Arch. Bas. App. Med. 10 (2022):84-91
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Research Article

Visceral Adiposity and Atherogenic Indices and Plasma Apolipoproteins levels in Young Adults in Ibadan, Nigeria.

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Accepted: September 13, 2022

Abstract
This study was prompted by the rising prevalence of non-communicable diseases (NCDs) in Nigeria, suspected increasing visceral adiposity index (VAI) and atherogenic index of plasma (AIP) as plausible biomarkers of NCDs. We investigated the relationship between VAI, plasma apolipoproteins A1 and B, lipid, and AIP as surrogate measures for cardiovascular disease (CVD) risk. A systematic random sampling technique was used to select 221 participants aged 19 to 31 years for this cross-sectional study. Plasma cholesterol, apoA1, and apoB levels were measured. AIP was computed using triglyceride and high-density lipoprotein cholesterol levels (HDL-c). VAI was calculated using body mass index (BMI), waist circumference, triglyceride, and HDL-c levels. For the relationship between VAI and other parameters, linear stepwise regression models were used. The mean VAI and AIP were 1.11±0.57 and -0.32±0.49 respectively, and the mean VAI was significantly higher in women (1.42±0.6) than men (0.90±0.39) ($p<0.001$) while the mean AIP was not different. For all, CVD risk was high in 12.2%, medium in 8.6%, and low in 79.2%. In both men and women, there were strong positive associations between VAI and HDL-c, LDL-c, Triglyceride, LDL-c/HDL-c ratio, and AIP. The stepwise regression analysis produced models that removed AIP and valid equations for predicting VAI with r2 of 0.95 and 0.93 for men and women, respectively.
Our findings suggest that VAI would be a good tool for measuring adipose tissue dysfunction and its associated CVD risk in the study population. AIP was also supported as a proxy measure for CVD prediction.

Key Words: Visceral adiposity, Cardiovascular disease, Plasma lipids, Apolipoprotein B

INTRODUCTION

With the recognised rising incidence of cardiovascular diseases (CVDs) in Nigeria like in several other developing countries, there has been a renewed effort to use more affordable ways to stop this trend (Hamid *et al*., 2019).To be most effective, cardiovascular risk factors reduction strategies should be geared toward people who have multiple risk factors including diabetes, high blood pressure, and/or dyslipidaemia, especially those who have high body fat or mass (WHO 2007). For this aim, excess adiposity and dyslipidaemia are recognised drivers of CVDs in young Nigerians, and they are currently the targets for CVD prevention (Sani *et al*., 2010, Oguejiofor *et al*., 2012), but evidence that can inform policy and drive clinical practises is still needed. Although some studies (Oluyombo *et al*., 2016, Onyenekwu *et al*., 2017) have reported the link between the distribution of body fat, blood pressure, and cholesterol, none of these studies, however, included data on apolipoproteins A1 and B, or the Atherogenic Index of Plasma (AIP), which are emerging drivers of CVD implicated in recent literature (Turgay Yildirim and Kaya, 2021, Wang *et al*., 2021, Won *et al*., 2021, Wu *et al*., 2021).
Despite the fact that both visceral and non-visceral adipose tissue play important roles in the pathogenesis of CVDs, anthropometric indices such as weight, height, and waist circumference (WC), as well as derivatives like body mass index (BMI), are unable to accurately measure the magnitude of visceral fat (Arderiu *et al*., 2020). Abdominal Magnetic Resonance Imaging (MRI) or Computed Tomography (CT) scans are the best ways to measure visceral adipose tissue, but these procedures are expensive and limited, therefore they are not utilised routinely for screening (Shuster *et al*., 2012). In response, the Visceral Adiposity Index (VAI) is presented as an alternative. It is a mathematical model that measures visceral adipose tissue by combining WC and BMI with two plasma lipids [triglyceride (TG) and high-density lipoprotein cholesterol (HDL-c)] (Amato *et al*., 2010). Recent publications have demonstrated that VAI can predict many CVD-related disorders including hypertension, metabolic syndrome, and type-2 diabetes mellitus (Nusrianto *et al*., 2019, Yang *et al*., 2020). Another reason for the search for other methods of measuring adiposity is that certain studies have indicated that BMI is not as accurate as other measures in detecting body adiposity (Okorodudu *et al*., 2010, Javed *et al*., 2015). It has been shown that BMI cut-off values commonly used to diagnose obesity are specific, but not sensitive to adiposity (Okorodudu *et al*., 2010, Javed *et al*., 2015). To compensate for the shortcomings of BMI, researchers have recently increased their interest in identifying specific blood lipid biomarkers (Bora *et al*., 2017, Zhu *et al*., 2018). Lipid

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biomarkers used to monitor people in the prevention and treatment of obesity, can also accurately reflect body adiposity (Cai *et al*., 2017, Zhu *et al*., 2018).

