World Nutrition, June 2026;17(2): 33-43
DOI: https://doi.org/10.26596/wn.202617233-43

WORLD NUTRITION
The Official Journal of the World Public Health Nutrition Association
Journal homepage: https://www.worldnutritionjournal.org
WPHNA
ISSN: 2041-9775

Research Article

Anthropometric characteristics and prevalence of metabolic syndrome among in-school adolescents in Gusau urban area, Zamfara State

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Article History
Received: June 13, 2025
Reviewed: September 01, 2025
Revised: April 06, 2026
Accepted: April 18, 2026
Published: June 30, 2026

Citation
Itiat J.F., Onabanjo O.O., Sanni S.A., & Adebowale A.A. (2026). Anthropometric characteristics and prevalence of metabolic syndrome among in-school adolescents in Gusau urban area, Zamfara State *World Nutrition*, 17(2), June, 33–43. https://doi.org/10.26596/wn.202617233-43

Academic Editor
Ted Greiner, PhD

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Highlights/Key Messages

- Stunting and underweight were higher in males aged 15-19 years.
- Overweight, obesity and MetS were more prevalent in females 10-14.
- Overall, MetS prevalence was 3.0%, within the global range of 2.5-12.1%.
- WC and WHR correlated strongly with BP, TRIG and LDL in adolescents.
- School-based nutrition and activity programs are urgently recommended.

Background
There is an increasing prevalence of metabolic syndrome among adolescents globally. In Nigeria, early detection may be a promising and preventive measure in nutrition sciences.

Objective
This study assesses the association between anthropometric characteristics and prevalence of metabolic syndrome among adolescents in Gusau urban area, Zamfara State.

Methods
The study is cross-sectional in design, where 400 respondents within 10-19 years were selected from 6 private and 5 public secondary schools in Gusau Urban Area, Zamfara State using stratified proportionate and random sampling techniques. Anthropometry was conducted using standard instruments and methods. BMI-for-age was calculated using WHO AnthroPlus. Biochemical parameters of Metabolic syndrome (MetS) were measured: blood pressure, fasting blood sugar (FBS), total cholesterol (TCH), triglycerides (TRIG), high-density lipoproteins (HDL), and low-density lipoproteins (LDL) were measured using standard methods.

Results
Mean MetS components were within the normal range. There was severe stunting of 19.4% and 6.8% among males and females of 15-19 years respectively. The overall prevalence of MetS was 3.0%. Low HDL was identified as the most common MetS components and was particularly high among females, highlighting the importance of monitoring these components in adolescent health assessments.

Conclusion
In conclusion, this paper has provided baseline prevalence data on MetS among adolescents in an underserved urban area in Nigeria. Since some adolescents are malnourished, diet and lifestyle as modifiable factors should be the pivot for nutrition education intervention for in-school adolescents

Keywords: anthropometry, metabolic-syndrome, adolescents, Gusau-Urban, prevalence.

Introduction

The rapid industrialisation and adoption of Western-style diets have significantly contributed to the escalating burden of obesity, metabolic disorders, and cardiovascular diseases (CVDs) (Liu et al., 2021). The prevalence of obesity among adolescents has tripled during the last thirty years (Agu et al., 2022b). The shift from traditional dietary patterns to Westernised diets represents a profound lifestyle change, characterised by a substantial increase in sodium consumption and a concomitant decline in potassium intake (Zhang et al., 2022a). This dietary transition has far-reaching consequences, including an increased risk of non-communicable diseases (NCDs) (World Health Organization, 2021b). WHO has developed guidelines to reduce dietary salt consumption across populations.

MetS is a predictor of future cardiovascular disease and Type 2 diabetes. It is indicated by the presence of at least two of the following: central or abdominal obesity, high triglycerides, low HDL cholesterol, elevated blood pressure, high fasting blood sugar, or type 2 diabetes. It is characterised by oxidative stress, cellular inflammation, and dysfunction of adipocytes, myocytes, and hepatocytes, which often co-occur due to underlying processes that lead to insulin resistance (Kumar et al., 2022). Indeed, insulin resistance remains the underlying pathophysiological mechanism (IDF, 2022). While obesity is more prevalent among females, hypertension is more predominant among males (Njelekela et al., 2022).

Globally, MetS already impacts a quarter of the adult population, and alarmingly, it's becoming increasingly common among children and teenagers as well, according to the World Health Organization (2022). Approximately 5% of adolescents worldwide, with some regional and national variations, are considered to have MetS, according to available data (Noubiap et al., 2022). More than 35 million teenagers aged 13 to 18 are projected to have MetS. Age, ethnicity, and geography all have substantial effects on the prevalence of MetS (DeBoer, 2019).

