WHtR and each new anthropometric index in pairs. The subjects were segregated by sex (boys and girls) and by Body Mass Index-for-age (lean and overweight/obese).

Result: The overall prevalence of hypertension was higher in boys (7.1%) than girls (2.6%), especially in O/O boys (20.0%) compared to girls (11.4%). The overall prevalence of dysglycemia was higher in girls (12.5%) than in boys (7.1%). The median low-density lipoprotein cholesterol (LDL-c) was significantly higher in girls (295.4 mg/dL; P-value=0.002). The means (±sd) of SBP and DBP were 108.3 (12.4) and 66.2 (9.5). The overall median values (in mg/dL) of other components of MetS were FPG=87.5, TG=199.4; T-Chol=180.8, and HDL=55.9. Only WHtR had significant correlations with 4 components of MetS – SHT, dFPG, hypertriglyceridemia and low HDL-c and BRI with one – low HDL-c. In general, BRI has the highest diagnostic accuracy in identifying MetS among all the adolescent study population (AUC=0.611), especially in lean subjects (AUC=0.550), whereas ABSI had the highest diagnostic accuracy in O/O subjects (AUC=0.739). In all and lean subjects, the diagnostic ability of AVI, ABSI and WWI for MetS were the weakest, while that of BRI, WHtR and AVI were the weakest in obese subjects.

Conclusion: This study therefore shows BRI has the highest diagnostic accuracy and particularly the most effective tool in identifying MetS in adolescents while ABSI has the highest diagnostic accuracy and particularly the most effective tool in identifying MetS among overweight/obese subjects. AVI was the optimal anthropometric index for the identification of hypertension, hypertriglyceridemia and high LDL-c. WHtR and ABSI can also be considered as discriminators but in different categories of adolescents.

Keywords: Anthropometry, Black Africans, Cardiovascular Disease, Indigenous, Metabolic syndrome, Lipid

Introduction

That metabolic syndrome (MetS) is a collection of disorders that collectively increases the threat of atherosclerotic disease and other cardiovascular accidents is now well known and has been a major health burden in developed and now in developing countries [1,2]. In humans, MetS has been classically defined as clustering of at least three of the following five co-morbid conditions: abdominal obesity, high blood pressure, high blood sugar, high serum triglycerides, and low serum high-density lipoprotein (HDL) linked with the risk of developing cardiovascular disease and type 2 diabetes [3-6]. Body Mass Index, typically defined as weight (kg) of an individual divided by the square of the individual's height (cm) Wt/ht^2 has been the traditional index of classifying an adult individual into underweight, normal, overweight or obese. Because growth process is still on-going, BMI-for-age is generally used for the same purpose in adolescents. However, a major drawback of the use of BMI either in adults or in adolescents is the fact that it measures excess weight rather than excess fat [7]. Li and McDermott reported that BMI was the poorest predictor while waist-hip ratio was the best among the four measures – BMI, waist circumference (WC), waist-to-hip ratio (WHpR) and waist-to-height ratio (WHtR) [7]. Shrestha et al documented that BMI is inferior to WHt ratio and WC as a metric for obesity detection and hypertension prediction and Liu et al concluded that BMI overestimated body fat while WC overestimated trunk fat in a comparative study between African Americans and European Americans [8,9]. On its own, obesity, a major component of MetS, has long been strongly associated with a plethora of complications such as cardiovascular diseases (CVD) including coronary artery disease (CAD) and malignancy being the most common causes of death [10-13]. Other documented morbidity and mortality risks of obesity included but are not limited to high blood pressure, type 2 diabetes (T2DM), high cholesterol, breathing problems, sleep apnoea, gall bladder disease, gout, osteoarthritis and many additional circumstances, including all-cause mortality within a specific time-frame and population, mostly in industrialized countries but now in developing countries [14,21]. To bridge this gap, attempts to produce novel anthropometric indices for the evaluation of metabolic syndrome (MetS) have intensified. For this reason, waist-to-height ratio (WHtR), determined as waist circumference divided by height, has lately gained consideration as an anthropometric index for determining central adiposity, being more sensitive than BMI in predicting metabolic health risks, and in being affordable and more amenable [22,23]. One study claims that neither BMI nor abdominal circumference, as anthropometric measures routinely used to evaluate MetS, is able to recognize accumulation of visceral adipose tissue from subcutaneous adipose tissue [24,25]. Studies have shown concordance between WC and WHtR in the United States children and adolescents aged 8-18 years and WHtR has demonstrated concordance with percent body fat among Spanish adolescents, showing reliable outcome than WC and BMI in forecasting percent body fat [26-28]. Recently, however, there has been even more interest in novel anthropometric indices of body geometry such as Body Roundness Index (BRI), Weight-adjusted Waist Index (WWI), A Body Shape Index (ABSI) and Abdominal Volume Index (AVI), which are regarded as good predictors of visceral fat [29-31]. Studies have shown that BRI is best in distinguishing metabolic components of MetS and arteriosclerosis of overweight/obese adults; that ABSI is linked with visceral fat, carotid atherosclerosis [35] and obesity-related mortality risk unrelated to BMI and WC; that WWI, proposed by Park et al [36, 37] is an exceptional indicator of obesity, having an exceptional analytical power for cardiometabolic disease, CVD and all-cause mortality risk; and that AVI indirectly displays visceral fat content by assessing the entire abdominal volume, intimately interrelated with impaired glucose tolerance (IGT) and diabetes mellitus (DM), with an excellent diagnostic capacity for MetS [37-39]. Although BRI, ABSI, WWI and AVI seemingly possess compelling aptitude to recognize MetS and its components from the perspective of body shape, data is scarce on whether they are superior to the conventional anthropometric indicators such as WHtR. Data is even scarcer on whether these novel anthropometric indices have been applied to adolescents in general and indigenous sub-Sahara Black African adolescents in particular. The objective of this current study was therefore to compare the traditional WHtR and the other four novel anthropometric indices for identifying MetS and its components among lean and overweight/obese Nigerian adolescents.

Materials and Methods

This segment of the study had previously been reported in an earlier publication [40]. Briefly though, the study was conducted in Lagos, Nigeria, a city-state with modern social amenities and acceptable infrastructures such as highways, international airport, good housing facilities, security and museums for tourist attractions. It is the most populated metropolitan in Nigeria and one of such in entire Africa. The target population was students in selected government-approved secondary schools in Lagos State. In this study, 650 adolescents, aged 10-19 years (according to the World Health Organization (WHO) definition of adolescence), who were attending various secondary schools in Lagos were recruited between October 2019 and March 2020 [41]. Study participants were from 3 Senatorial Districts – Lagos East, Lagos West and Lagos Central – with 5, 10 and 5 Local Government Areas, respectively. Participants were recruited using simple random sampling, probability proportional to size and systematic sampling technique. All study participants were indigenous Black Africans from Nigerian ethnicity living in the southwest corner of the country. To be included in the study, a participant must fulfil the following criteria: (i) age must be between 10 and 19 years (ii) must be a registered and regular student in the selected government-approved secondary school and (iii), must be an indigenous Nigerian resident in the community of study for a minimum of 5 years. To be excluded from the study a prospective participant must fulfill these criteria: (i) on therapeutic diet or drugs (ii) admissions to a health facility in previous 6 months (iii) pregnant (iv) suspected to be pregnant (v) breastfeeding (vi using oral contraceptive (vi) known diabetic (vii) has a history of vascular/liver/renal or other chronic illness (viii) taking lipid-lowering medications. Finally, of the 650 recruited, 624 (96.0%), 241 (38.6%) boys and 484 (61.4%) girls, fulfilled the inclusion/exclusion criteria and completed clinical examinations, biochemical investigations and a standard questionnaire that contained participant's demographic and anthropometric variables such as age, body height and weight, waist circumference, diet, exercise, and sleep pattern among others. All study subjects were requested to fast overnight after which anthropometric measurements were recorded, blood pressure was taken, and a venous blood sample was collected from the left ante-cubital fossa of each study participant. The study was approved by the Institutional Review Board of the Nigerian Institute of Medical Research (NIMR IRB (IRB/18/062) on 4th February 2019. The purpose of the study was clearly explained to each participating student. Each student was given a chance to ask questions for better understanding of the study. Thereafter, students who, in the presence of their teachers, gave verbal assent to participate in the study, were then given consent forms for their parents to also read, understand and sign or thumbprint.

Anthropometric Measurements

Field workers were trained to take measurements including body weight and height (to the nearest 0.1 kg, with light clothing and no shoes and nearest millimeter) using electronic scale (FBS machine Model HBF-514C and DP scale HN-283) and a portable stature meter (SURGILAC). Cloth tape was used to measure waist circumference after exhalation (to the nearest millimeter) midway between the lowest rib and the iliac crest. Hip circumference was measured at maximum extension of each greater trochanter of the hip bones. To get WHtR, WC (cm) was divided by height (cm); to obtain BMI, weight (kg) was divided by the square of height (ht^2). The other anthropometric criterion variables were calculated according to the following formulae as described by various authors [37,38,42,43]

$$\mathrm{BRI} = 364.2 - 365.5 \times \sqrt{1 - \left(\frac{(\mathrm{WC}/2\pi)^2}{(0.5 \times \mathrm{height})^2}\right)}$$

$$AVI = \frac{2\,x\,(waist)^2 + 0.7\,x\,(waist - hip)^2}{1000}$$

$$WWI = \frac{WC}{\sqrt{weight}}$$

$$\mathrm{ABSI} = \frac{\mathrm{WC}}{\mathrm{BMI}^{2/3}\mathrm{height}^{1/2}}$$

Where BRI stands for Body Roundness Index, AVI for Abdominal Volume Index, ABSI for A Body Shape Index and WWI for Weight adjusted Waist Index.

AnthroPlus V1.0.4 (WHO, Geneva, Switzerland) was used to calculate BMI-for-age and height-for-age percentiles for boys and girls separately [44].

Clinical and Biochemical Investigations

The processes of clinical and biochemical assessment had also been reported in an earlier publication [40]. In brief, after resting for 30 min, the study participants systolic and diastolic blood pressures were checked from the left upper arm, using automatic sphygmomanometer {Medical Instrument WUXI, Ltd, EN-BL-8030 [China]} and the average of three readings was taken and recorded for statistical analysis. After overnight fasting, 5 ml of venous blood was taken, processed, separated into appropriate tubes for the analyses of fasting plasma glucose (FPG), total cholesterol, triglyceride, high-density lipoprotein-cholesterol (HDL-C) and low-density lipoprotein-cholesterol (LDL-C). Randox Glucose-PAP (Randox Laboratories, UK) reagent was used for analyzing FPG and lipid profile, using a photo spectrometric analyzer (BioSystems EN ISO 13485 and EN ISO 9001 standards (Barcelona, Spain).