Furthermore, clinical studies have suggested that the apoB/apoA1 ratio is better than LDL-c or any other apolipoprotein at predicting future atherosclerotic CVD (Yusuf *et al*., 2004, Du *et al*., 2015). A study that involved participants from 52 countries demonstrated that the apoB/apoA1 ratio was the most vital risk factor for CVDs (Yusuf *et al*., 2004). Apo B and apo A1 are major components of non-HDL and HDL lipoprotein particles, respectively, and there is a lot of evidence that measuring them can help with CVD risk prediction (Walldius *et al*., 2001, Collaboration* 2009). As a result, the apoB/apoA1 ratio has been proposed as a dependable indicator of lipid disorder and atherosclerosis risk (Kappelle *et al*., 2011, Lee *et al*., 2011). In Western populations, the risk of CVD is directly associated with plasma lipid, lipoprotein, and apolipoprotein concentrations (Collaboration* 2009, Kappelle *et al*., 2011, Lee *et al*., 2011), however, the relationships between apoA1, apoB, the apoB/apoA1 ratio, and other atherogenic indices in Nigerians are inconsistent.

According to other studies, CVDs are rapidly becoming the leading causes of death in Nigeria, with overweight, obesity, and dyslipidaemia being key risk factors (Okorodudu *et al*., 2010, Javed *et al*., 2015). Because disorders of lipid and atherosclerosis trends start early, population-specific, and individual risk factors are important in the prevention planning and policymaking of CVD. Blood lipids, weight, obesity, and fat distribution can all be checked over time to help prevent CVD (Camhi and Katzmarzyk, 2010, Reilly and Kelly, 2011). To address the threat of atherosclerotic cardiovascular disease in Nigeria, it is necessary to have a fundamental understanding of lipid abnormalities indicators and the risk of atherosclerosis in young adults. Thus, the current study investigated the relationships between apoA1, apoB, the apoB/apoA1 ratio, and adiposity indices in Nigerian young adults.

MATERIALS AND METHODS

Study design and setting: This was a cross-sectional study. Information was collected after Ethical Approval was obtained from UI/UCH ethics committee (UI/EC/19/0117). Blood samples were collected from undergraduate and postgraduate students who went to the University of Ibadan Health Centre in the southwest of Nigeria for standard medical examinations. The University of Ibadan accepts people from all over Nigeria who are qualified. This makes it a suitable place to study Nigeria's multi-ethnic population.

Study population and sample size: The study's target population is young Nigerian adults. However, university students were chosen as the study population because they are a readily accessible group of individuals who can easily be targeted for early cardiovascular preventative measures. We hypothesized that the mean VAI in male and female populations would be about 0.5 less or more than 1.90 ± 1.48 and 2.77 ± 1.40, respectively reported by Hamzeh and colleagues in non-CVD adults in Iran (Hamzeh *et al*., 2021). We estimated that a minimum of 69 men and 69 women would be the sample size required to attain 80% power at 95% level of confidence (alpha = 0.05) using the sample size formula for a one-sample. In addition, we envisaged as many as 20% may decline requests for participation, so the required minimum sample size was therefore increased to 87.

Sampling and data collection procedure: A questionnaire administered by an interviewer was used to obtain data on age, sex, and anthropometrics as well as blood pressure. The participants' height was determined using a stadiometer (SECA® model 213, Germany), with their backs of the heels and occiput against the stadiometer. A weighing scale (SECA® model: 881, Germany) was used to determine weight. The waist circumference (WC) was calculated as the smallest circumference at the umbilicus level. The hip circumference was measured at its broadest point above the buttocks, and the waist-to-hip ratio (WHR) was calculated to determine the body fat distribution.

After 5 minutes of rest, the participant's blood pressure was taken three times using an Omron Blood Pressure Monitor. Model: HEM-907XL (Omron Healthcare China, Shanghai) on the right upper arm, with a one-minute interval between measurements. An individual's blood pressure was taken as the average of three readings. Systolic blood pressure (SBP) of greater than 140 mmHg and/or diastolic blood pressure (DBP) of more than 90 mmHg were considered as hypertension (Giles *et al*., 2009), as was the use of antihypertensive medications within the two weeks preceding the interview.

We collected venous blood samples aseptically from the antecubital fossa vein using a disposable sterile needle into an Ethylenediaminetetraacetic acid (EDTA) container before participants had their breakfast to ensure a fasting period of at least 8 hours. Plasma was kept at -20^{o}C until laboratory analysis of blood lipids, apoA1, and apoB concentrations were performed. The plasma total cholesterol, HDL-c, and triglycerides (TGs) were measured using an enzymatic technique with the appropriate test kits (Fortress Diagnostic, UK). The Friedewald formula was used to calculate plasma LDL-c. ApoB and apoA1 plasma concentrations were measured using an immunoturbidimetric technique with standard kits (Fortress Diagnostic, UK).

