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Original Article

Anthropometric parameter that best predict metabolic syndrome in South west Nigeria

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ABSTRACT

Aim: This study compared the ability of anthropometric parameters to predict Metabolic Syndrome (MetS).
Methods: Eleven anthropometric parameters: waist circumference (WC), body mass index (BMI), waist-to-height ratio (WHtR), a body shape index (ABSI), body roundness index (BRI), visceral adiposity index (VAI), abdominal volume index (AVI), Conicity Index (CI), body adiposity index (BAI), lipid accumulation product (LAP) and waist circumference-triglyceride index (WTI) were measured and calculated in apparently healthy subjects with and without MetS. A receiver operating characteristic (ROC) curve was applied to assess their ability to predict MetS.
Results: Of the 535 subjects recruited 23% had MetS. WC had the largest area under the curve (AUC) in both men (0.814 95% CI 0.721–0.907) and women (0.819 95%CI 0.771–0.867). This did not differ from the AUC of BMI, WHtR, BRI, CI, BAI, LAP in men and BMI, WHtR, BAI, LAP, VAI and WTI in women ($P > 0.05$). The cutoff point for WC was 89.5 cm and 91.8 cm in men and women respectively. The AUC of WC was the largest in the 40–49 and 60 years and above age groups while the AUC of LAP was the largest for age groups 30–39 and 50–59 years.
Conclusion: Of the 11 anthropometric parameters assessed, the WC was the best at predicting MetS in both men and women. There is need to ascertain the cutoff point and establish landmark for measuring WC especially for the sub Saharan region.

1. Introduction

Metabolic syndrome (MetS) is known to be a cluster of interrelated risk factors of metabolic origin such as elevated blood pressures, glucose metabolism disturbances, dyslipidemia, and obesity which are linked to the development of atherosclerotic cardiovascular diseases and type 2 diabetes mellitus (T2DM) [1,2]. Of these risk factors, obesity or body fat seems to be the predominant underlying risk factor not only in the development of MetS but also other cardiovascular (CVD) risk factors [3].

Central obesity considered as a marker of body fat can be conveniently and cost effectively estimated by measuring body mass index (BMI) and waist circumference (WC) which might in turn effectively predict the MetS [4]. Some other indices of abdominal obesity such as waist hip ratio (WHR) and waist height ratio (WHtR) have been reported to be better discriminators of CVD and metabolic risk factors than BMI and/or WC [4]. However, studies from different countries and ethnicities have different conclusions regarding the superiority of one or the other obesity index and related cut-off points to diagnose obesity and hence MetS [5,6]. Researchers believe that ethnic and racial variation among population from different regions might need different cut-off points and/or use of different anthropometric measurement to

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diagnose obesity and MetS [6].

Studies from South Africa and elsewhere have shown that WHtR is a better predictor of MetS than other anthropometric measurements [7–9]. The WHtR has also been found to be a good predictor of T2DM and oxidative stress [10,11]. It has been suggested that BMI lacks precision of discriminating between excess adipose tissue and lean muscle mass [12] irrespective of ethnic variations and WC has tendency to over and under evaluate the risk of CVD in short and tall individuals with similar WC [13] even though other studies have demonstrated that WC is strongly associated with CVD risk factors and correlate better than BMI [14,15]. Though WHtR has been suggested to be a better index than WC and BMI in some studies [16], reports from Denmark and Japan showed that WHtR is not a good measure of adiposity in both men and women to identify metabolic risk factors [17,18]. More recently other indices of estimating body fat such as a body shape index (ABSI), body roundness index (BRI), visceral adiposity index (VAI), abdominal volume index (AVI), Conicity Index (CI), body adiposity index (BAI), lipid accumulation product (LAP) and waist circumference-triglyceride index (WTI) have been opined to be good predictors of MetS [22–27]. However, no consensus has been agreed upon about the best anthropometric indices for evaluating the MetS.

Some studies from Nigeria have attempted to determine the anthropometric measurement that best predicts MetS and the cutoff points. However, these studies have been limited to WC, BMI, WHR and WHtR. The findings from these studies have not been consistent either. While some studies reported WC to have better discriminatory ability than BMI and WHR [19,20]. Other studies showed that WHtR was more predictive than WC, BMI and WHR [21].