Definition of Metabolic Syndrome and its Components:

The definition and prevalence of MetS among the study participants as well as the normal, borderline, and high cutoff points of various components of MetS have also been reported in a previous publication [40]. Dyslipidemia was defined as a combination of TC ≥ 200 mg/dL, LDL-C ≥ 130 mg/dL, TG ≥ 130 mg/dL, or HDLC < 40 mg/dL [45]. This study used the National Heart, Lung and Blood Institute (NHLBI) criteria specifically for children and adolescents to distinguish MetS among participants aged 10–19 years [46] which necessitates three or more of the following indicators: (i) BMI for-age of ≥95th percentile; fasting plasma levels of (ii) TG ≥ 130 mg/dL; (iii) HDL-cholesterol < 40 mg/dL; (iv) LDL-cholesterol ≥ 130 mg/dL; (v) TC ≥ 200 mg/dL; (vi) glucose ≥ 100mg/dL; and (vi) pre-hypertension as systolic/diastolic BP (SBP/DBP) 120–129/ <80 mmHg, stage 1 hypertension, BP 130–139/80–89, and stage 2 ≥140/90 mmHg [47].

Statistical Analysis

SPSS 23.0 (IBM) was used for statistical analysis and NCSS 22 for ROC curve comparison. The study used mean (±sd) for continuous variables and frequencies and percentage for categorical variables. The study subjects were characterized into lean and overweight/obese and by gender of individuals. The study used partial correlation to assess the relationship between anthropometric indices and metabolic variables – systolic and diastolic blood pressures (SBP, DBP), fasting plasma glucose (FPG), triglyceride (TG) high-density lipoprotein cholesterol HDL-c and low-density lipoprotein cholesterol LDL-c. The study also evaluated the strength of the link between the anthropometric indices and MetS as well as its components by using binary logistic regression inquiry. In partial correlation and binary logistic regression analysis, z-scores of anthropometric indices were used while age was adjusted for all subjects, and both age and sex were adjusted for in lean and overweight/obese individuals. Receiver Operating Characteristics (ROC) and Area Under the Curve (AUC) were utilized to evaluate the capacity of WHtR, BRI, ABSI, WWI and AVI in distinguishing MetS and its components. Further, the study employed Hanley and McNeil's method [48] as described by Wu et al to assess AUC differences in MetS among BRI, WWI, AVI, ABSI and WHtR [48,49]. The optimal cut-off values of the anthropometric indices for distinguishing MetS and its components were verified. A p-value < 0.05 was considered as statistically significant. Confidence interval (CI) in this study refers to a range of values for specific variables constructed so that this range has a specified probability of including the true value of that variable. The results of analyses were presented as tables and figures.

Results

The Demographic, Anthropometric and Clinical Statistics of the Study Population

In all, 624 indigenous sub-Sahara Black Africans of Nigerian descent (241 boys and 383 girls) participated in the study. The overall prevalence of MetS among the study subjects was 8.3%, (14.1% among boys and just 4.7% among girls) and that of hypertension, dysglycemia hypertriglyceridemia, low HDL-c and high LDL-c were 4.3%, 11.5%, 42.3%, 24.7% and 92.5%, respectively. Physical measurement indicators such as WHtR, AVI, ABSI and BRI were significantly higher in boys but height-for-age Z-score (HAZ), BMI-for-age and BRI were notably higher among girls. While HAZ, BMI-for age, median AVI and LDL-c were significantly higher among lean girls than boys, no such significant difference was observed among O/O boys and girls. Further, O/O boys were 3.8 times more likely to be hypertensive than lean boys (χ^2=2.25, P-value=0.13, OR=3.79, 95% CI=0.96, 15.00); O/O girls were 7.4 times more likely to be hypertensive than lean girls (χ^2=8.27, P-value=0.004, OR=7.35, 95% CI=1.97, 27.46); O/O boys were 1.4 times more likely to be dysglycemic than lean boys (χ^2=0.00, P-value=1.00, OR=1.43, 95% CI=0.30, 6.74) and O/O girls were approximately 1.2 times more likely to be dysglycemic than lean girls (χ^2=0.004, P-value=0.95, OR=1.18, 95% CI=0.44, 3.21). Lean boys were 1.2 times more likely to have high TG (χ^2=0.10, P-value=0.75, OR=1.19, 95% CI=0.41, 3.46) than O/O boys but O/O girls were 1.2 times more likely to have high TG (χ^2=0.32, P-value=0.57, OR=1.22, 95% CI=0.61, 2.46) compared to lean girls; Lean boys were 1.1 times more likely to have low HDL-c (χ^2=0.00, P-value=1.00, OR=1.06, 95% CI=0.33, 3.46) than O/O boys but O/O girls were 1.2 times more likely to have low HDL-c (χ^2=0.20, P-value=0.66, OR=1.20, 95% CI=0.54, 2.66) compared to lean girls; lastly, O/O boys were 4.7 times more likely to have high LDL-c (χ^2=8.81, P-value=0.003, OR=4.71, 95% CI=1.56, 14.25) than lean boys while O/O girls were 7.7 times more likely to have high LDL-c (χ^2=20.08, P-value<0.000007, OR=7.66, 95% CI=2.75, 21.31) than lean girls (Table 1).

Variables		Total (n=624)	Boys (n=241)	Girls (n=383)	t-test (P-value)	Total Lean (n=574)	Lean Boys (n=226)	Lean Girls (n=348)	t-test (P-value)	Total O/O (n=50)	O/O Boys (n=15)	O/O Girls (n=35)	t-test (P-value)
Age (yrs)		14.7 (2.1)	14.8 (2.2)	14.7 (2.1)	0.56 (0.57)	14.8 (2.1)*	14.9 (2.2)	14.8 (2.0)	0.55 (0.58)	13.5 (2.2)*	13.2 (2.4)	13.6 (2.2)	-0.55 (0.58)
Type of school	Private (n, %)	132 (21.2)	63 (26.1)	69 (18.0)	-	122 (21.2)	60 (26.5)	62 (17.8)	-	10 (20.0)	3 (20.0)	7 (20.0)	
	Public (n, %)	492 (78.8)	178 (73.9)	314 (82.0)		452 (78.8)	166 (73.5)	286 (82.2)		40 (80.0)	12 (80.0)	28 (80.0)	
Height (cm)		157.0 (10.6)	157.7 (13.0)	156.5 (8.8)	1.26 (0.21)	156.9 (10.7)	157.7 (13.0)	156.4 (8.9)	1.32 (0.19)	157.5 (10.1)	157.8 (13.0)	157.4 (8.9)	0.11 (0.91)
Weight (kg)		47.4 (11.6)	46.5 (12.5)	48.0 (11.0)	-1.54 (0.13)	45.8 (10.1)	45.5 (11.5)	46.1 (9.1)	-0.66 (0.51)	65.6 (12.2)	61.8 (15.8)	67.3 (10.2)	-1.24 (0.23)
WC (cm)		65.4 (6.6)	65.0 (6.6)	65.7 (6.6)	-1.29 (0.20)	64.5 (5.4)	64.4 (5.6)	64.6 (5.3)	-0.43 (0.67)	76.1 (9.6)	74.5 (11.5)	76.8 (8.7)	-0.69 (0.50)
WHtR		0.42 (0.04)	0.41 (0.04)	0.42 (0.04)	-3.04 (0.002)	0.41 (0.03)	0.41 (0.03)	0.41 (0.03)	0.00 (1.00)	0.49 (0.06)	0.48 (0.07)	0.49 (0.05)	-0.50 (0.62)
HAZ		-0.60 (1.67)	-0.90 (1.91)	-0.42 (1.48)	-3.32 (0.001)	-0.68 (1.61)	-0.96 (1.84)	-0.51 (1.42)	-3.12 (0.002)	0.29 (2.06)	-0.02 (2.68)	0.43 (1.76)	-0.60 (0.56)
BMI-for-age		-0.48 (1.32)	-0.70 (1.35)	-0.35 (1.28)	-3.22 (0.001)	-0.69 (1.13)	-0.87 (1.18)	-0.58 (1.07)	-2.98 (0.003)	1.95 (0.72)	1.95 (0.57)	1.95 (0.78)	0.00 (1.00)
AVI (median)		2863.4	1968.3	3389.4	<0.0001	2686.8	1964.3!	3240.4 !!	<0.0001	4327.9	3607.5!	4993.1 !!	0.04
ABSI (median)		0.074	0.075	0.073	<0.0001	0.07	0.075 ^	0.073^^	0.0001	0.069	0.069 ^	0.069^^	0.65
WWI (median)		1.39	1.40	1.38	0.10	1.40	1.41#	1.40##	0.34	1.18	1.29#	1.16##	0.08
BRI (median)		1.84	1.78	1.90	0.01	1.80	1.77α	1.84αα	0.06	2.94	2.62α	3.05αα	0.22
SBP (mm Hg)		108.3 (12.4)	107.9 (11.5)	108.6 (13.0)	-0.70 (0.48)	108.4 (12.4)	108.4 (11.2)	108.4 (13.2)	0.00 (1.00)	107.5 (12.2)	101.2 (13.5)	110.2 (10.7)	-2.29 (0.03)
DBP (mm Hg)		66.2 (9.5)	66.9 (9.5)	65.8 (9.6)	1.40 (0.16)	66.4 (9.6)	67.2 (9.5)	65.8 (9.7)	1.71 (0.1)	64.7 (8.3)	62.1 (8.7)	65.8 (8.1)	-1.41 (0.17)
FPG (mg/dL) (median)		87.5	85.7	89.7	0.17	87.8	85.5	89.8	0.12	82.6	87.2	82.2	0.82
TG (mg/dL) (median)		199.4	204.7	198.0	0.49	198.9	205.5	196.2	0.24	221.2	187.2	230.2	0.14
T-Chol (mg/dL) (median)		180.8	187.1	179.5	0.40	180.2	187.5	177.9	0.40	189.3	171.0	192.1	0.87
HDL-c (mg/dL) (median)		55.9	54.2	56.5	0.56	55.8	54.4	56.2	0.75	57.4	49.1	58.5	0.28
LDL-c (mg/dL) (median)		289.6	271.5	295.4	0.002	284.3	272.3	293.8	0.009	303.8	207.1	309.5	0.09
Systolic hypertensive (n, %)		27 (4.3)	17 (7.1)	10 (2.6)	-	20 (3.5)	14 (6.2)	6 (1.7)	-	7 (14.0)	3 (20.0)	4 (11.4)	-
Diastolic hypertension (n, %)		47 (7.5)	20 (8.3)	27 (7.0)		37 (6.4)	15 (6.6)	22 (6.3)		10 (20.0)	5 (33.3)	5 (14.3)	
Sys/Dia hypertension (n, %)		15 (2.4)	9 (1.4)	6 (1.6)		9 (1.6)	6 (2.7)	3 (0.9)		6 (12.0)	3 (20.0)	3 (8.6)	
Dysglycemia (n, %)		72 (11.5)	24 (10.0)	48 (12.5)		65 (11.3)	22 (9.7)	43 (12.4)		7 (14.0)	2 (13.3)	5 (14.3)	
High TG level (n %)		264 (42.3)	106 (44.0)	158 (41.2)		242 (42.2)	100 (44.2)	142 (40.8)		22 (44.0)	6 (40.0)	16 (45.7)	
Low HDL-c level (n, %)		154 (24.7)	67 (27.8)	87 (22.7)		141 (24.6)	63 (27.9)	78 (22.4)		13 (26.0)	4 (26.7)	9 (25.7)	
High LDL-c level (n, %)		577 (92.5)	219 (90.9)	358 (93.5)		529 (92.2)	206 (91.1)	323 (92.8)		48 (96.0)	13 (86.7)	35 (100.0)	
MetS (n, %)		52 (8.3)	34 (14.1)	18 (4.7)		39 (6.8)	28 (12.4)	11 (3.2)		13 (26.0)	6 (40.0)	7 (20.0)	