Variable definitions and data analysis: We defined AIP as the logarithm [log] of the ratio of plasma triglycerides to HDL-c concentrations (Sami Khaza, 2013). We classified study participants as low, medium, and high CVD risk when calculated AIP is −0.3 to 0.1, 0.1 to 0.24 and greater than 0.24, respectively (Dobiasova, 2006). The VAI was calculated using sex-specific formulas: males $(WC/39.68 + [1.88 \times BMI]) \times (TGs/1.03) \times (1.31/HDL\text{-}c)$; females: $(WC/36.58 + [1.89 \times BMI]) \times (TGs/0.81) \times (1.52/HDL\text{-}c)$, where both TGs and HDL-c levels are expressed in mmol/L (Amato *et al*. 2010). The waist-to-hip, apoB/apoA1, and LDL-c/HDL-c ratios are also derived factors. Males and females were compared in terms of age, anthropometric characteristics, plasma lipids, and their derivatives. Due to the non-parametric distributions of the majority of variables, comparisons between different sex groups were made using chi-square tests for categorical variables and two-sample Mann-Whitney-U tests for continuous variables. We explored the associations between AIP and VAI, plasma lipids, body mass index, apoA1 and apoB. Multiple regression analysis was utilised to identify variables that have an independent connection with VAI in men and women separately. Stata/BE 17.0 Software for

Windows was used to conduct all statistical analyses (Stata Corp LLC, USA).

RESULTS

Characteristics of the Study Participants: The study participants comprised 129 (58.4%) males and 92 (41.6%) females whose ages ranged from 19 to 31 years, with a mean age of 22.1±2.2 years. The mean age of the men (22.7±2.4 years) was significantly higher than that of the women (21.3±1.7 years), (p 0.001). Twelve out of the 221 participants [men, 10/129 (7.8%) and women, 2/92 (2.2%); p = 0.071] were hypertensive. By comparing BMI categories by sex, obesity and overweight were more frequent in women [6.5% (6/92) and 22.8% (21/92), respectively] than in men [3.1% (4/112) and 10.1% (13/129), respectively], p = 0.012.

The mean values of participants' anthropometric parameters, blood pressure, apolipoproteins, and lipid profiles are shown in Table 1. The men's mean weight, height, BMI, systolic and diastolic blood pressures, as well as apoA1 and apoB, were significantly higher than those of the women (p<0.05 for each). Conversely, women had significantly higher WHR, total cholesterol, LDL-c, LDL-c/HDL-c ratio, and triglycerides than men (p<0.05 for each). As shown in Table 1, women also had a significantly higher mean VAI than men (1.42±0.65 versus 0.90±0.39).

Table 1:
Characteristics of All Study Participants by Sex

Characteristics	Men (n = 129)	Women (n = 92)	*P-value
Weight (kg)	67.14±10.18	62.85±12.12	<0.001
Height (m)	1.74±0.69	1.60±0.18	<0.001
BMI (kg/m)	22.30±3.00	23.80±4.30	0.007
Waist circumference (cm)	75.42±6.60	74.70±7.98	0.305
Hip circumference (cm)	137.00±7.21	142.27±7.21	<0.001
Waist-to-hip ratio (WHR)	0.53±0.04	0.56±0.28	<0.001
Systolic BP (mmHg)	128.50±15.27	110.00±11.68	<0.001
Diastolic BP (mmHg)	74.14±10.74	71.22±9.85	0.014
Apo B (mg/dL)	89.10±38.56	83.09±27.88	0.622
Apo A1 (mg/dL)	95.68±36.19	85.92±36.62	0.016
Apo B/Apo A1 ratio	1.12±0.78	1.1±0.65	0.242
Total cholesterol (mmol/L)	4.46±1.00	4.79±1.04	0.016
HDL-c (mmol/L)	2.09±0.52	2.07±0.54	0.692
LDL-c (mmol/L)	1.85±0.81	2.10±0.89	0.043
LDL-c/HDL-c ratio	0.97±0.56	1.14±0.71	0.110
Total cholesterol/HDL-c ratio	2.27±0.73	2.48±0.88	0.121
Triglycerides (mmol/L)	1.47±0.46	1.62±0.46	0.025
Atherogenic index of plasma (AIP)	-0.37±0.48	-0.27±0.49	0.105
Visceral adiposity index (VAI)	0.90±0.39	1.42±0.65	<0.001

*Mann Whitney U test

Visceral adiposity index and cardiovascular risk: Overall, the AIP ranged from -1.58 to 0.56 (median =-0.28) and there was no significant difference between the mean AIP of men and women. Using the AIP classification, CVD risk was high in 27 (12.2%), medium in 19 (8.6%) and low in 175 (79.2%) out of 221 participants. However, the mean AIP differed significantly between the three CVD categories in both men and women (Figure 1). The distributions of men and women were not significantly different in terms of AIP classification.