This present study which is a follow up to a study that assessed the prevalence of MetS in South west Nigeria using three different definitions [28] is aimed at comparing the ability of ABSI, BRI, VAI, AVI, CI, BAI, LAP and WTI to predict the MetS and its components to WC, BMI or WHtR in South west Nigeria.

2. Methods

In order to assess the anthropometric indices that best predict the MetS and its components in South west Nigeria, a cross sectional study was designed and multi stage sampling technique was used to select one rural (Ilara -Akaka) and one urban (Ikeja) community from Ogun and Lagos state respectively (purposefully selected for logistic reasons). Apparently healthy volunteer subjects who were 18 years and above, had resided within the community at least 2 years prior to the study and were not previously diagnosed of diabetes and hypertension were consecutively recruited into the study. Socio demographic details of the subjects were collected on a proforma after recruitment into the study. This was followed by anthropometric and blood pressure measurements and collection of venous blood for lipid profile and blood glucose estimation after an overnight fast. Details of study location, sample size determination, selection criteria and study procedure were earlier published [28].

2.1. Measurements and classification of outcome variables

2.1.1. Measurement and calculation of anthropometric indices

The anthropometric indices, such as BMI, WHR, WHtR, ABSI, AVI, BAI, BRI, CI, VAI, LAP and WTI were calculated using the following formulas [23, 29–34].

- WC was measured with a flexible tape in a horizontal plane above the level of the iliac crest at the end of normal expiration to the nearest 0.1 cm.
- Height of subjects was measured to the nearest 0.1 m with a portable stadiometer without shoes, caps or head gear.
- Weight was measured to the nearest 0.1 kg using a portable standardized digital scale which was calibrated daily, with participants lightly clothed and without shoes.
- Body mass index (BMI) was be calculated by dividing weight (in kilograms) by the square of the height (in meters).
- Waist to height ratio (WHtR) was calculated as WC (cm) divided by height (cm)
- $ABSI = WC\ (m)/[BMI^{2/3}\ (kg/m^2) Height^{1/2}\ (m)]$;
- $AVI = [2WC^2\ (cm) + 0.7(WC - HC)^2\ (cm)]/1000$;
- $BAI = [HC\ (m)/Height^{2/3}\ (m)] - 18$;
- $BRI = 364.2 - 365.5\ [1 - \pi^{-2} WC^2\ (m)\ Height^{-2}\ (m)]^{1/2}$;
- $CI = 0.109^{-1} WC\ (m)[Weight\ (kg)/Height\ (m)]^{-1/2}$;
- $VAI\ male = [WC\ (cm)/39.68 - 1.88 BMI\ (kg/m^2)]\ [TG\ (mmol/L)/1.03][1.31/HDL\ (mmol/L)]$; $VAI female = [WC(cm)/36.58 - 1.89 BMI\ (kg/m^2)][TG\ (mmol/L)/0.81][1.52/HDL\ (mmol/L)]$.
- LAP was calculated as $(WC\ [cm] - 65) \times (TG\ [mmol/L])$ for males, and $(WC\ [cm] - 58) \times (TG\ [mmol/L])$ for females
- $WTI = WC(cm) \times TG\ (mmol/L)$

2.1.2. Measurement of blood pressure

Blood pressure was measured in the morning with the subjects in sitting position after about 5 min rest using a calibrated OMRON automated BP monitor (Omron Healthcare, Kyoto, Japan) that uses an upper arm cuff. The average of two blood pressure measurements taken on the right arm of the subjects was recorded for the subjects.

2.1.3. Definition of MetS

MetS was defined using the criteria of the joint interim statement of the IDF Task Force (JIS). The task force recommended MetS could be diagnosed when three or more of the following conditions are fulfilled [1]: (1) raised triglycerides: ≥150 mg/dl (1.7 mmol/l) or history of specific treatment for this lipid abnormality; (2) reduced HDL cholesterol: < 40 mg/dl (1.03 mmol/l) in men and <50 mg/dl (1.29 mmol/l) in women or history of specific treatment for this lipid abnormality; (3) raised blood pressure: systolic BP ≥ 130 mm Hg or diastolic BP ≥ 85 mm Hg or on treatment for previously diagnosed hypertension; (4) raised Fasting plasma glucose (FPG): ≥100 mg/dl or previously diagnosed type 2 diabetes mellitus; (5) WC ≥ 94 cm in men or ≥80 cm in women (as recommended for Europeans).