Table 1: Characteristics of all the Study Participants According to Gender of Lean and Overweight/Obese Adolescents

O/O means Overweight and obese, p value means the differences between groups according to gender among non-overweight/obese adults, *WC* waist circumference, *WtHR* waist-to-height ratio, BMI body mass index, *AVI* abdominal volume index, *ABSI* a body shape index, *WWI* weight adjusted waist index, *BRI* body roundness index, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *FBG* fasting blood glucose, *TC* total cholesterol, *TG* triglyceride, *HDL-C HDL* cholesterol, *LDL-C LDL* cholesterol, *MetS* metabolic syndrome. *t-test=4.02, p-value=0. 0002; Mann-Whitney U-test=2.47, p-value=0.01;!! Mann-Whitney U-test=4.04, p-value<0.001; ^ Mann-Whitney U-test=-2.43, p-value<0.05; ^^ Mann-Whitney U-test=-5.164, p-value<0.00001; # Mann-Whitney U-test=-2.59, p-value<0.01; ## Mann-Whitney U-test=-7.48, p-value<0.00001; α Mann-Whitney U-test=4.22, p-value<0.0001; α α Mann-Whitney U-test=7.60, p-value<0.00001;

Partial Correlation between Different Anthropometric Indices and Metabolic Variables

After adjusting for age and gender as appropriate, a few anthropometric indices were correlated with metabolic variables. In all subjects, significant correlations were observed between WHtR and both SBP (coeff: 0.155; P-value<0.0001) and DBP (coeff: 0.144, P-value<0.0003) and a marginally significant negative correlation with HDL-c (coeff: -0.077P-value=0.05), reflected especially in girls and lean subjects. A significant positive correlation was also observed between WHtR and TG (coeff: 0.129, P-value=0.015) and between WHtR and FPG (coeff: 0.388, P-value=0.03) among lean and among O/O girls, respectively. Statistically significant negative correlation was noted between BRI and SBP (coeff: -0.454, P-value=0.01) and a positive one with HDL-c (coeff:0.455, P-value-0.01) in overweight/obese girls. The only significant correlation that ABSI had was with HDL-c in all O/O subjects (coeff:0.404, P-value=0.004), pronounced only among O/O girls (coeff: 0.536, P-value=0.002). A significant but negative correlation was noted between WWI and SBP (coeff: -0.305, P-value=0.03) mainly among girls (coeff: -0.481; P-value=0.007), and HDL-c (coeff: 0.470; P-value=0.001) also among girls (coeff: 0.672, P-value=0.00005). In all, AVI had a significant negative correlation with HDL-c (Coeff: --0.091, P-value=0.02), which was reflected in girls (coeff: -0.123, P-value=0.02), especially those who were lean (coeff: -0.119; P-value=0.03) (Table 2).

Subjects	Metabolic variables	WHtR		BRI		ABSI		WWI		AVI	
		Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
All subjects	SBP	0.155	<0.0001	0.061	0.13	-0.024	0.55	-0.041	0.30	0.067	1.00
	DBP	0.144	<0.0003	0.026	0.52	-0.006	0.89	-0.015	0.57	0.03	0.42
	FPG	-0.031	0.43	-0.010	0.80	-0.015	0.71	-0.015	0.71	-0.046	0.25
	TG	0.048	0.23	-0.025	0.53	-0.037	0.36	-0.006	0.87	-0.025	0.53
	HDL-c	-0.077	0.05	0.011	0.78	0.051	0.21	0.090	0.02	-0.091	0.02
	LDL-c	-0.032	0.43	-0.004	0.92	0.043	0.28	0.066	0.10	-0.020	0.62
Boys	SBP	0.089	0.17	0.050	0.44	-0.013	0.84	-0.015	0.82	0.016	0.81
	DBP	0.082	0.20	0.049	0.45	-0.010	0.88	0.024	0.71	-0.018	0.78
	FPG	-0.096	0.14	-0.005	0.94	-0.054	0.40	-0.094	0.15	0.062	0.34
	TG	-0.032	0.63	-0.036	0.58	-0.26	0.68	-0.008	0.90	-0.078	0.23
	HDL-c	0.068	0.29	-0.045	0.49	0.027	0.68	0.067	0.30	-0.013	0.24
	LDL-c	-0.024	0.72	-0.017	0.79	0.028	0.67	0.100	0.12	0.038	0.56
Girls	SBP	0.020	0.00006	0.071	0.16	-0.032	0.53	-0.060	0.24	0.090	0.08
	DBP	0.186	0.0002	0.013	0.79	0.0005	0.99	-0.057	0.26	0.051	0.32
	FPG	0.005	0.93	-0.008	0.88	0.023	0.65	0.042	0.42	-0.082	0.11
	TG	0.049	0.38	-0.024	0.64	-0.054	0.29	-0.012	0.79	-0.006	0.90
	HDL-c	-0.162	0.001	0.042	0.41	0.076	0.14	0.110	0.03	-0.123	0.02
	LDL-c	-0.033	0.51	0.007	0.89	0.066	0.20	0.059	0.25	-0.042	0.42

All lean	SBP	0.154	0.0002	0.074	0.08	-0.016	0.70	-0.013	0.75	0.062	0.14
	DBP	0.157	0.0002	0.031	0.46	-0.002	0.95	0.010	0.82	0.020	0.64
	FPG	-0.049	0.24	-0.007	0.86	-0.020	0.62	-0.010	0.82	-0.044	0.29
	TG	0.062	0.14	-0.017	0.69	-0.040	0.34	-0.011	0.80	-0.031	0.46
	HDL-c	-0.078	0.06	-0.001	0.98	0.027	0.51	0.063	0.13	-0.087	0.04
	LDL-c	-0.035	0.40	-0.006	0.89	0.046	0.27	0.071	0.09	-0.026	0.54
Lean boys	SBP	0.079	0.04	0.043	0.52	0.025	0.72	-0.016	0.81	0.017	0.80
	DBP	0.090	0.18	0.026	0.71	-0.017	0.80	0.030	0.66	-0.027	0.69
	FPG	-0.090	0.18	-0.018	0.79	-0.069	0.31	-0.107	0.11	0.070	0.30
	TG	-0.039	0.57	-0.035	0.61	-0.050	0.46	-0.040	0.55	-0.068	0.31
	HDL-c	0.070	0.30	-0.047	0.48	0.013	0.85	0.065	0.33	-0.010	0.88
	LDL-c	-0.028	0.68	-0.008	0.90	0.042	0.53	0.108	0.11	0.031	0.65
Lean Girls	SBP	0.212	0.00006	0.099	0.06	-0.004	0.95	-0.006	0.92	0.081	0.13
	DBP	0.206	0.0001	0.036	0.51	0.015	0.78	-0.006	0.91	0.036	0.50
	FPG	-0.025	0.64	0.002	0.96	0.025	0.65	0.0662	0.24	-0.081	0.13
	TG	0.129	0.015	-0.011	0.83	-0.035	0.51	0.006	0.90	-0.018	0.73
	HDL-c	-0.166	0.002	0.026	0.63	0.046	0.39	0.058	0.21	-0.119	0.03
	LDL-c	-0.036	0.50	0.002	0.97	0.058	0.27	0.060	0.26	-0.048	0.37
All Overweight/Obese	SBP	0.170	0.25	-0.171	0.24	-0.106	0.47	-0.305	0.03	0.20	0.16
	DBP	0.004	0.98	-0.014	0.92	-0.005	0.97	-0.253	0.08	0.236	0.11
	FPG	0.208	0.16	-0.057	0.70	-0.005	0.97	-0.077	0.60	-0.258	0.08
	TG	-0.174	0.24	-0.143	0.33	-0.029	0.85	0.036	0.81	0.075	0.61
	HDL-c	-0.015	0.92	0.228	0.12	0.404	0.004	0.470	0.001	-0.105	0.48
	LDL-c	0.056	0.71	0.052	0.72	0.059	0.59	0.043	0.77	0.200	0.17
Overweight/Obese boys	SBP	0.259	0.30	0.150	0.55	0.091	0.72	-0.024	0.93	0.027	0.91
	DBP	0.020	0.94	0.437	0.07	0.222	0.38	0.107	0.67	-0.041	0.87
	FPG	-0.421	0.08	0.074	0.77	0.160	0.53	0.197	0.43	-0.106	0.68
	TG	0.076	0.76	-0.019	0.94	0.222	0.37	0.497	0.04	-0.216	0.39
	HDL-c	0.044	0.86	0.121	0.63	0.167	0.51	-0.0015	0.95	0.08	0.74
	LDL-c	0.309	0.21	-0.125	0.62	-0.295	0.23	-0.071	0.78	0.315	0.20
Overweight/Obese girls	SBP	0.136	0.47	-0.454	0.01	-0.296	0.11	-0.481	0.007	0.339	0.07
	DBP	0.001	1.00	-0.284	0.13	-1.20	0.53	-0.355	0.05	0.349	0.06
	FPG	0.388	0.03	-0.148	0.43	-0.045	0.81	-0.117	0.54	-0.317	0.09
	TG	-0.319	0.09	-0.236	0.21	-0.240	0.20	-1.61	0.39	0.265	0.16
	HDL-c	-0.028	0.88	0.455	0.01	0.536	0.002	0.672	0.00005	-0.97	0.30
	LDL-c	0.01	0.95	0.111	0.56	0.152	0.42	0.063	0.74	0.189	0.32

Table 2: Partial Correlation between Anthropometric Indices and Metabolic Variables

Binary Logistic Regression Analysis of Anthropometric Indicators for MetS and its Components

The study then analyzed the OR and 95% confidence interval (CI) using anthropometric Z-scores, controlling for age and gender for all, lean and O/O subjects but for only age when boys or girls were considered. The strongest significant correlation that WHtR had was with systolic hypertension (OR=951.184, P-value=<0.05); the strongest significant correlation BRI had was with low HDL-c (OR=1.455, P-value<0.05). While WHtR had a significant correlation with dysglycemia among boys (OR=0.000, P-value<0.05), it was significantly correlated with systolic hypertension (OR==64299.068, P-value<0.001), hypertriglyceridemia (OR=1372.626, P-value<0.05) and low HDL-c (OR=0.001, P-value<0.05) among the girls (Table 3). In all lean subjects, BRI significantly correlated with low HDL-c (OR=1.371, P-value<0.05) but in girls it was WHtR that had significant correlation with systolic hypertension (OR=37868.97, P-value=<0.001) hypertriglyceridemia (OR=2674.647, P-value<0.05) and low HDL-c (OR=0.001, P-value<0.05). No significant correlation was observed among overweight/obese individuals, be they boys or girls (Table 3).