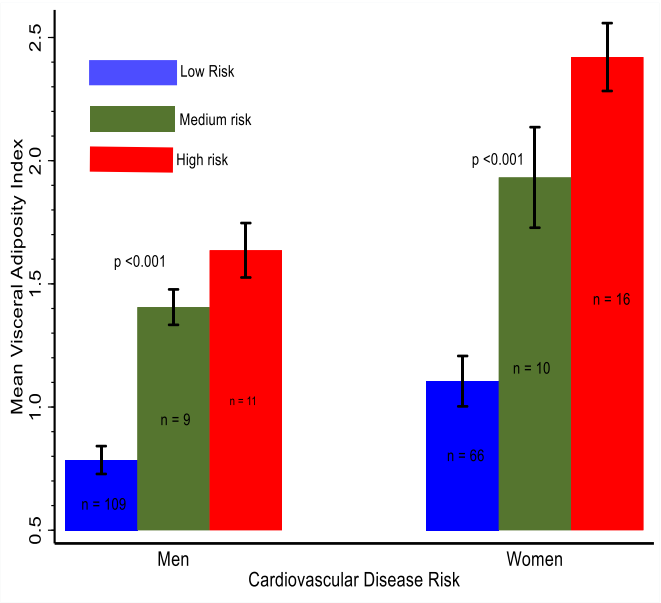

Figure 1:
Mean visceral adiposity index according to cardiovascular risk by sex

Anthropometry and lipid profile according to Tertiles of VAI and CVD risk by sex: Table 2 shows the mean anthropometric measurements and lipid profiles of subjects by sex tertiles of VAI. The plasma levels of total cholesterol, HDL-c, LDL-c, total cholesterol/HDL-c ratio, and triglycerides increased significantly from the first to third tertile of VAI in both men (p <0.001 for each) and women (p <0.001 for each). On the contrary, mean weight, height, BMI, waist, and hip circumferences, WHR, blood pressure, as well as the values of apoB, apoA1, and their ratios were not significantly different within and between the three groups of VAI tertiles (p > 0.05 for each).

Table 3 shows the mean anthropometric measures and lipid profiles of participants according to the AIP classification of CVD risk. Notably, the mean values of the HDL-c decreased significantly from the low-risk (2.2±0.5 mmol/L) to medium-risk (1.8±0.3 mmol/L) and high-risk (1.4±0.2 mmol/L) groups (p <0.001). Conversely, the mean values of LDL-c/HDL-c ratio, total cholesterol/HDL-c ratio, triglycerides, and VAI showed significant increasing trend from CVD low-risk to high-risk groups (p <0.001). Other parameters showed no significant differences across the three CVD risk classes.

Correlations between Visceral Adiposity Index and other variables: The results of the pair-wise Spearman's correlations between VAI and age, anthropometric measures, apolipoproteins, and plasma lipids by sex of the participants are shown in Table 4. There were significant positive weak correlations between VAI and waist circumference (r = 0.224; p = 0.011) and waist-to-hip ratio (r = 0.261; p = 0.003) among men, but no such correlations were observed among women. There were relatively strong significant positive correlations between VAI and each of HDL-c, LDL-c, triglyceride, LDL-c/HDL-c ratio, TC/HDL-c, and AIP in both men and women (Table 4).

Table 2:
Anthropometry and lipid profile of participants according to tertiles of visceral adiposity index by sex

Characteristics	Men (n = 129)				Women (n = 92)			
	T1 (n= 54)	T2 (n= 51)	T3 (n= 24)	P-value	T1 (n= 14)	T2 (n= 28)	T3 (n= 50)	P-value
Weight (kg)	65.7±10.1	67.9±10.4	68.8±10.4	0.445	58±8.2	63.3±9.9	64.0±13.9	0.277
Height (cm)	1.7±0.1	1.7±0.1	1.8±0.1	0.775	1.6±0.1	1.6±0.1	1.6±0.2	0.155
BMI (kg/m)	21.9±3.3	22.6±3.1	22.6±2.8	0.313	22.7±2.4	24.0±3.5	24.0±5.1	0.656
Waist circumference (cm)	74.1±5.8	76.0±7.3	77.3±6.4	0.085	71.4±4.4	74.8±7.8	75.6±8.7	0.265
Hip circumference (cm)	136.2±6.7	137.6±6.7	137.1±9.3	0.406	140.5±8.0	142.9±8.3	142.4±12.0	0.567
Waist-to-hip ratio (WHR)	0.5±0.0	0.6±0.0	0.6±0.0	0.016	0.5±0.0	0.5±0.0	0.5±0.0	0.077
Systolic BP (mmHg)	121.1±9.3	118.9±20.0	122.9±15.0	0.834	109.8±12.0	109.4±10.1	110.4±12.6	0.764
Diastolic BP (mmHg)	75.6±7.4	72.7±13.6	74.0±10.1	0.268	69.1±12.8	70.6±7.8	72.2±10.0	0.282
Apo B (mg/dL)	85.2±35.1	97.1±43.6	80.9±32.6	0.393	86.5±23.0	82.1±28.1	82.7±29.4	0.682
Apo A1 (mg/dL)	96.5±30.0	97.5±38.8	90.2±43.6	0.408	79.0±29.0	89.0±29.0	86.2±42.3	0.640
Apo B/Apo A1 ratio	1.0±0.6	1.2±1.0	1.1±0.6	0.541	1.2±0.6	1.0±0.4	1.2±0.8	0.501
Total cholesterol (mmol/L)	4.1±1.1	4.8±0.8	4.6±0.8	0.001	3.7±0.9	4.9±1.0	5.1±0.9	<0.001
HDL-c (mmol/L)	2.5±0.5	2.0±0.4	1.6±0.3	<0.001	2.6±0.3	2.4±0.5	1.7±0.4	<0.001
LDL-c (mmol/L)	1.5±0.7	2.1±0.8	2.1±0.6	<0.001	1.3±0.5	1.9±0.7	2.4±0.9	<0.001
LDL-c/HDL-c ratio	0.6±0.3	1.2±0.6	1.4±0.4	<0.001	0.5±0.2	0.8±0.4	1.5±0.7	<0.001
Total cholesterol/HDL-c ratio	1.7±0.5	2.6±0.6	3.0±0.4	<0.001	1.4±0.3	2.1±0.4	3.0±0.8	<0.001
Triglycerides (mmol/L)	98.2±31.0	144.6±26.3	172.4±25.6	<0.001	80.0±25.8	125.3±26.8	170.9±28.5	<0.001