2.2. Statistical analysis

Subjects were grouped as having MetS and non-MetS using the JIS definition [28]. Student ‘t’ test was used to compare the mean of anthropometric indices and clinical parameters of subjects with and without MetS. The area under the receiver operating (ROC) curves was determined to assess the abilities of anthropometric indices to discriminate MetS and its components. The higher the area under the curve, the higher the likelihood of the anthropometric index to discriminate MetS. Sensitivity, specificity, the Youden index and the cut off of each predicting variable was determined. The area under the ROC curves (AUC) was used to determine the ability of each anthropometric parameter to predict MetS. The AUCs were compared using a DeLong et al. non-parametric approach [35]. For all statistical test, the confidence interval was set at 95% unless otherwise indicated and $p < 0.05$ was considered to be statistically significant. IBM SPSS statistics for windows, version 20,0 (Armonk, NY: IBM Corp) was used to conduct the statistical analysis.

2.3. Ethical considerations

The ethical approvals for this study were obtained from the Babcock University Health Research and Ethical committee (BUHREC) Ilishan, Ogun State and the Health Research and Ethical Committee of the Lagos State University Teaching Hospital Ikeja, Lagos. Written informed consent was obtained from the subjects before enrollment into the study. Subjects were assured of strict confidentiality.

3. Results

3.1. Characteristics of participants

A total of 535 apparently subjects were recruited into the study. The male:female ratio was 1:2.7. One hundred and twenty three (23%) of the 535 subjects had MetS out of which 81.3% were females. The subjects with MetS had significantly higher levels of FPG, TRG, TC ($p < 0.001$) and reduced level of HDL-C compared with subjects without MetS in both men and women ($p < 0.001$). The anthropometric parameters such as WC, HC, BMI, WHtR, BRI, CI, BAI, LAP, VAI and WTI in addition to SBP and DBP were higher in subjects with MetS regardless of gender (Table 1).

3.2. Comparison of the anthropometric parameters in predicting MetS

In general, AVI and WC had the smallest and largest AUC respectively. It varied from 0.377 (0.257–0.496) for AVI to 0.814 (0.721–0.907) for WC in men and 0.483 (0.413–0.552) for AVI to 0.819 (0.771–0.867) for WC in women. Aside from AVI and ABSI the AUC of all the anthropometric parameters were different from 0.5 ($p < 0.05$) in both gender. Though the WC had the largest AUC in both men and women, this did not differ from the AUC of BMI, WHtR, BRI, CI, BAI, LAP in men and BMI, WHtR, BAI, LAP, VAI and WTI in women ($p > 0.05$). Furthermore among the men, the AUC of AVI, ABSI, VAI and WTI were significantly lower than WC ($p < 0.05$) while among women, the AUC of AVI, CI and ABSI were lower than WC ($p < 0.05$).

Generally there was gender differences in the cutoff point of all the anthropometric parameters. The cutoff point for WC was 89.5 cm and 91.8 cm in men and women respectively as shown in Table 2 and Table 3.

3.3. Comparing the anthropometric parameters in predicting components of MetS

There is no gender pattern in the ability of the anthropometric parameters to predict the components of MetS. Generally speaking for central obesity and high plasma glucose, WC had the largest AUC in both gender, while for high TG and low HDL-C, WTI and VAI had the largest AUC respectively in both men and women. For high blood pressure, BMI had the highest UC in men while LAP had the largest AUC in women (Table 4 and Table 5).

For central obesity except for AVI and VAI, the AUC of all the anthropometric parameters had predictive significance in both men and women ($p < 0.05$). The AUC of AVI was significantly lower than 0.5 ($p > 0.05$) while the AUC of VAI did not differ from 0.5 ($p > 0.05$). WTI had the largest AUC for high TRG in men and women. The AUC of WC, BMI, WHtR, LAP and VAI was higher than 0.5 ($p < 0.05$) in men while among the women, the AUC of WHtR, BRI, CI, LAP and VAI was higher than 0.5 ($p < 0.05$). Among the men, only VAI had predictive significance for reduced HDL-C. The AUC of ABSI was lower than 0.5 ($p = 0.04$) while the AUC other anthropometric parameters did not differ from 0.5 ($p > 0.05$). Among the women WC, BMI, BAI and VAI had predictive significance for reduced HDL-C but the AUC of other anthropometric parameters did not differ from 0.5 ($p > 0.05$). The AUC of BMI and LAP were the largest for high blood pressure in men and women respectively. The AUCs of AVI, BRI, CI, ABSI, VAI and WTI did not differ from 0.5 in men ($p > 0.05$) while the AUCs of BMI and ABSI did not differ from 0.5 among women ($p > 0.05$) (Tables 4 and 5).