Recent studies have identified several factors contributing to the rising prevalence of overweight and obesity among adolescents, including energy-dense diets rich in ultra-processed foods that are high in fat, sugar, and salt, and low in essential nutrients (World Health Organization [WHO], 2021a). Other factors include sedentary lifestyles with little physical activity, linked to urbanisation and the increased use of labour-saving devices (Hales et al., 2022), and inadequate and inappropriate parental influence on children's eating habits and dietary choices (Brown et al., 2020). These factors can lead to MetS, which can have far-reaching impacts on various aspects of an adolescent's life, including psychological and emotional well-being (Zhang et al., 2022b), cardiovascular health (Agu et al., 2022a), and overall physical health and quality of life (WHO, 2021).

Contrary to previous beliefs, MetS is now a significant health burden in Africa, with increasing prevalence across age groups (Agu et al., 2022). MetS affects younger individuals, with obesity and dyslipidaemia being the most common components (Kengne et al., 2022). A recent study by Salisu-Olatunji et al. (2024) in Lagos, Nigeria, found that about 7.7% of adolescents were overweight or obese.

Identifying and addressing cardiovascular and metabolic issues early on is vital to preventing serious long-term health consequences (American Heart Association, 2022). Hypertension is the most widespread chronic condition globally, impacting people of all ages, sexes, and backgrounds, according to the World Health Organization (2021). Research has shown that hypertension that develops in childhood can persist and worsen into adulthood, increasing the chances of cardiovascular disease and premature death (Lurbe et al., 2022). Despite this, global studies on hypertension tend to focus on adults in midlife and beyond, perpetuating misconceptions that younger individuals are not at risk (Chaturvedi et al., 2022). However, hypertension in children and adolescents is a significant concern, and its diagnosis is often missed, even by paediatricians (Jensen et al., 2022).

Noubiap et al. (2022) found that approximately 5% of adolescents aged 13-18 years worldwide have MetS, with prevalence rates for the global, regional, and country-level burden of MetS in children and adolescents varying widely from 0.5% to 43.8%.

Notably, the prevalence of MetS doesn't always increase with a country's wealth, suggesting that the issue is more complex than economic development alone. It is less expensive and more efficient to identify problems early. Unfortunately, not enough research has been done in African nations, including Nigeria, on the biomarkers of MetS in adolescents. This study measured anthropometric status and other markers to estimate the prevalence of MetS among adolescents in the Gusau urban area of Zamfara State, Nigeria.

Methods

Study Design

An analytical cross-sectional descriptive approach was utilised to conduct this study among adolescents aged 10-19 years from selected secondary schools in the Gusau urban area of Zamfara state.

Study Area

The research was undertaken in the urban area of Gusau, the capital city of Zamfara State, North-West Nigeria. Many households in Zamfara experience food insecurity, particularly during the lean season (WFP, 2021). As of the 2006 census, the city had a population of 383,162 (NPC, 2006), likely increasing to about 700,000 currently (NPC and NBS, 2025). Gusau Local Government is made up of 11 political wards: six rural and five urban.

Study Population

The population under study consisted of in-school adolescents (10-19 years) in the urban Gusau Local Government Area, selected from randomly selected private and public schools within their respective political wards.

Exclusion Criteria

Adolescents who were excluded from the study were those on any form of medication, pregnant, with acute illness, with a known disease or those who moved into the area less than three months before the commencement of the study.