Table 3:
Anthropometry and lipid profile of participants according to CVD risk classification by sex

Characteristics	CVD risk in Men (n = 129)				CVD risk in Women (n = 92)			
	Low (n=109)	Medium (n=9)	High (n=11)	*P-value	Low (n=66)	Medium (n=10)	High (n=16)	*P-value
Weight (kg)	66.8±10.1	69.7±12.3	68.3±10.0	0.793	63.1±12.1	60.4±7.7	63.5±14.6	0.829
Height (m)	1.7±0.1	1.7±0.1	1.7±0.1	0.962	1.6±0.2	1.6±0.1	1.6±0.1	0.946
BMI (kg/m)	22.2±.3.0	23.2±3.1	22.8±3.1	0.486	23.6±3.9	25.1±4.7	23.8±5.5	0.470
Waist circumference (cm)	75.2±6.6	78.3±8.3	75.6±5.2	0.425	75.0±8.0	73.4±6.0	74.5±9.3	0.847
Hip circumference (cm)	137.0±6.6	138.3±9.2	135.9±11.0	0.974	142.1±9.4	137.9±4.8	145.6±15.3	0.307
Waist-to-hip ratio (WHR)	0.6±0.0	0.6±0.0	0.6±0.0	0.141	0.5±0.0	0.5±0.0	0.5±0.0	0.479
Systolic BP (mmHg)	119.9±15.2	123.7±14.4	124.6±17.0	0.964	109.8±12.3	112.0±9.4	109.4±10.6	0.778
Diastolic BP (mmHg)	74.0±10.8	76.8±11.5	73.0±10.1	0.740	71.2±9.6	76.5±10.3	68.1±9.6	0.164
Apo B (mg/dL)	91.3±40.1	73.1±21.0	80.4±30.6	0.549	85.3±30.9	72.0±17.3	80.8±17.3	0.390
Apo A1 (mg/dL)	96.5±34.0	108.3±52.0	77.7±40.7	0.152	87.5±40.0	80.7±31.3	82.6±25.2	0.972
Apo B/Apo A1 ratio	1.1±0.8	0.8±0.4	1.2±0.7	0.273	1.1±0.7	1.0±0.5	1.1±0.5	0.861
Total cholesterol (mmol/L)	4.4±1.0	4.8±1.0	4.4±0.6	0.600	4.7±1.0	4.8±1.0	5.0±1.0	0.738
HDL-c (mmol/L)	2.2±0.5	1.8±0.3	1.4±0.2	<0.001	2.3±0.5	1.7±0.3	1.5±1.2	<0.001
LDL-c (mmol/L)	1.8±0.8	2.0±0.7	2.0±0.5	0.160	2.0±0.8	2.1±0.9	2.6±1.1	0.083
LDL-c/HDL-c ratio	1.0±0.6	1.1±0.3	1.5±0.4	<0.001	1.0±0.5	1.3±0.5	1.8±1.0	<0.001
Total cholesterol/HDL-c ratio	2.2±0.7	2.7±0.3	3.1±0.4	<0.001	2.2±0.7	2.8±0.6	3.6±1.0	<0.001
Triglycerides (mmol/L)	121.0±35.7	186.2±26.4	177.0±22.2	<0.001	126.9±38.4	181.4±23.7	186.6±22.5	<0.001
Visceral adiposity index (VAI)	0.78±0.30	1.41±0.09	1.64±0.16	<0.001	1.11±0.42	1.93±0.29	2.42±0.26	<0.001

*Kruskal–Wallis equality-of-populations rank test

Table 4:
Bivariate Spearman's correlations between Visceral Adiposity Index and Age, Anthropometric Measures, Apolipoproteins and Plasma Lipids