Subjects	Metabolic variables	Hypertension				Dysglycemia		Hypertriglyceridemia		Low HDL-c		High LDL-c		MetS	
		Systolic		Diastolic											
		OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
All subjects	WHtR	951.184!	6.74, 134187.01	287.758	0.00, 2580548074.02	0.017	0.00, 14.16	26.917	0.27, 2695.94	0.021	0.00, 1.54	115.66	0.18, 73510.71	6.856	0.05, 1031.40
	BRI	1.168	0.83, 1.56	1.512	0.61, 3.73	0.980	0.65, 1.47	0.929	0.71, 1.22	1.455*	1.07, 1.98	1.130	0.75, 1.70	1.045	0.75, 1.46
	ABSI	746.353	0.00, 4.729E+24	0.000	0.00, 5.182E+46	0.001	0.00, 4.29E+23	0.000	0.00, 6.856+11	0.000	0.00, 5.60	161374.061	0.00, 2.126E+29	0.000	0.00, 1.533E+14
	WWI	1.138	0.32, 4.04	20.578	0.53, 841.66	0.885	0.19, 4.02	0.819	0.31, 2.46	2.487	0.90, 6.89	0.436	0.11, 1.64	2.592	0.80, 8.39
	AVI	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00
Boys	WHtR	2.128	0.001, 8442.64	0.000	0.00, 5.388E+11	0.000*	0.00, 0.14	0.043	0.00, 62.17	11.007	0.01, 18941.59	3.897	0.00. 55485.78	0.043	0.00, 9157.39
	BRI	1.408	0.82, 2.41	3.613	0.76, 17.14	1.018	0.45, 2.33	0.742	0.44, 1.25	1.297	0.77, 2.17	1.147	0.56, 2.35	0.617	0.27, 1.38
	ABSI	7.438E+10	0.00, 6.108E+39	0.000	0.00, 4.464E+21	0.009	0.00, 3.195E+41	0.000	0.00, 6.283E+33	0.000	0.00, 3.12E+10	4557888.58	0.00, 5.904E+42	0.194	0.00, 4.830E+37
	WWI	0.756	0.12, 4.85	152.580	0.60, 38845.00	0.780	0.51, 12.04	0.582	0.10, 3.24	2.832	0.52, 15.29	0.809	0.09, 7.09	3.430	0.31, 37.61
	AVI	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1400	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00
Girls	WHtR	64299.068!	110.74, 37333056.70	143384.987	0.00, 1.527E+13	0.773	0.00, 1293.96	1372.626*	3.56, 694220.40	0.001#	0.00, 0.14	1599.145	0.28, 9275449.61	46.278	0.13, 16955.17
	BRI	1.065	0.78, 1.35	0.912	0.18, 4.69	0.973	0.71, 1.31	1.002	0.72, 1.40	1.547*	1.04, 2.30	1.147	0.69, 1.90	1.192	0.83, 1.71
	ABSI	0.000	0.89, 1.26	1.920E+48	0.00, 1.121E+140	0.000	0.00, 1.56	0.000	0.00, 2.000E+21	0.000	0.00, 51078208.72	1.553	0.00, 1.864E+35	0.000	0.00, 6.503E+14
	WWI	2.176	0.75, 1.96	4.435	0.07, 274.36	0.793	0.00, 3.239E+31	0.855	0.25, 2.88	2.361	0.58, 9.53	0.354	0.07, 1.72	3.027	0.68, 13.46
	AVI	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00
All lean	WHtR	801.795*	4.83, 133079.13	486.388	0.00, 2.949E+10	0.002	0.00, 4.14	24.875	0.23, 2677.59	0.036	0.00, 2.92	103.661	0.15, 71559.13	16.288	0.09, 2852.67
	BRI	1.175	0.84, 1.63	1.609	0.62, 4.15	0.995	0.64, 1.54	0.961	0.73, 1.27	1.371*	1.01, 1.87	1.209	0.79, 1.85	1.049	0.74, 1.49

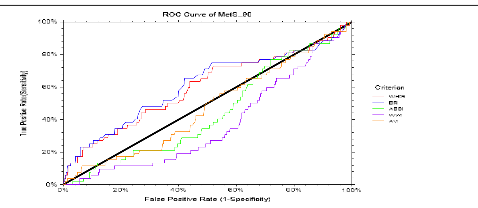
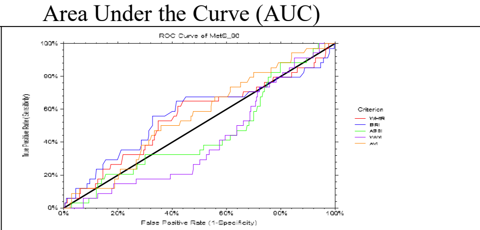
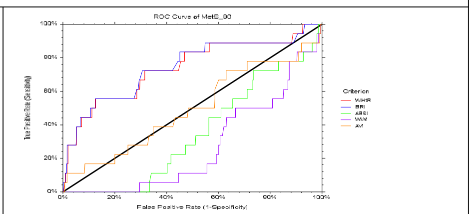
	ABSI	3.802	0.00, 5.860E+23	0.000	0.00, 9.392E+43	0.000	0.00, 2.953E+17	0.000	0.00, 234769590.60	0.000	0.00, 5811.27	920806163.223	0.00, 1.555E+34	0.000	0.00, 6.283E+13
	WWI	1.276	0.34, 4.75	16.018	0.20, 1263.65	1.333	0.27, 6.65	0.807	0.30, 2.20	2.165	0.75, 6.27	0.541	1.33, 2.19	2.554	0.70, 9.33
	AVI	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00
Lean boys	WHtR	2.506	0.00, 14099.20	0.001	0.00, 6.931E+12	0.000*	0.00, 0.10	0.017	0.00, 29.11	24.161	0.01, 53758.06	3.775	0.00, 59729.68	0.319	0.00, 74737.42
	BRI	1.472	0.84, 2.58	3.455	0.74, 16.22	0.798	0.53, 1.94	0.704	0.41, 1.21	1.209	0.72, 2.04	1.331	0.63, 2.81	0.557	0.22, 1.41
	ABSI	11472942.71	0.00, 3.352#+37	0.000	0.00, 8.552E+24	0.173	0.00, 4.42E+44	0.000	0.00, 1.536E+23	0.000	0.00, 1.633E+12	1.655E+14	0.00, 3.100E+52	32.455	0.00, 2.186E+44
	WWI	0.961	0.14, 6.50	151.014	0.47, 48642.81	0.804	0.05, 13.48	0.510	0.09, 2.98	2.721	0.49, 15.08	0.671	0.07, 6.16	3.415	0.26, 45.12
	AVI	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00,1.00	1.000	1.00, 1.00
Lean Girls	WHtR	37868.97!	54.61, 26262952.86	2968296.537	0.00, 1.319E+16	0.127	0.00, 466.81	2674.647*	5.43, 1317649.88	0.001*	0.00, 0.22	1266.048	0.20, 8036444.86	93.855	0.23, 43395.56
	BRI	1.060	0.68, 1.65	0.730	0.04, 13.10	1.068	0.65, 1.74	1.080	0.77, 1.52	1.466	0.98, 2.19	1.178	0.70, 1.97	1.215	0.83, 1.77
	ABSI	0.000	0.00, 8.745E+26	0.018	0.00, 1.340E+141	0.000	0.00, 9.078E+21	0.000	0.00, 2.816E+16	0.000	0.00, 6.933E+10	15.815	0.00, 8.196E+37	0.000	0.00, 6.496E+11
	WWI	2.029	0.28, 14.66	0.141	0.00, 50.03	1.487	0.20, 11.15	0.950	0.27, 3.36	1.920	0.43, 8.58	0.473	0.08, 2.68	2.624	0.48, 14.40
	AVI	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00
All O/O	WHtR	6462576987.68	0.01,3.062E+21	0.000	0.00	4690.387	0.00, 6.981E+15	179.992	0.00, 8.159E+14	0.000	0.00, 2107.81	0.000	0.00, 5.635E+33	0.918	0.00, 3.75E+12
	BRI	0.993	0.14, 6.84	2.505E+13	0.00	2.535	0.23, 27.54	0.215	0.22, 2.14	12.076	0.77, 190.33	0.001	0.00, 119.25	0.535	0.06, 4.78
	ABSI	1.157E+62	0.00, 5.821E+146	0.000	0.00	5.348E+55	0.00, 2.930E+162	2.808E+19	0.00, 4.051E+126	0.000	0.00, 1.472E+49	0.000	0.00, 1.408E+133	56467041.098	0.00, 4.095E+89
	WWI	0.203	0.00, 18.01	0.000	0.00	0.005	0.00, 2.96	31.187	0.00, 313255.79	3.593	0.04, 296.96	0.004	0.00, 8862.96	25.222	0.20, 3162.83
	AVI	1.000	1.00, 1.00	1.028	0.02, 63.56	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00	1.000	1.00, 1.00
O/O boys	WHtR	5.267E+30	0.00, 4.094E+82	-	-	-	-	2.282E+15	0.0, 1.736E+40	0.000	0.00, 2.260E+48	-	-	0.000	0.00, .
	BRI	0.259	0.01, 9.84	-	-	-	-	0.544	0.04, 7.12	61896.120	0.00, 4.441E+12	-	-	5.953E+66	0.00,
	ABSI	2.152E+249	0.00, 0.00	-	-	-	-	1.742E+52	0.00, 1.611E+202	0.000	0.00, 0.00	-	-	0.000	0.00,
	WWI	0.000	0.00, 17414.56	-	-	-	-	3.953	0.00, 254597.82	9154.489	0.00, 2.636E+21	-	-	-	0.00
	AVI	1.001	1.00, 1.00	-	-	-	-	1.000	1.00, 1.00	1.000	1.00, 1.00	-	-	1.053	0.01, 98.32
O/O girls	WHtR	6042984881.43	0.00, 6.506E+25	0.001	0.00	74188338.06	0.00, 1.116E+23	2.982E+23	0.00	0.000	0.00, 18038.66	0.000	0.00, 0.00	0.795	0.23, 2.73
	BRI	1.420	0.02, 108.96	8.4E+21	0.00	0.099	0.00, 8.60	0.000	0.00	4.940	0.23, 105.97	5.530E+186	0.00, 0.00	0.707	0.01, 35.85
	ABSI	0.000	0.00, 4.064E+125	3.77E+14	0.00	3.446E+31	0.00, 6.471E+163	0.000	0.00	0.000	0.00, 2.308E+73	0.000	0.00, 0.00	2387.136	0.00, 4.173E+110
	WWI	2.565	0.00, 1991.53	0.000	0.00	0.029	0.00. 28.62	1.523E+42	0.00	3.313	0.02, 518.02	0.000	0.00, 0.00	13.909	0.04, 4591.46
	AVI	1.000	1.00, 1.00	1.816E+39	0.00	1.000	1.00, 1.00	1.000	0.00, 791123.72	1.000	1.00, 1.00	0.744	0.00, 126553.84	1.000	1.00. 1.00