3.4. Comparing the anthropometric parameters in predicting components of MetS by age groups

The AUC of WC was the largest in 40–49 and 60 years and

Table 1
Anthropometric and Clinical parameters of men and women with and without metabolic syndrome.

Variables	Men			Women		
	No MetS	MetS	p	No MetS	MetS	p
	n = 123	n = 23		n = 289	n = 100	
Age	44.14 ± 13.7	57.48 ± 13.16	<0.001	46.37 ± 15.73	50.21 ± 11.42	0.025
WC	85.29 ± 9.65	100.20 ± 9.76	<0.001	87.36 ± 13.15	100.14 ± 12.74	<0.001
HC	96.37 ± 7.98	105.59 ± 11.83	<0.001	101.94 ± 11.77	113.02 ± 13.20	<0.001
SBP	123.63 ± 18.99	148.35 ± 22.85	<0.001	120.14 ± 23.81	140.59 ± 20.80	<0.001
DBP	76.19 ± 11.41	89.22 ± 16.23	<0.001	74.81 ± 12.10	86.86 ± 12.62	<0.001
Fasting glucose	94.20 ± 24.83	110.30 ± 36.71	0.010	80.57 ± 15.69	105.34 ± 32.99	<0.001
Triglyceride	87.17 ± 51.85	121.54 ± 24.33	0.028	81.97 ± 40.56	113.30 ± 64.29	<0.001
HDL-C	54.94 ± 20.06	40.64 ± 10.71	0.001	59.40 ± 21.74	45.84 ± 14.94	<0.001
BMI	23.14 ± 3.43	28.78 ± 3.86	<0.00	25.83 ± 5.75	30.78 ± 7.45	<0.001
LDL-C	95.97 ± 51.81	133.13 ± 69.03	0.003	98.33 ± 50.48	113.70 ± 60.05	0.013
WHtR	0.50 ± 0.06	0.59 ± 0.07	<0.001	0.55 ± 0.09	0.62 ± 0.08	<0.001
AVI	0.29 ± 0.11	0.26 ± 0.06	0.197	0.37 ± 0.18	0.39 ± 0.24	0.430
BRI	9.77 ± 1.71	11.97 ± 1.97	<0.001	1.74 ± 2.37	13.22 ± 0.19	<0.001
CI	1.25 ± 0.10	1.32 ± 0.11	0.002	1.26 ± 0.11	1.37 ± 0.63	0.002
BAI	49.57 ± 5.70	56.39 ± 8.27	<0.001	56.83 ± 8.94	64.15 ± 9.12	<0.001
LAP	21.77 ± 20.02	42.17 ± 24.72	<0.001	27.01 ± 18.4	53.95 ± 34.90	<0.001
ABSI	13.75 ± 1.13	13.96 ± 1.39	0.449	12.74 ± 1.21	14.25 ± 11.79	0.032
VAI	1.04 ± 0.81	1.78 ± 1.44	0.001	1.34 ± 1.11	2.34 ± 1.53	<0.001
WTI	85.74 ± 56.54	131.36 ± 110.63	0.004	80.69 ± 41.75	128.14 ± 74.15	<0.001

Note: WC = Waist circumference, HC, Hip circumference; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; HDL-C, high density lipoprotein cholesterol; BMI, Body mass index; LDL-C, Low density lipoprotein cholesterol; WHtR, waist – to – height ratio; ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BRI, body roundness index; CI, conicity; MetS, metabolic syndrome; VAI, visceral adiposity index; WTI, waist circumference triglyceride index. LAP, lipid accumulation product.

Table 2
Area under the ROC curve, optimal cut-off points, and validity parameters of different anthropometric parameters predicting the MetS in men.