	Men		Women	
	r	p	R	p
Age (years)	-0.047	0.599	-0.008	0.941
Weight (kg)	0.141	0.112	0.109	0.302
Height (m)	0.092	0.298	0.192	0.067
BMI (kg/m)	0.130	0.143	-0.027	0.796
Waist circumference (cm)	0.224	0.011	0.163	0.122
Hip circumference (cm)	0.133	0.134	0.043	0.686
Waist-to-hip ratio	0.261	0.003	0.193	0.065
Apo B (mg/dL)	0.017	0.848	-0.038	0.717
Apo A1 (mg/dL)	-0.078	0.378	0.001	0.996
Apo B and Apo A1 ratio	0.103	0.245	-0.027	0.794
Total cholesterol (mmol/L)	0.390	<0.001	0.275	0.008
HDL-c (mmol/L)	-0.732	<0.001	-0.754	<0.001
LDL-c (mmol/L)	0.516	<0.001	0.427	<0.001
Triglyceride (mmol/L)	0.804	<0.001	0.814	<0.001
LDL-c/HDL-c ratio (mmol/L)	0.747	<0.001	0.682	<0.001
TC/HDL-c ratio (mmol/L)	0.849	<0.001	0.806	<0.001
Atherogenic index of plasma (AIP)	0.993	<0.001	0.983	<0.001

Relationship between VAI and Plasma Lipid Profile: Tables 5 and 6 show the observed coefficient (β) and probability of being equal to zero (p values) from univariate linear and multivariate regression analyses in men and women, respectively. Each of the following factors has a p-value less than 0.05: TC, HDL-c, LDL-c, LDL-c/HDL-c ratio, and TG. This indicates that the variables have a significant effect on VAI.

Table 5:
Relationship between visceral adiposity index and plasma lipids among men

Variables	Unadjusted Estimates			*Adjusted Estimates		
	β	95% CI	p	β	95% CI	p
Total cholesterol (mmol/L)	0.13	0.70, 0.20	<0.001	-0.08	-0.14, -0.03	0.002
HDL cholesterol (mmol/L)	-0.55	-0.64, -0.46	<0.001	-0.17	-0.24, -0.11	<0.001
LDL cholesterol (mmol/L)	0.21	0.14, 0.29	<0.001	-0.13	-0.24, -0.02	0.013
LDL-c/HDL-c ratio	0.45	0.35, 0.54	<0.001	0.65	0.60, 0.70	<0.001
Triglyceride (mmol/L)	0.69	0.60, 0.78	<0.001	0.41	0.28, 0.53	<0.001
AIP	0.78	0.74, 0.817	<0.001	-	-	-
Constant				0.55	0.40, 0.70	<0.001

*Model, VAI = (-0.08 x TC) + (-0.17 x HDL-c) + (-0.13 x LDL-c) + (0.65 x LDL-c/HDL-c ratio) + (0.41 x TG) + 0.55
AIP – Atherogenic Index of Plasma

Table 6:
Relationship between visceral adiposity index and plasma lipids among women

Variables	Unadjusted Estimates			*Adjusted Estimates		
	β	95% CI	p	β	95% CI	p
Total cholesterol (mmol/L)	0.18	0.06, 0.31	0.005	0.56	0.35, 0.77	<0.001
HDL cholesterol (mmol/L)	-0.90	-1.07, -0.73	<0.001	-0.37	-0.50, -0.24	<0.001
LDL cholesterol (mmol/L)	0.31	0.17, 0.44	<0.001	-0.31	-0.44, -0.18	<0.001
LDL-HDL ratio (mmol/L)	0.58	0.43, 0.73	<0.001	0.84	0.77, 0.92	<0.001
Triglyceride (mmol/L)	1.04	0.88, 1.22	<0.001	-	-	-
AIP	1.25	1.17, 1.33	<0.001	-	-	-
Constant				.83	0.51, 1.14	<0.001

*Model: VAI = (0.56 x TC) + (-0.37 x HDL-c) + (-0.31 x LDL-c) + (-84 x LDL-c/HDL-c ratio) + 0.83
AIP – Atherogenic Index of Plasma

Figures 2 and 3 illustrate the correlations between VAI and AIP, HDL-c, TG, TC, and LDL-c/HDL-c ratio using scatter plots and fitted regression lines, as well as equations. The negative regression coefficient (-0.55 for males and -0.90 for women) reveals that VAI and HDL-c have an inverse association, whereas TG, TC, and the LDL-c/HDL-c ratio have a direct link with VIA (Figure 2). Each of the equations in Figure 2 demonstrated that for TG, TC, and LDL-c/HDL-c ratio, an average of the same coefficient value happened for each incremental unit rise in the values of the variables. On the other hand, an increase of one unit in HDL-c results in a decrease of the same value of 0.05 mmol/L in men and 0.09 mmol/L in women.