*P-value<0.05; !P-value<0.005; #P-value<0.0001; O/O=overweight/Obese (O/O boys: *The dependent variables, DBP and high LDL-c, each has very few data which SPSS did not process*)

Table 3: Binary Logistic Regression Analysis of Anthropometric Indicators for MetS and its Components in All, Lean and Overweight/obese Boys and Girls in the Study Population

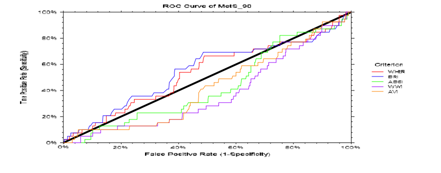
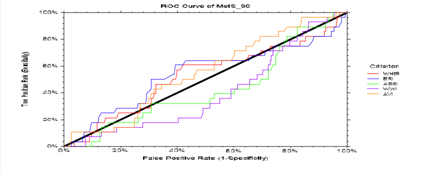
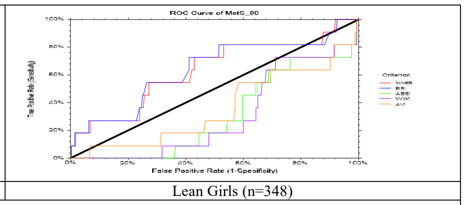
The Diagnostic Ability of Anthropometric Indicators for MetS and its Components

As shown in Tables/Figures 4a-e, BRI had the strongest discriminative power to identify MetS (AUC=0.611 for all subjects; 0.570 for boys, 0.745 for girls; 0.550 for all lean subjects, 0.542 for lean boys, 0.640 for lean girls). However, ABSI had a stronger predictive power to identify MetS in O/O subjects (AUC=0.739 for all O/O subjects, 0.778 for O/O boys, 0.684 for O/O girls). Overall, AVI had the strongest predictive ability to identify systolic hypertension (AUC=0.633), diastolic hypertension (AUC=0.621), combine systolic/diastolic hypertension (AUC=0.670), hypertriglyceridemia (AUC=0.536) and high LDL-c (AUC=0.583). On the other hand, BRI and WWI were only able to identify low HDL-c (AUC=0.552) and diabetic FPG (AUC=0.521) respectively.

Area Under the Curve (AUC)															
Statistics for ROC															
	All (n=624)					Boys (n=241)					Girls (n=383)				
	Metabolic syndrome (Yes=1; No=0)														
	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI
AUC	0.598	0.611	0.445	0.370	0.475	0.555	0.570	0.451	0.40	0.560	0.740	0.745	0.348	0.269	0.497
Cut-off	≥0.41	≥1.91	≥0.07	≥0.97	≥7009.24	≥0.41	≥1.84	≥0.07	≥1.18	≥2654.4	≥0.45	≥2.54	≥0.06	≥0.97	≥9566.4
Sensitivity	0.73	0.65	0.77	1.00	0.12	0.65	0.65	0.88	0.91	0.47	0.56	0.56	1.00	1.00	0.11
Specificity	0.48	0.58	0.28	0.007	0.94	0.56	0.58	0.20	0.15	0.67	0.87	0.88	0.01	0.006	0.98
DTC	0.59	0.54	0.76	0.99	0.89	0.56	0.55	0.81	0.85	0.63	0.46	0.46	0.99	0.99	0.89

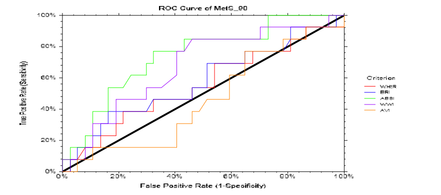
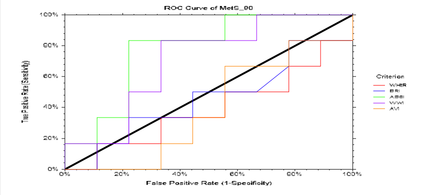
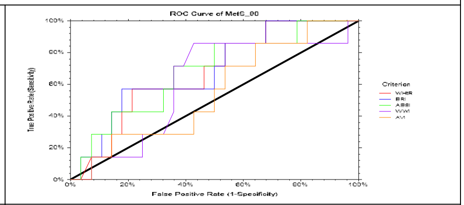
(a)

Area Under the Curve (AUC)

Statistics for ROC			

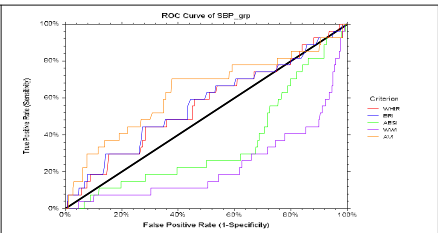
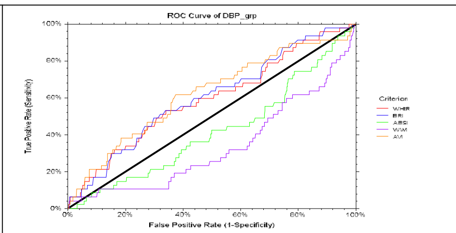
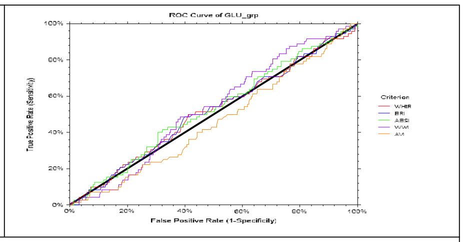
	All lean (n=574)					Lean Boys (n=226)					Lean Girls (n=348)				
	Metabolic syndrome (Yes=1; No=0)														
	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI
AUC	0.536	0.550	0.431	0.375	0.424	0.526	0.542	0.429	0.400	0.551	0.634	0.640	0.309	0.305	0.359
Cut-off	≥0.41	≥1.81	≥0.07	≥1.03	≥7009.2	≥0.41	≥1.81	≥0.07	≥1.18	≥1220.0	≥0.42	≥1.96	≥0.06	≥1.30	≥7009.2
DTC	0.59	0.58	0.77	0.98	0.90	0.57	0.56	0.83	0.87	0.71	0.51	0.49	0.99	0.76	0.91
Sensitivity	0.67	0.69	0.82	1.00	0.10	0.61	0.64	0.89	0.93	0.82	0.73	0.73	1.00	0.73	0.09
Specificity	0.51	0.51	0.25	0.02	0.95	0.58	0.57	0.17	0.14	0.31	0.57	0.59	0.01	0.29	0.93

(b)

Area Under the Curve (AUC)			
Statistics for ROC			

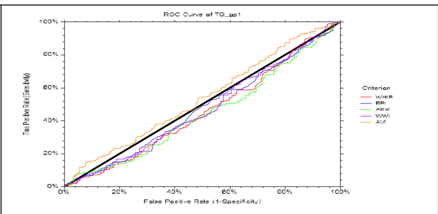
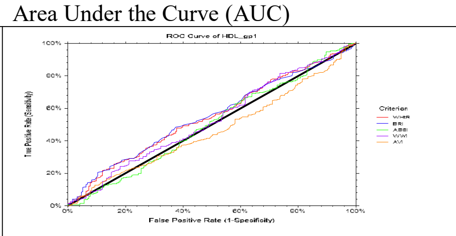
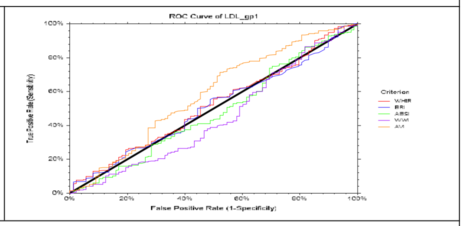
	All O/O (n=50)					O/O Boys (n=15)					O/O Girls (n=35)				
	Metabolic syndrome (Yes=1; No=0)														
	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI
AUC	0.550	0.576	0.739	0.673	0.456	0.389	0.454	0.778	0.704	0.389	0.676	0.689	0.684	0.607	0.551
Cut-off	≥0.52	≥3.75	≥0.07	≥1.16	≥3406.2	≥0.61	≥2.83	≥0.07	≥1.29	≥3591.48	≥0.52	≥3.79	≥0.07	≥1.16	≥3809.08
DTC	0.65	0.64	0.40	0.48	0.71	0.84	0.67	0.28	0.37	0.65	0.48	0.46	0.46	0.45	0.66
Sensitivity	0.38	0.38	0.77	0.85	0.77	0.17	0.50	0.83	0.83	0.67	0.57	0.57	0.71	0.86	0.86
Specificity	0.78	0.81	0.68	0.54	0.32	0.89	0.56	0.78	0.67	0.44	0.79	0.82	0.64	0.57	0.36

(c)

Area Under the Curve (AUC)			
Statistics for ROC			

	All														
	Systolic hypertension (Yes=1; No=0)					Diastolic hypertension (Yes=1; No=0)					Diabetic FPG (Yes=1; No=0)				
	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI
AUC	0.561	0.566	0.350	0.232	0.633	0.592	0.601	0.419	0.335	0.621	0.513	0.514	0.526	0.531	0.456
Cut-off	≥0.43	≥2.16	≥0.06	≥0.99	≥3437.69	≥0.43	≥2.07	≥0.06	≥2.25	≥3437.69	≥0.42	≥1.98	≥0.08	≥1.24	≥622.78
DTC	0.62	0.62	1.00	0.99	0.48	0.58	0.58	0.99	0.96	0.54	0.65	0.65	0.67	0.77	0.95
Sensitivity	0.44	0.44	1.00	1.00	0.70	0.53	0.53	1.00	0.04	0.62	0.50	0.72	0.42	0.87	0.97
Specificity	0.72	0.73	0.005	0.01	0.62	0.66	0.66	0.005	1.00	0.63	0.59	0.25	0.68	0.24	0.05

(d)

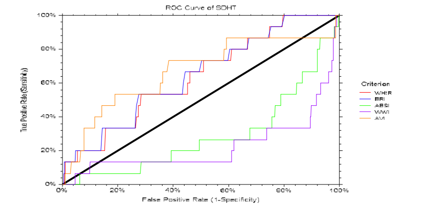
Area Under the Curve (AUC)			
Statistics for ROC			