Variable	AUC (95%CI)	p	Cut off value	Sensitivity	Specificity	Youden index
WC	0.814 (0.721–0.907)	<0.001	89.5	0.880	0.711	0.591
BMI	0.807 (0.717–0.898)	<0.001	27.2	0.640	0.909	0.549
WHtR	0.773 (0.673–0.874)	<0.001	0.54	0.640	0.777	0.417
AVI	0.377* (0.257–0.496)	0.052	0.21	0.800	0.207	0.007
BRI	0.740 (0.635–0.846)	<0.001	11.90	0.440	0.934	0.374
CI	0.713 (0.602–0.825)	0.001	1.28	0.680	0.711	0.391
BAI	0.722 (0.595–0.850)	<0.001	51.42	0.720	0.653	0.373
LAP	0.773 (0.693–0.852)	<0.001	22.94	0.880	0.661	0.541
ABSI	0.616* (0.491–0.740)	0.069	14.15	0.520	0.736	0.256
VAI	0.687* (0.587–0.786)	0.003	0.84	0.920	0.496	0.416
WTI	0.658* (0.564–0.752)	0.013	81.88	0.800	0.579	0.379

DeLong. Delong. Clarke-Pearson's nonparametric approach was used to compare the AUCs of indices.
*Compared with the AUC of waist circumference, p is less than 0.05.
ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BMI, body mass index; BRI, body roundness index; CI, conicity; MetS, metabolic syndrome; ROC, receiver operating characteristic; VAI, visceral adiposity index; WC, waist circumference; WHtR, waist-to-height ratio; WTI, waist circumference triglyceride index. LAP, lipid accumulation product.
AUC, area under curve; 95%CI, 95% confidence interval.

Table 3
Area under the ROC curve, optimal cut-off points, and validity parameters of different anthropometric parameters predicting the MetS in women.

Variable	AUC (95%CI)	p	Cut off value	Sensitivity	Specificity	Youden index
WC	0.819 (0.771–0.867)	<0.001	91.75	0.875	0.635	0.510
BMI	0.768 (0.715–0.821)	<0.001	28.3	0.705	0.688	0.393
WHtR	0.787 (0.737–0.837)	<0.001	0.59	0.761	0.684	0.445
AVI	0.483* (0.413–0.552)	0.624	0.35	0.420	0.558	-.0022
BRI	0.742 (0.689–0.796)	<0.001	12.56	0.705	0.664	0.369
CI	0.654* (0.590–0.718)	<0.001	1.25	0.739	0.525	0.254
BAI	0.766 (0.712–0.819)	<0.001	58.08	0.784	0.588	0.372
LAP	0.801 (0.748–0.853)	<0.001	28.29	0.818	0.614	0.459
ABSI	0.554* (0.482–0.625)	0.125	12.90	0.523	0.611	0.134
VAI	0.745 (0.684–0.805)	<0.001	1.15	0.830	0.522	0.352
WTI	0.738 (0.678–0.799)	<0.001	85.13	0.727	0.638	0.365

DeLong. Delong. Clarke-Pearson's nonparametric approach was used to compare the AUCs of indices.
*Compared with the AUC of waist circumference, p is less than 0.05.
ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BMI, body mass index; BRI, body roundness index; CI, conicity; MetS, metabolic syndrome; ROC, receiver operating characteristic; VAI, visceral adiposity index; WC, waist circumference; WHtR, waist-to-height ratio; WTI, waist circumference triglyceride index. LAP, lipid accumulation product.
AUC, area under curve; 95%CI, 95% confidence interval.

Table 4
Comparison of Area under the ROC curve for anthropometric indices in predicting Components of MetS in men.