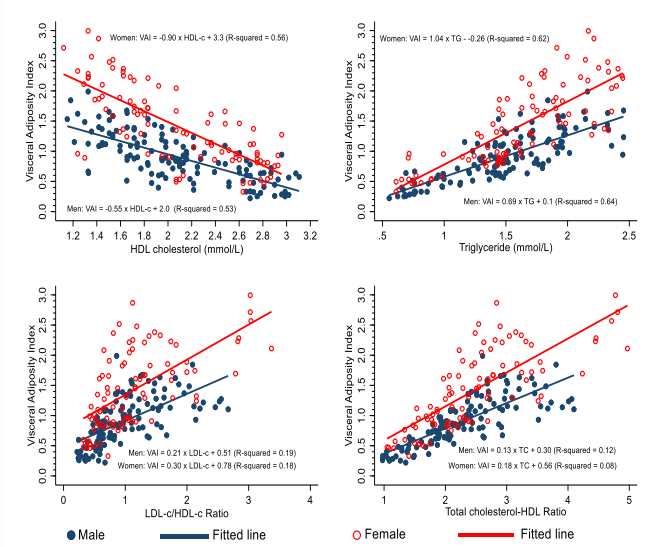

Figure 2:
Relationship between Visceral Adiposity Index and Plasma Lipids and their Ratios

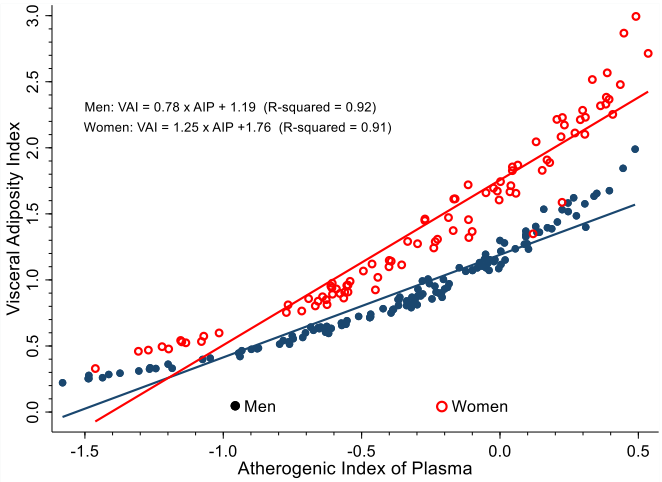

Figure 3:
Relationship between Visceral Adiposity Index and Atherogenic Index of Plasma

Additionally, Figure 3 depicts the correlations between VAI and AIP using scatter plots, fitted regression lines, and equations. The fact that the regression coefficient is positive (0.78 for men and 1.25 for women) implies that there is a direct association between VAI and AIP. According to Figure 3, each extra unit increase in AIP results in an average increase in VAI of 0.78 mmol/L in males and 1.25 mmol/L in women. Although the fitted lines and coefficient values indicated that the correlations are valid, the R-squared values for each linear regression model ranged from 0.53 to 0.64. The computed R-squared statistics reveal that HDL-c, TG, TC, and the LDL-c/HDL-c ratio jointly explained around 53% to 64% of the variance in the VAI. When combined, the stepwise regression analysis provided models that removed AIP and a good

equation for predicting VAI in men [VAI = (-0.08 x TC) + (-0.17 x HDL-c) + (-0.13 x LDL-c) + (0.65 x LDL-c/HDL-c ratio) + (0.41 x TG) + 0.55] with an R-squared of 0.95. For women, the stepwise regression model produces a prediction equation that is devoid of TG and AIP [VAI = (0.56 x TC) + (-0.37 x HDL-c) + (-0.31 x LDL-c) + (-84 x LDL-c/HDL-c ratio) + 0.83] with an R-squared of 0.93.

DISCUSSION

We examined the relationship between VAI and total cholesterol, lipoprotein cholesterol, triglycerides, and apolipoproteins A1 and B in this study. This study found a positive association between AIP and VAI and the risk of cardiovascular disease in adults, even after controlling for possible confounding factors. We found that whereas TC, HDL-c, LDL-c, LDL-c/HDL-c ratio, and TG were all independent predictors of VAI in both men and women in the research area, the combination of HDL-c, LDL-c, LDL-c/HDL-c ratio, and TG produced a more accurate prediction regardless of gender. Increased VAI and AIP levels were also associated with increased anthropometric and lipid profiles. These findings demonstrate that changes in plasma concentrations of TC, HDL-c, LDL-c, the LDL-c/HDL-c ratio, and TG are linked with changes in an individual's VAI value. This is the first time, to our knowledge, that a direct association between VIA, a gender-specific mathematical indicator, and biochemical parameters (such as TG and HDL cholesterol) and other commonly measured plasma lipids will be reported in an apparently healthy Nigerian population.