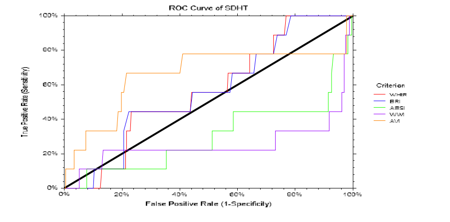
	All														
	Hypertriglyceridemia (Yes=1; No=0)					Low HDL (Yes=1; No=0)					High LDL (Yes=1; No=0)				
	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI
AUC	0.457	0.472	0.446	0.469	0.536	0.549	0.552	0.502	0.526	0.465	0.520	0.507	0.478	0.445	0.583
Cut-off	≥0.38	≥4.78	≥0.08	≥1.03	≥1002.63	≥0.44	≥1.90	≥0.07	≥1.23	≥5972.48	≥0.43	≥1.79	≥0.07	≥1.18	≥1729.96
DTC	0.88	0.99	0.93	0.95	0.82	0.79	0.64	0.71	0.76	0.88	0.77	0.66	0.74	0.83	0.60
Sensitivity	0.89	0.01	0.07	0.99	0.90	0.22	0.48	0.68	0.81	0.13	0.26	0.55	0.79	0.87	0.71
Specificity	0.13	1.00	0.96	0.05	0.18	0.88	0.63	0.36	0.26	0.91	0.80	0.51	0.23	0.18	0.48

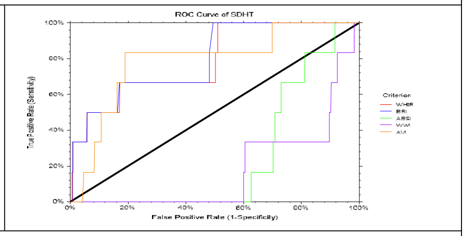
(e)

Area Under the Curve (AUC)

Statistics for ROC







	Systolic/Diastolic hypertension (Yes=1; No=0)														
	All					Boys					Girls				
	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI	WHtR	BRI	ABSI	WWI	AVI
AUC	0.637	0.644	0.288	0.226	0.670	0.564	0.565	0.302	0.256	0.659	0.790	0.799	0.251	0.182	0.786
Cut-off	≥0.43	≥2.16	≥0.06	≥1.82	≥3437.69	≥0.39	≥2.16	≥0.08	≥1.82	≥3437.69	≥0.45	≥1.90	≥0.07	≥1.03	≥5465.07
DTC	0.55	0.54	1.00	0.87	0.47	0.77	0.60	0.89	0.79	0.40	0.83	0.49	0.92	0.98	0.25
Sensitivity	0.53	0.53	1.00	0.13	0.73	1.00	0.44	0.11	0.22	0.67	0.67	1.00	1.00	1.00	0.83
Specificity	0.72	0.72	0.005	0.90	0.62	0.23	0.78	0.92	0.87	0.78	0.83	0.51	0.08	0.02	0.81

(f)

Tables/Figures 4a-e: The Discriminative Power of the Anthropometric Indices for MetS and its Components in Nigerian Adolescents

WtHR= waist-to-height ratio, *BRI* = body roundness index, *WWI* =weight adjusted waist index, *AVI* = abdominal volume index, *ABSI* = a body shape index, BP blood pressure, *TG* triglyceride, *HDL-C* HDL cholesterol, MetS metabolic syndrome, AUC=Area Under the Curve; DTC=Distance to corner

The Differences in ROC Curves of Anthropometric Indices for MetS Identification

For the identification of MetS in all subjects, no statistically significant differences were observed between WHtR and BRI, between ABSI and AVI and between AVI and WWI, though notable variances were noted between WHtR and ABSI (P-value = 0.008), WHtR and WWI (P-value = 0.0002), WHtR with AVI (P-value = 0.02), BRI and ABSI (P-value = 0.003), BRI and WWI (P-value = 0.0001), BRI and AVI (P-value = 0.008) as well as ABSI and WWI (P-value=0.01), most of these among girls. The discriminatory power of WHtR in the identification of MetS was analogous to that of BRI but superior to that of ABSI, AVI and WWI (Tables 5).

	Criteria	WHtR -BRI	WHtR -ABSI	WHtR -WWI	WHtR -AVI	BRI -ABSI	BRI -WWI	BRI -AVI	ABSI -WWI	ABSI -AVI	AVI -WWI
All subjects	Diff. in AUC	-0.01	0.15	0.23	0.12	0.17	0.24	0.14	0.07	-0.03	0.10
	SE	0.009	0.06	0.06	0.05	0.06	0.06	0.05	0.03	0.07	0.07
	P-value	0.15	0.008	0.0002	0.02	0.003	0.0001	0.008	0.01	0.66	0.13
Boys	Diff. in AUC	-0.02	0.10	0.15	-0.005	0.12	0.16	0.01	0.04	0.11	0.15
	SE	0.02	0.07	0.07	0.07	0.07	0.07	0.07	0.04	0.09	0.09
	P-value	0.32	0.11	0.04	0.95	0.07	0.03	0.88	0.30	0.22	0.10
Girls	Diff. in AUC	-0.005	0.39	0.47	0.24	0.40	0.48	0.25	0.08	0.15	0.23
	SE	0.004	0.08	0.10	0.08	0.08	0.10	0.08	0.05	0.10	0.11
	P-value	0.26	<0.00001	<0.00001	0.002	<0.000001	<0.00001	0.001	0.10	0.15	0.03
All Lean	Diff. in AUC	-0.01	0.10	0.16	0.11	0.01	0.18	0.13	0.06	0.01	0.05
	SE	0.01	0.06	0.07	007	0.01	0.07	0.06	0.04	0.07	0.08
	P-value	0.23	0.10	0.02	0.09	0.06	0.01	0.05	0.13	0.93	0.52
Lean Boys	Diff. in AUC	-0.02	0.10	0.13	-0.02	0.11	0.14	-0.01	0.03	-0.12	0.15
	SE	0.02	0.07	0.08	0.08	0.07	0.08	0.08	0.04	0.10	0.10
	P-value	0.38	0.18	0.10	0.76	0.12	0.08	0.92	0.53	0.21	0.12
Lean Girls	Diff. in AUC	-0.006	0.32	0.33	0.27	0.33	0.34	0.28	0.005	-0.05	0.05
	SE	0.006	0.11	0.12	0.12	0.11	0.12	0.12	0.05	0.12	0.11
	P-value	0.28	0.004	0.006	0.02	0.003	0.006	0.02	0.93	0.69	0.61
All O/O	Diff. in AUC	-0.03	-0.19	-0.12	0.09	-0.16	-0.10	0.12	0.07	0.28	0.22
	SE	0.03	0.10	0.12	0.11	0.09	0.12	0.11	0.08	0.14	0.16
	P-value	0.44	0.047	0.32	0.41	0.07	0.44	0.29	0.40	0.04	0.19
O/O Boys	Diff. in AUC	-0.06	-0.39	-0.31	0.00	-0.32	-0.25	0.06	0.07	0.39	-0.31
	SE	0.08	0.15	0.21	0.17	0.13	0.20	0.19	0.11	0.22	0.27
	P-value	0.41	0.008	0.13	1.00	0.02	0.21	0.73	0.52	0.08	0.25
O/O Girls	Diff. in AUC	-0.01	-0.01	0.07	0.12	0.01	0.08	0.14	0.08	0.13	0.06
	SE	0.04	0.10	0.14	0.16	0.09	0.14	0.17	0.14	0.19	0.22
	P-value	0.74	0.94	0.63	0.45	0.96	0.57	0.41	0.58	0.48	0.80

Definitions: Criterion 1, The first specified Criterion Variable; Criterion 2, The second specified Criterion Variable; AUC1, the calculated area under the ROC curve for Criterion 1; AUC2, the calculated area under the ROC curve for Criterion 2; Z-Value, the calculated Z-statistic for testing H0: AUC1 = AUC2; P-Value, the probability that the true AUC1 equals AUC2, given the sample data. (H0: AUC1 = AUC2, H1: AUC1 ≠ AUC2).

Table 5: Paired Comparison of ROC Curves for Identification of MetS in all, Lean, and Overweight/obese Subjects and by Gender

The Optimal Cutoff Value of Sex-Based and BMI-for-Age Anthropometric Indices for the Identification of MetS

In all study subjects, the optimal cut-off value of WHtR, BRI, ABSI, WWI and AVI for predicting MetS were 0.41, 1.91, 0.07, 0.97 and 7009.24 respectively, (0.41, 1.84, 0.07, 1.18 and 2654.4 for boys, and 0.45, 2.54, 0.06, 0.97 and 9566.4 for girls). In all subjects, BRI had the shortest distance to corner (0.54 for all, 0.55 for boys, 0.46 for girls; 0.58 for all lean, 0.56 for lean boys, 0.49 for lean girls), making it a strong instrument for predicting MetS in adolescents while WWI and ABSI were the weakest. However, ABSI had the shortest distance to corner among overweight/obese adolescents (0.40 for all O/O, 0.28 for O/O boys, 0.46 for O/O girls). However, WWI had the shortest distance to corner (0.45) among O/O girls. For all subjects, AVI had the shortest distance to corner to predict Hypertriglyceridemia (DTC=0.82, Sensitivity=0.90) as well as high LDL-c (DTC=0.60, Sensitivity=0.71) whereas BRI has the shortest distance to corner in predicting low HDL (DTC=0.64, Sensitivity=0.48).