Variable	Central obesity		High TG		Low HDL-C		High BP		High blood glucose	
	AUC (95%CI)	p	AUC (95%CI)	p	AUC (95%CI)	p	AUC (95%CI)	p	AUC (95%CI)	p
WC	0.894 (0.844–0.944)	<0.001	0.698 (0.567–0.829)	0.029	0.445 (0.337–0.553)	0.272	0.656 (0.565–0.747)	0.001	0.679 (0.582–0.776)	<0.001
BMI	0.765 (0.676–0.853)	<0.001	0.723 (0.614–0.832)	0.014	0.522 (0.418–0.625)	0.665	0.694 (0.607–0.781)	<0.001	0.642 (0.539–0.746)	0.007
WHtR	0.887 (0.836–0.939)	<0.001	0.709 (0.596–0.822)	0.021	0.422 (0.313–0.513)	0.117	0.641 (0.549–0.733)	0.004	0.621 (0.520–0.721)	0.022
AVI	0.333 (0.243–0.422)	0.002	0.351 (0.234–0.468)	0.101	0.576 (0.480–0.672)	0.129	0.469 (0.374–0.563)	0.519	0.515 (0.410 = - 0.620)	0.779
BRI	0.854 (0.793–0.915)	<0.001	0.664 (0.558–0.770)	0.071	0.413 (0.306–0.520)	0.079	0.624 (0.531–0.717)	0.100	0.569 (0.466–0.673)	0.188
CI	0.879 (0.825–0.933)	<0.001	0.669 (0.521–0.818)	0.062	0.372 (0.270–0.474)	0.010	0.577 (0.484–0.671)	0.111	0.619 (0.520–0.718)	0.024
BAI	0.765 (0.672–0.858)	<0.001	0.618 (0.460–0.775)	0.196	0.488 (0.381–0.594)	0.802	0.625 (0.530–0.720)	0.010	0.647 (0.544–0.750)	0.005
LAP	0.764 (0.678–0.850)	<0.001	0.982 (0.962–1.000)	<0.001	0.507 (0.400–0.614)	0.888	0.613 (0.520–0.706)		0.654 (0.560–0.747)	0.003
ABSI	0.723 (0.632–0.814)	<0.001	0.632 (0.478–0.785)	0.147	0.398 (0.300–0.495)	0.040	0.497 (0.402–0.592)	0.949	0.632 (0.530–0.733)	0.012
VAI	0.562 (0.455–0.669)	0.253	0.912 (0.841–0.984)	<0.001	0.760 (0.677–0.843)	<0.001	0.508 (0.412–0.604)	0.871	0.578 (0.482–0.675)	0.136
WTI	0.629 (0.525–0.733)	0.017	0.998 (0.993–1.000)	<0.001	0.519 (0.418–0.620)	0.707	0.561 (0.468–0.655)	0.208	0.572 (0.477–0.668)	0.169

ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BMI, body mass index; BRI, body roundness index; CI, conicity; MetS, metabolic syndrome; ROC, receiver operating characteristic; VAI, visceral adiposity index; WC, waist circumference; WHtR, waist-to-height ratio; WTI, waist circumference triglyceride index. LAP, lipid accumulation product.
AUC, area under curve; 95%CI, 95% confidence interval.

above age groups while the AUC of LAP was the largest for age groups 30–39 and 50–59 years. The AUC of AVI, CI and ABSI were lower than the AUC of WC across all the age groups ($p < 0.05$) while the AUCs of WC, BMI, WHtR, BRI, BAL and LAP were not significantly different in all the age groups ($p > 0.05$) as shown in Table 6.

4. Discussion

Evidences abound to show that central obesity is an important risk factor and major component that characterize MetS [36]. The inclusion of central obesity by expert groups in the definition of MetS further pinpoint its contribution [1]. Although measurement

Table 5
Comparison of Area under the ROC curve for anthropometric indices in predicting Components of MetS in women.

Variable	Central obesity		High TG		Low HDL-C		High BP		High blood glucose	
	AUC (95%CI)	p	AUC (95%CI)	p	AUC (95%CI)	p	AUC (95%CI)	p	AUC (95%CI)	p
WC	1.000 (1.000–1.000)	<0.001	0.579 (0.488–0.670)	0.091	0.572 (0.514–0.630)	0.015	0.607 (0.551–0.664)	<0.001	0.610 (0.529–0.691)	0.004
BMI	0.918 (0.890–0.947)	<0.001	0.555 (0.481–0.629)	0.237	0.573 (0.514–0.631)	0.014	0.557 (0.498–0.615)	0.057	0.595 (0.520–0.670)	0.013
WHtR	0.976 (0.965–0.988)	<0.001	0.603 (0.516–0.690)	0.028	0.543 (0.485–0.602)	0.143	0.602 (0.546–0.658)	0.001	0.599 (0.519–0.680)	0.009
AVI	0.386 (0.327–0.444)	<0.001	0.379 (0.297–0.461)	0.010	0.543 (0.485–0.600)	0.147	0.415 (0.357–0.474)	0,004	0.494 (0.418–0.569)	0.865
BRI	0.917 (0.890–0.944)	<0.001	0.621 (0.536–0.705)	0.010	0.520 (0.462–0.579)	0.490	0.588 (0.532–0.644)	0.003	0.589 (0.511–0.668)	0.019
CI	0.819 (0.775–0.862)	<0.001	0.604 (0.498–0.710)	0.027	0.510 (0.452–0.568)	0.732	0.597 (0.540–0.654)	0.001	0.531 (0.457–0.606)	0.412
BAI	0.920 (0.893–0.946	<0.001	0.493 (0.412–0.573)	0.877	0.584 (0.526–0.643)	0.004	0.562 (0.503–0.621)	0.038	0.580 (0.503–0.656)	0.036
LAP	0.864 (0.829–0.900)	<0.001	0.900 (0.845–0.955)	<0.001	0.511 (0.453–0.569)	0.702	0.614 (0.558–0.670)	<0.001	0.588 (0.507–0.668)	0.022
ABSI	0.630 (0.573–0.687)	<0.001	0.524 (0.418–0.630)	0.610	0.509 (0.451–0.567)	0.758	0.553 (0.495–0.611)	0.074	0.500 (0.424–0.575)	0.993
VAI	0.548 (0.490–0.607)	0.106	0.854 (0.804–0.905)	<0.001	0.741 (0.691–0.791)	<0.001	0.595 (0.539–0.651)	0.001	0.599 (0.519–0.679)	0.009
WTI	0.684 (0.630–0.737)	<0.001	0.985 (0.974–0.996)	<0.001	0.494 (0.435–0.552)	0.826	0.602 (0.546–0.658)	0.001	0.593 (0.514–0.671)	0.015

ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BMI, body mass index; BRI, body roundness index; CI, conicity; MetS, metabolic syndrome; ROC, receiver operating characteristic; VAI, visceral adiposity index; WC, waist circumference; WHtR, waist-to-height ratio; WTI, waist circumference triglyceride index. LAP, lipid accumulation product.
AUC, area under curve; 95%CI, 95% confidence interval.

Table 6
Comparison of Area under the ROC curve for anthropometric indices in predicting Components of MetS by age groups.

Variable	30–39 years		40–49 years		50–59 years		≥60 years	
	AUC (95%CI)	p	AUC (95%CI)	p	AUC (95%CI)	p	AUC (95%CI)	p
WC	0.854 (0.732–0.976)	<0.001	0.806 (0.729–0.884)	<0.001	0.727 (0.609–0.845)	<0.001	0.825 (0.752–0.897)	<0.001
BMI	0.840 (0.715–0.965)	<0.001	0.787 (0.712–0.861)	<0.001	0.682 (0.559–0.806)	0.004	0.775 (0.690–0.861)	<0.001
WHtR	0.849 (0.734–0.964)	<0.001	0.757 (0.674–0.839)	<0.001	0.713 (0.596–0.830)	0.001	0.817 (0.745–0.889)	<0.001
AVI	0.541* (0.416–0.667)	0.608	0.607* (0.498–0.716)	0.043	0.363* (0.253–0.473)	0.031	0.443* (0.329–0.556)	0.363
BRI	0.820 (0.691–0.949)	<0.001	0.702 (0.614–0.790)	<0.001	0.666 (0.551–0.780)	0.009	0.765 (0.684–0.846)	<0.001
CI	0.753* (0.637–0.869)	0.002	0.582* (0.475–0.689)	0.121	0.599* (0.476–0.722)	0.118	0.720* (0.621–0.820)	<0.001
BAI	0.828 (0.705–0.951)	<0.001	0.756 (0.671–0.842)	<0.001	0.615* (0.484–0.746)	0.071	0.744 (0.658–0.829)	<0.001
LAP	0.879 (0.777–0.982)	<0.001	0.749 (0.660–0.837)	<0.001	0.746 (0.642–0.850)	<0.001	0.757 (0.671–0.844)	<0.001
ABSI	0.508* (0.343–0.673)	0.920	0.494* (0.380–0.608)	0.906	0.546* (0.415–0.677)	0.469	0.565* (0.439–0.691)	0.305
VAI	0.805 (0.684–0.926)	<0.001	0.654* (0.558–0.751)	0.004	0.727 (0.601–0.854)	<0.001	0.760 (0.662–0.858)	<0.001
WTI	0.809 (0.684–0.933)	<0.001	0.696* (0.599–0.792)	<0.001	0.684 (0.564–0.804)	0.004	0.670* (0.568–0.772)	0.007

DeLong. Delong. Clarke-Pearson's nonparametric approach was used to compare the AUCs of indices.
*Compared with the AUC of waist circumference, p is less than 0.05.
ABSI, a body shape index; AVI, abdominal volume index; BAI, body adiposity index; BMI, body mass index; BRI, body roundness index; CI, conicity; MetS, metabolic syndrome; ROC, receiver operating characteristic; VAI, visceral adiposity index; WC, waist circumference; WHtR, waist-to-height ratio; WTI, waist circumference triglyceride index. LAP, lipid accumulation product.
AUC, area under curve. 95%CI, 95% confidence interval.

of abdominal visceral fat by MRI is the best method to evaluate central obesity [28], cost, safety and other logistics makes it unrealistic especially in resource poor countries like Nigeria. To this end, studies have been conducted to determine simple, cost effective and reliable anthropometric parameters or indices derived from it that are good predictors of MetS.