The mean AIP and VAI values observed in this study were much lower than those reported in previous investigations among postmenopausal women in Enugu, Nigeria (Nwagha *et al*., 2010) and in other studies (Moussavi Javardi *et al*., 2020, Hamzeh *et al*., 2021). These disparities may be explained by variances in age groups as well as the frequency of obesity and overweight in the research populations. Women had greater VAI and AIP values than men, similar to the findings of an Iranian cohort study; higher VAI levels were also related to an increased risk of CVDs in both males and females. However, women had a greater BMI and a higher VAI than men in this study . In comparison to the Iranian sampled population, males had a greater BMI and a lower VAI than females (Hamzeh *et al*., 2021).

In this study, 8.6% had an intermediate risk of CVD and 12.2% had a high risk. AIP had a favourable connection with total cholesterol, LDL-c, and triglycerides, but a negative relationship with HDL-c. These data corroborate a prior study that demonstrated a substantial increase in AIP when total cholesterol, triglycerides, and LDL-c were elevated while HDL-c was lowered (Bo *et al*., 2018). Additionally, we discovered a positive relationship between AIP and triglycerides and a negative relationship between AIP and HDL-c. As a result, AIP appears to be a more robust predictor of CVD risk than the other indexes in our study sample. Despite the fact that almost one in five participants had an intermediate or high risk of CVD according to the AIP categorization, the average age of the participants was 22.1 years, showing that they were relatively young. While real body fat was not evaluated in this study, the significant link between AIP and BMI, as well as visceral fat, implies that these individuals, particularly those with a high body fat percentage, should be observed in the future to prevent CVD.

The present study of the relationship between VAI and plasma lipids provides important information that may impact on clinical and public health practice since a number of existing and growing non-communicable diseases (NCDs) in Nigeria, such as hypertension, diabetes, and metabolic syndrome, are associated with visceral adiposity (Tchernof and Després, 2013). The pathophysiology of several of these NCDs has been linked to visceral adiposity, in part due to excess fatty acids in visceral tissue being reabsorbed into the portal circulation and accumulating in the liver (Tchernof and Després, 2013). Several theories proposed in the literature include an increase in the liver's gluconeogenic and lipogenic activity, as well as an increase in hepatic triglyceride levels. Additionally, the liver's insulin extraction reduces, resulting in metabolic imbalance and increased insulin resistance. When there is an excess of visceral adipose tissue, the adipokine-specific cytokines resistin and visfatin inhibit the generation of adiponectin (Amato *et al*., 2014, Graffy and Pickhardt, 2016). This results in an increase in inflammation; macrophages in visceral adipose tissue have been found to release TNF-α and IL-6 indirectly (Amato *et al*., 2014, Graffy and Pickhardt, 2016). Thus, having a lot of visceral fat may cause the body to be in a state of longstanding low-grade inflammation.

The predictive value of AIP for VAI and the fact that the regression equation linking the two calculated parameters explained over 90% of the variance in this study have significant implications. Individuals with high lipid ratios or atherosclerotic indexes are at an increased risk of developing heart disease due to an imbalance of atherogenic and anti-atherogenic lipoproteins (Millán *et al*., 2009). As a result, they are effective predictors. The AIP reflects the particle sizes of HDL-c, LDL-c, and VLDL and has been described as a more sensitive indicator of CVD risk than the other three atherogenic indices, which are Castelli's risk indices, the atherogenic coefficient, and triglyceride elevation (Ranjit *et al*., 2015). As a result, if all other risk factors for atherosclerosis appear to be normal, AIP may be utilised as a diagnostic option.

The study's key strength was the prospective collection of primary data. This is the only study that we are aware of that examines the connection between AIP and VAI in asymptomatic people in Nigeria's southwest area. However, this research has a few limitations. To begin, the study participants were university students, and so the findings may not be generalizable to the total adult population in the study area. Additionally, because this was a cross-sectional study, no causal association could be established. Additionally, the study's conclusions are constrained by the absence of physical activity and nutritional assessment. As a result, caution should be exercised in extrapolating our findings. Future research may address these limitations by adding physical activity, eating patterns, and the effects of social and environmental factors. As a result, additional research is required in a variety of geopolitical regions and ethnic groups.

CONCLUSION

Our findings suggest that, given the ease with which waist circumference and body mass index, as well as triglyceride and HDL-c levels can be measured, the VAI could be a simple tool for assessing adipose tissue dysfunction and associated

cardiometabolic risk in a variety of patients in Nigeria, particularly those without overt metabolic syndrome. Unless and until further research with a larger sample size establishes otherwise, our findings justify the use of AIP as a proxy for CVD risk prediction in addition to individual plasma lipid levels and/or TC/HDL-c and LDL/HDL-c ratios. Early detection and measures to reduce VAI have the potential to stem the tide of cardiovascular events in Nigeria.

Acknowledgments
The authors would like to thank the staff of the University Health Center, Jaja, for their assistance, as well as the undergraduate students at the University of Ibadan who participated in this study.

Authors' contributions:
BEO conceptualized and design the study, supervised the acquisition of data, analysis, and interpretation of data as well as the drafting of the article. ZOS and ATA contributed to the design of the study, carry out data collection and laboratory analysis as well as revision of the manuscript. All the authors have read and approved the final version of the manuscript.

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