Discussion

This cross-sectional study on MetS and its components was conducted on adolescent boys and girls attending various government-approved secondary schools in Lagos, Nigeria. It is the first to utilize novel anthropometric indices – BRI, ABSI, WWI and AVI – to predict metabolic syndrome among sub-Saharan Black African adolescents. The subjects were evaluated without any distinction and were later segregated into lean and overweight/obese subjects, each group being further segregated into boys and girls. As expected in a developing country, the proportion of lean adolescents (574/624, 92.0%) far outweighs that of overweight/obese (50/624, 8.0%) and that of girls (35/50, 70.0%) far outweighs that of boys (15/50, 30.0%). In an attempt to come up with an applicable cut-off values for separate populations, modern anthropometric matrices such as Lipid Accumulation Product (LAP), a novel index of central lipid accumulation based on a combination of waist circumference and serum triglycerides [50-52], Visceral Adiposity Index (VAI), Visceral Adiposity Index (VAI), which utilizes Body Mass Index (kg/m^2), Waist Circumference (WC in cm), triglycerides and high-density lipoprotein-cholesterol have been utilized [53]. Most of these measurements were conducted in adults and it is not yet decided whether these anthropometric indices are applicable to adolescents who are still in the process of growing. Nevertheless, there are some salient points that this current study exposes. First, mean WHtR was significantly higher in girls compared to boys, indicating that adolescent obesity was more frequent in girls than boys. Also, the area under the curve (AUC) for WHtR in identifying MetS was higher among girls (0.740) than boys (0.555) indicating that, in general, WHtR may be better suited for girls than for boys. However, in all lean adolescents, the AUC for BRI in identifying MetS was higher than that of WHtR (0.550 vs 0.536), especially in lean girls (0.640 vs 0.634) compared to lean boys (0.542 vs 0.526). In contrast, a Korean study reported that WHtR is more related to cardiometabolic risk factors in lean adolescents [54]. This difference in these findings may be related to living standards of the two groups of adolescents, one in a developing, the other in an industrialized nation. Further, the optimal WHtR cut-off points of 0.41 in boys and 0.42 in girls observed in this study are lower than the 0.47 in boys and 0.45 in girls reported by Zhou et al in China but closer to the 0.44 for boys and o.43 for girls reported in another Korean study [55,56]. This indicates that cut-off points for anthropometric indices to identify MetS, specifically among adolescents, may be dependent on growth potential, regional, ethnic and other salient differences. In all the subjects WHtR and BRI were superior to ABSI, WWI and AVI in identifying MetS, especially among lean but not obese individuals (girls mostly). Unlike what is reported here for adolescents, a systematic review and meta-analysis reported that, in adult males and females from diverse populations, BRI possesses a good discriminatory power for MetS which may be taken that different anthropometric indices may be needed to predict MetS in adolescents and among adults [57]. Another vital point is that AVI was superior to other anthropometric indices in predicting systolic, diastolic, and combined systolic/diastolic hypertension (in all, AUC=0.670 and in boys, AUC=659), hypertriglyceridemia (AUC=0.536) and high LDL-c (AUC=0.583). The AUC of 0.659 (boys) and 0.786 (girls) for hypertension reported in this study is lower than the 0.83 (boys) and 0.83 (girls) reported by Personal et al. for adults while Khan and his colleagues concluded that WHtR and AVI showed the highest AUC to diagnose metabolic syndrome and were better associated with metabolic diseases though they did not specify gender differentiation, contrary to the submission of a systematic review and meta-analysis by Calderon-Garcia et al that BRI was significantly better predictor of hypertension than ABSI [58-60]. Also, although ABSI was superior to all other anthropometric indices in identifying MetS in the obese subjects, it was not gender specific as it was superior to the others in identifying MetS only in boys (AUC=0.778) and not in girls (0.684) among whom BRI was superior (AUC=0.689) than other anthropometric indices. Garazova et al confirmed ABSI being relevant in screening at-risk population, including obese individuals [61]. In this study WWI significantly correlated with HDL-c, in all subjects, especially girls; in all overweight/obese subjects, both boys and girls; and with systolic blood pressure in overweight/obese adolescents. However, it was barely able to predict only diabetic fasting plasma glucose, with an AUC of 0.531. The findings of Wand et al suggested that higher WWI levels are linked to diabetic kidney disease (DKD) in adults which indicates the usefulness of this instrument as a cost-effective and straightforward way to detect this disease [62]. Some other studies on WWI also found a relationship between WWI and type 2 diabetes, being an independent predictor of mortality in adults with type 2 diabetes and in cardiovascular diseases [65]. Findings on WWI in this paper may be a pointer to future incidence of DKD, making this a possible candidate for screening of this disease in adolescents. That WWI did not feature strongly as a discriminatory instrument for MetS in lean or obese individuals compared to WHtR or BRI may probably be for the speculated reason, it is grounded on two anthropometric measurements – body weight and waist circumference thus unable to differentiate between fat distribution and body weight composition, thereby underestimating fat content and visceral adipose tissue (VAT) of short stature people while over-estimating that of tall people [49]. Other probable reasons why WWI did not feature prominently in this analysis is that, in adolescent obesity, ABSI had a superiority as marker of MetS and probably because overweight and obese adolescents were few.

Study Limitations

Limitations in this study have already been documented [40]. However, they are summarily discussed below. The study has notable limitations, including a small sample size that may affect the understanding of metabolic conditions among adolescents, particularly in the southern region of the country. Additionally, the sample may be biased due to an uneven gender ratio and exclusion of some overweight or obese students. As the study focused on a specific geographical area, its findings may not be applicable nationwide, highlighting the need for further research on dyslipidemia, metabolic syndrome and appropriate anthropometric discriminator among secondary school adolescents across the country.

Conclusion

Probably because humans are of different shapes and sizes and most probably because growth in adolescence is continuous, different anthropometric indices are necessary to predict not only MetS but other cardiometabolic indices. This study demonstrates that of all the novel anthropometric indices, BRI had the highest diagnostic accuracy to recognize MetS in all the adolescents, both boys and girls, in lean subjects both boys and girls and to also recognize low HDL in all adolescents of Black Nigerian ethnicity. On the other hand, ABSI was the strongest instrument to distinguish MetS among all overweight/obese subjects though only in boys and not girls. Meanwhile, AVI had the strongest capacity to identify systolic, diastolic and combined systolic/diastolic hypertension, hypertriglyceridemia, and high LDL-c. There is still a paucity of data on this topic and extensive studies are required in sub-Sahara Africa so as to add to collective knowledge on this topic. Ministry of Health at Federal and State levels in Nigeria should make this a matter of urgency and fund studies on cheap and useful diagnostic instruments for metabolic syndrome and its components. These simple clinically inclined anthropometric tools may assist health workers to identify, and refer for further evaluation, subjects at risk of MetS and its components.

Authors' Contributions

SJH contributed to the conception of the study; SJH and BMA designed the study, performed statistical analysis, interpreted the data and drafted the manuscript. BMA drafted the manuscript and SJH reviewed and edited it. Both authors read and approved the final manuscript.

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Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate.

The study was approved by the Institutional Review Board of the Nigerian Institute of Medical Research (IRB/18/062) on 4th February 2019). An informed written consent was obtained from each participant.

Competing Interests

The authors declare that they have no competing interests.

References

1. Pekgor, S., Duran, C., Berberoglu, U., & Eryilmaz, M. A. (2019). The role of visceral adiposity index levels in predicting the presence of metabolic syndrome and insulin resistance in overweight and obese patients. Metabolic syndrome and related disorders, 17(5), 296-302.
2. Tabassum, M., Mozaffor, M., Rahman, M. M., & Huda, R. M. (2022). Lipid accumulation product: an effective obesity index to predict metabolic syndrome. Journal of Bangladesh College of Physicians and Surgeons, 40(1), 5-9.
3. Ambroselli, D., Masciulli, F., Romano, E., Catanzaro, G., Besharat, Z. M., Massari, M. C., ... & Mannina, L. (2023). New advances in metabolic syndrome, from prevention to treatment: the role of diet and food. Nutrients, 15(3), 640.
4. Dobrowolski, P., Prejbisz, A., Kuryłowicz, A., Baska, A., Burchardt, P., Chlebus, K., ... & Bogdański, P. (2022). Metabolic syndrome—A new definition and management guidelines. Arterial Hypertension, 26(3), 99-121.
5. Swarup, S., Goyal, A., Grigorova, Y., & Zeltser, R. (2023). Metabolic Syndrome. [Updated 2022 Oct 24]. StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing.
6. Peterseim, C. M., Jabbour, K., & Kamath Mulki, A. (2024). Metabolic Syndrome: An Updated Review on Diagnosis and Treatment for Primary Care Clinicians. Journal of Primary Care & Community Health, 15, 21501319241309168.
7. Li, M., & McDermott, R. A. (2010). Using anthropometric indices to predict cardio-metabolic risk factors in Australian indigenous populations. Diabetes research and clinical practice, 87(3), 401-406.
8. Shrestha, R., Upadhyay, S. K., Khatri, B., Bhattarai, J. R., Kayastha, M., & Upadhyay, M. P. (2021). BMI, waist to height ratio and waist circumference as a screening tool for hypertension in hospital outpatients: a cross-sectional, non-inferiority study. BMJ open, 11(11), e050096.
9. Liu, Z., Asuzu, P., Patel, A., Wan, J., & Dagogo-Jack, S. (2025). Fidelity of BMI, Waist, and Waist-to-Height Ratio

as Adiposity Measures in Normoglycemic Black vs White American Adults. Journal of the Endocrine Society, 9(1), bvae202.