In order to assess the best predictor of MetS in this study, 11 anthropometric parameters were considered. In general, all the anthropometric parameters except for AVI and ABSI showed significant ability to predict MetS in both men and women. Previous cross-sectional and prospective studies from China and Iran have reported ABSI to be a weak predictor of MetS [22,27,37]. The AVI is thought to have an association with disglyceamia and has been found to be a strong predictor of MetS in some studies contrary to what was obtained in our study [[27] [38]]. Although gender specific ROC showed that WC had a higher AUC and hence a better predictor of MetS in both men and women than other anthropometric parameters, the AUC of WC and that of BMI, WHtR, BRI, LAP, CI and BAI were not significantly different in our study. Studies from China and Kenya showed WC was better predictor of MetS than VAI, LAP, AVI, CI, ABSI and BRI [27,39–41]. VAL has been shown by another study to be better at predicting cardiometabolic risk than WC [23,39,42]. It is not enough to consider anthropometric parameter with the highest AUC as the most predictive of MetS, it has been suggested that simplicity of measurement and interpretation, widespread use and significant difference between AUC measurements are other factors to be considered [27]. A study from China reported the AUC of BMI and AVI to be higher but not significantly different from the AUC of WC in men and women respectively. However, WC was a more useful predictor of MetS because of its simplicity of measurement and widespread [27]. Another Chinese study showed that LAP and WTI to be better predictor of MetS especially in both men and women [43].

Studies have been done in many countries to determine the race- and gender specific cutoffs for WC since the joint interim statement accepted the IDF recommendations [1]. In this study, the cutoff of WC was 89.5 cm for men and 91.8 cm for women. Interestingly, this is contrary to the pattern of WC recommended by the JIS definition, women had a higher WC than men in this study. Studies from South Africa reported a cutoff for WC similar to what was obtained in our study [44,45]. Contrary to our findings, studies from Nigeria, Kenya and China reported a lower WC cutoff [21,27,41]. This difference may be due to ethnic difference, the sample size of the study and how the WC was measured. Measurement of WC has been taken at the level of umbilical cord [42], smallest girth above the umbilicus in standing position [46], midway between the costal margin and the iliac crest [21]. In view of the several calls to review the WC cut point for sub Saharan

African [44], studies are needed not only to resolve this issue but also to determine a uniform landmark for the measurement of WC.

Our study also showed WC and LAP had higher AUC compared to other anthropometric parameters although their difference was not significant. While LAP had the highest AUC in age groups 30–39 years and 50–59 years, WC had the highest AUC for age group 40–49 and 60 and above years. It has been postulated that LAP may be a better predictor of MetS than WC because of its ability to discriminate individuals with varying metabolic abnormalities and cardiometabolic risk among metabolically healthy especially among type 2 diabetic patients [46].

Different discriminatory ability for different MetS components was shown in our study. WTI had the largest AUC for elevated triglyceride in both men and women, on the other hand VAI for men and women had the largest AUC for reduced HDL-C while in both men and women WC had the largest AUC for elevated glucose while for high blood pressure BMI in men and LAP in women had the largest AUC. In a prospective study, none of the anthropometric parameters were able to discriminate reduced HDL-C. and elevated blood glucose [27] which is in contrast to our findings and other similar studies [23,42].

5. Conclusion

Our findings showed that WC had the highest predictive significance for the MetS in both men and women. Although there was no significant difference between the AUC of WC and BMI, WHtR, BRI, LAP, CI and BAI, the simplicity of measurement and ease of application make WC to have comparative advantage over other anthropometric parameters. The cutoff point of WC obtained in this study is higher than what was recommended by the JIS. However, more studies need to be done not only to determine the cutoff point of WC applicable to the sub Saharan region but also the best landmark for measuring WC.

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