10. Baskaran, K., dos-Santos-Silva, I., Leon, D. A., Douglas, I. J., & Smeeth, L. (2018). Association of BMI with overall and cause-specific mortality: a population-based cohort study of 3· 6 million adults in the UK. The lancet Diabetes & endocrinology, 6(12), 944-953.
11. Aune, D., Sen, A., Prasad, M., Norat, T., Janszky, I., Tonstad, S., ... & Vatten, L. J. (2016). BMI and all-cause mortality: systematic review and non-linear dose-response meta-analysis of 230 cohort studies with 3.74 million deaths among 30.3 million participants. bmj, 353.
12. Prospective Studies Collaboration. (2009). Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. The Lancet, 373(9669), 1083-1096.
13. Di Angelantonio, E., Bhupathiraju, S. N., Wormser, D., Gao, P., Kaptoge, S., De Gonzalez, A. B., ... & Hu, F. B. (2016). Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. The lancet, 388(10046), 776-786.
14. Gary H. Gibbons. (2013). Managing overweight and obesity in adults.
15. Aune, D., Norat, T., & Vatten, L. J. (2015). Body mass index, abdominal fatness and the risk of gallbladder disease. European journal of epidemiology, 30, 1009-1019.
16. Aune, D., Norat, T., & Vatten, L. J. (2014). Body mass index and the risk of gout: a systematic review and dose–response meta-analysis of prospective studies. European journal of nutrition, 53, 1591-1601.
17. Guh, D. P., Zhang, W., Bansback, N., Amarsi, Z., Birmingham, C. L., & Anis, A. H. (2009). The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. BMC public health, 9, 1-20.
18. Patterson, R. E., Frank, L. L., Kristal, A. R., & White, E. (2004). A comprehensive examination of health conditions associated with obesity in older adults. American journal of preventive medicine, 27(5), 385-390.
19. Reeves, G. K., Balkwill, A., Cairns, B. J., Green, J., Beral, V., & Million Women Study Collaborators. (2014). Hospital admissions in relation to body mass index in UK women: a prospective cohort study. BMC medicine, 12, 1-12.
20. Whitlock G, Lewington S, Sherliker P, et al. Prospective Studies Collaboration. (2009). Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. The Lancet, 373(9669), 1083-1096.
21. Berrington de Gonzalez, A., Hartge, P., Cerhan, J. R., Flint, A. J., Hannan, L., MacInnis, R. J., ... & Thun, M. J. (2010). Body-mass index and mortality among 1.46 million white adults. New England Journal of Medicine, 363(23), 2211-2219.
22. Hsieh, S. D., & Yoshinaga, H. (1995). Abdominal fat distribution and coronary heart disease risk factors in men-waist/height ratio as a simple and useful predictor. International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity, 19(8), 585-589.
23. Ashwell, M., & Hsieh, S. D. (2005). Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the international public health message on obesity. International journal of food sciences and nutrition, 56(5), 303-307.
24. Zhao, S., Ren, Z., Yu, S., Chi, C., Tang, J., Maimaitiaili, R., ... & Zhang, Y. (2021). Association between lipid accumulation product and target organ damage in elderly population: the northern shanghai study. Clinical Interventions in Aging, 1769-1776.
25. Camhi, S. M., Bray, G. A., Bouchard, C., Greenway, F. L., Johnson, W. D., Newton, R. L., ... & Katzmarzyk, P. T. (2011). The relationship of waist circumference and BMI to visceral, subcutaneous, and total body fat: sex and race differences. Obesity, 19(2), 402-408.
26. Li, C., Ford, E. S., Mokdad, A. H., & Cook, S. (2006). Recent trends in waist circumference and waist-height ratio among US children and adolescents. Pediatrics, 118(5), e1390-e1398.
27. Marrodán, M. D., Álvarez, J. M., de Espinosa, M. G. M., Carmenate, M. M., López-Ejeda, N., Cabanas, M. D., ... & Villarino, A. (2014). Predicting percentage body fat through waist-to-height ratio (WtHR) in Spanish schoolchildren. Public health nutrition, 17(4), 870-876.
28. Brambilla, P., Bedogni, G., Heo, M., & Pietrobelli, A. (2013). Waist circumference-to-height ratio predicts adiposity better than body mass index in children and adolescents. International journal of obesity, 37(7), 943-946.
29. Thomas, D. M., Bredlau, C., Bosy-Westphal, A., Mueller, M., Shen, W., Gallagher, D., ... & Heymsfield, S. B. (2013). Relationships between body roundness with body fat and visceral adipose tissue emerging from a new geometrical model. Obesity, 21(11), 2264-2271.
30. Krakauer, N. Y., & Krakauer, J. C. (2012). A new body shape index predicts mortality hazard independently of body mass index. PloS one, 7(7), e39504.
31. Guerrero-Romero, F., & Rodríguez-Morán, M. (2003). Abdominal volume index. An anthropometry-based index for estimation of obesity is strongly related to impaired glucose tolerance and type 2 diabetes mellitus. Archives of medical research, 34(5), 428-432.
32. Li, G., Yao, T., Wu, X. W., Cao, Z., Tu, Y. C., Ma, Y., ... & Hou, J. (2020). Novel and traditional anthropometric indices for identifying arterial stiffness in overweight and obese adults. Clinical Nutrition, 39(3), 893-900.
33. Liu, P. J., Ma, F., Lou, H. P., & Zhu, Y. N. (2017). Comparison of the ability to identify cardiometabolic risk factors between two new body indices and waist-to-height ratio among Chinese adults with normal BMI and waist circumference. Public health nutrition, 20(6), 984-991.
34. Chang, Y., Guo, X., Chen, Y., Guo, L., Li, Z., Yu, S., ... & Sun, Y. (2015). A body shape index and body roundness index: two new body indices to identify diabetes mellitus among rural populations in northeast China. BMC Public

health, 15, 1-8.
35. Geraci, G., Zammuto, M., Gaetani, R., Mattina, A., D'Ignoto, F., Geraci, C., ... & Mulè, G. (2019). Relationship of a body shape index and body roundness index with carotid atherosclerosis in arterial hypertension. Nutrition, Metabolism and Cardiovascular Diseases, 29(8), 822-829.
36. Krakauer, N. Y., & Krakauer, J. C. (2012). A new body shape index predicts mortality hazard independently of body mass index. PloS one, 7(7), e39504.
37. Park, Y., Kim, N. H., Kwon, T. Y., & Kim, S. G. (2018). A novel adiposity index as an integrated predictor of cardiometabolic disease morbidity and mortality. Scientific reports, 8(1), 16753.
38. Guerrero-Romero, F., & Rodríguez-Morán, M. (2003). Abdominal volume index. An anthropometry-based index for estimation of obesity is strongly related to impaired glucose tolerance and type 2 diabetes mellitus. Archives of medical research, 34(5), 428-432.
39. Perona, J. S., Schmidt-RioValle, J., Fernández-Aparicio, Á., Correa-Rodríguez, M., Ramírez-Vélez, R., & González-Jiménez, E. (2019). Waist circumference and abdominal volume index can predict metabolic syndrome in adolescents, but only when the criteria of the International Diabetes Federation are employed for the diagnosis. Nutrients, 11(6), 1370.
40. Holdbrooke, S. J., Afolabi, B. M., Onabanjo, O. O., Salau, I. O., & Lucas, O. T. (2025). Linking anthropometric indices with components of metabolic syndrome among Nigerian adolescents. Academia Medicine, 2.
41. WHO. Adolescent health. [cited 2022 Oct 22].
42. Thomas, D. M., Bredlau, C., Bosy-Westphal, A., Mueller, M., Shen, W., Gallagher, D., ... & Heymsfield, S. B. (2013). Relationships between body roundness with body fat and visceral adipose tissue emerging from a new geometrical model. Obesity, 21(11), 2264-2271.
43. Krakauer, N. Y., & Krakauer, J. C. (2012). A new body shape index predicts mortality hazard independently of body mass index. PloS one, 7(7), e39504.
44. World Health Organization. AnthroPlus V1.04. (2022).
45. National Cholesterol Education Program (NCEP). Expert Panel on Blood Cholesterol Levels in Children and Adolescents: highlight of the reports of the Expert Panel. Pediatrics. 1992; 89(3):495–501.
46. North American Association for the Study of Obesity, National Heart, Lung, Blood Institute, & NHLBI Obesity Education Initiative. (2000). The practical guide: identification, evaluation, and treatment of overweight and obesity in adults. National Institutes of Health, National Heart, Lung, and Blood Institute, NHLBI Obesity Education Initiative, North American Association for the Study of Obesity.
47. Lande, M. B., & Batisky, D. L. (2019). New American Academy of Pediatrics Hypertension Guideline: Who Is Up and Who Is Down. Hypertension, 73(1), 31-32.
48. Hanley, J. A., & McNeil, B. J. (1983). A method of comparing the areas under receiver operating characteristic curves derived from the same cases. Radiology, 148(3), 839-843.
49. Wu, L., Zhu, W., Qiao, Q., Huang, L., Li, Y., & Chen, L. (2021). Novel and traditional anthropometric indices for identifying metabolic syndrome in non-overweight/obese adults. Nutrition & Metabolism, 18, 1-10.
50. Chiang, J. K., & Koo, M. (2012). Lipid accumulation product: a simple and accurate index for predicting metabolic syndrome in Taiwanese people aged 50 and over. BMC cardiovascular disorders, 12, 1-6.
51. Kahn, H. S., & Valdez, R. (2003). Metabolic risks identified by the combination of enlarged waist and elevated triacylglycerol concentration. The American journal of clinical nutrition, 78(5), 928-934.
52. Kaneva, A. M., & Bojko, E. R. (2021). Age-adjusted cut-off values of lipid accumulation product (LAP) for predicting hypertension. Scientific Reports, 11(1), 11095.
53. Amato, M. C., Giordano, C., Pitrone, M., & Galluzzo, A. (2011). Cut-off points of the visceral adiposity index (VAI) identifying a visceral adipose dysfunction associated with cardiometabolic risk in a Caucasian Sicilian population. Lipids in health and disease, 10, 1-8.
54. Chung, I. H., Park, S., Park, M. J., & Yoo, E. G. (2016). Waist-to-height ratio as an index for cardiometabolic risk in adolescents: results from the 1998-2008 KNHANES. Yonsei medical journal, 57(3), 658-663.
55. Zhou, D., Yang, M., Yuan, Z. P., Zhang, D. D., Liang, L., Wang, C. L., ... & Zhu, Y. M. (2014). Waist-to-Height Ratio: a simple, effective and practical screening tool for childhood obesity and metabolic syndrome. Preventive Medicine, 67, 35-40.
56. Choi, D. H., Hur, Y. I., Kang, J. H., Kim, K., Cho, Y. G., Hong, S. M., & Cho, E. B. (2017). Usefulness of the waist circumference-to-height ratio in screening for obesity and metabolic syndrome among Korean children and adolescents: Korea National Health and Nutrition Examination Survey, 2010–2014. Nutrients, 9(3), 256.
57. Rico-Martín, S., Calderón-García, J. F., Sánchez-Rey, P., Franco-Antonio, C., Martinez Alvarez, M., & Sánchez Muñoz-Torrero, J. F. (2020). Effectiveness of body roundness index in predicting metabolic syndrome: a systematic review and meta-analysis. Obesity Reviews, 21(7), e13023.
58. Perona, J. S., Schmidt Rio-Valle, J., Ramírez-Vélez, R., Correa-Rodríguez, M., Fernández-Aparicio, Á., & González-Jiménez, E. (2019). Waist circumference and abdominal volume index are the strongest anthropometric discriminators of metabolic syndrome in Spanish adolescents. European Journal of Clinical Investigation, 49(3), e13060.
59. Khan, S. H., Shahid, R., Fazal, N., & Ijaz, A. (2019). Comparison of various abdominal obesity measures for predicting metabolic syndrome, diabetes, nephropathy, and dyslipidemia. J Coll Physicians Surg Pak, 29(12), 1159-1164.
60. Calderón-García, J. F., Roncero-Martín, R., Rico-Martín, S., De Nicolás-Jiménez, J. M., López-Espuela, F., Santano-Mogena, E., ... & Sanchez Munoz-Torrero, J. F. (2021). Effectiveness of body roundness index (BRI) and a body shape index (ABSI) in predicting hypertension: a systematic review and meta-analysis of observational studies.

International journal of environmental research and public health, 18(21), 11607.
61. Gazarova, M., Galsneiderova, M., & Meciarová, L. (2019). Obesity diagnosis and mortality risk based on a body shape index (ABSI) and other indices and anthropometric parameters in university students. Roczniki Państwowego Zakładu Higieny, 70(3).
62. Wang, Z., Shao, X., Xu, W., Xue, B., Zhong, S., & Yang, Q. (2024). The relationship between weight-adjusted-waist index and diabetic kidney disease in patients with type 2 diabetes mellitus. Frontiers in Endocrinology, 15, 1345411.
63. Zhang, T. Y., Zhang, Z. M., Wang, X. N., Kuang, H. Y., Xu, Q., Li, H. X., ... & Hao, M. (2024). Relationship between weight-adjusted-waist index and all-cause and cardiovascular mortality in individuals with type 2 diabetes. Diabetes, Obesity and Metabolism, 26(12), 5621-5629.
64. Tao, Z., Zuo, P., & Ma, G. (2024). The association between weight-adjusted waist circumference index and cardiovascular disease and mortality in patients with diabetes. Scientific Reports, 14(1), 18973.
65. Tao, Z., Zuo, P., & Ma, G. (2024). The association between weight-adjusted waist circumference index and cardiovascular disease and mortality in patients with diabetes. Scientific Reports, 14(1), 18973.