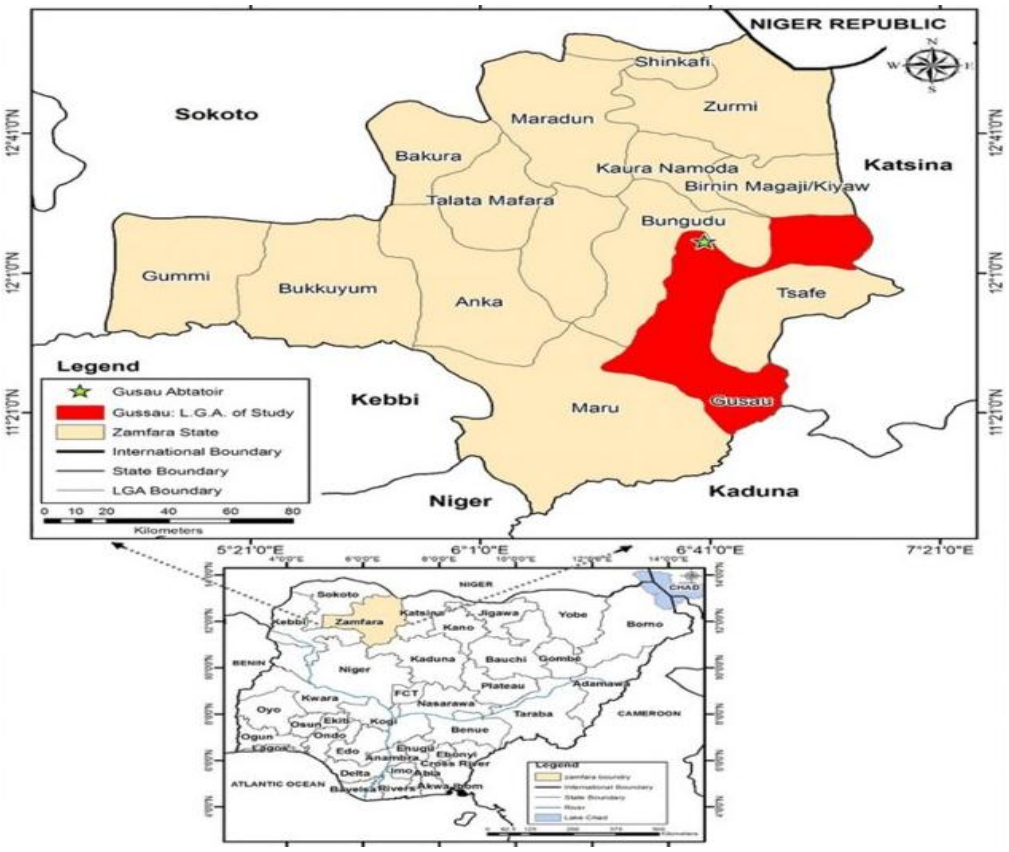


Figure 1. Map of Study Area

Sample size determination

Despite the lack of comprehensive national data, studies suggest that MetS prevalence among adolescents in urban cities of Northwest Nigeria has reached 35.1%, indicating a significant public health concern (Anas, et al., 2016).

The sample size was statistically derived using Cochran's formula

Cochran's sample size formula (1963);

$$n_o = Z^2pq/e^2$$

n_o is the sample size predicted

e is the intended accuracy level of precision (the margin of error)

p is the estimated percentage of the population that possesses the certain trait or attribute in question.

q is (1-p)

Z is a value found on the z-table

$$(1.96)^2\ (0.351)\ (1\text{-}0.351) / (0.05)^2$$

$$3.8416 \times \frac{0.227799}{0.0025}$$

$$0.8751126384 / 0.0025 = 350$$

The calculated sample size was 350, plus 10% attrition; this gives a total of 385 respondents (247 boys and 153 girls) for this research.

Sampling technique and Procedures

Respondents were proportionately and randomly selected from 6 private schools among 19 private secondary schools and 5 public secondary schools among 10 public secondary schools within the 5 urban political wards of the Gusau urban area, Zamfara, using a multi-stage sampling technique. In each ward, 1 private school and 1 public school were randomly selected after they were proportionately selected, except in Galadima ward, which had 2 private schools and 1 public school due to proportion, and participants were selected using a proportionate stratified sampling method. The population was stratified based on schools, classes, and gender to achieve a sample size of 400.

First stage: Using state political profiling data, stratify into urban and rural wards across 11 political wards in the Gusau Local Government Area, the state capital of Zamfara State.

Second stage: From the five urban political wards in the Gusau Local Government Area of Zamfara State, 11 secondary schools (5 public and 6 private) were proportionately and randomly selected from 29 secondary schools (10 public and 19 private) within the urban area.

Third stage: Respondents were selected proportionately and randomly from the selected schools, stratified by class and gender, in accordance with the study's inclusion criteria.

Anthropometric measurements

The anthropometric evaluation included weight, height, waist and hip circumferences, following the guidelines set out by the World Health Organization as outlined in "Physical Status" (WHO, 2019).

Height Measurement

Height measurements were obtained using a stadiometer,

accurate to 0.5cm and body weight was measured using a digital Seca scale, precise to 0.1kg. Respondents were barefoot and wore minimal clothing. According to the conventional formula, Body Mass Index (BMI) was calculated as the ratio of body weight (kg) to the square of height (m) (WHO, 2019).

Weight Measurement

The patients stood erect on the scale, barefooted, to ensure accuracy, participants stood upright with their arms relaxed and by their sides, avoiding any movement or tension., their heads straight in line, and their weight recoded to the closest 0.1kg resolution weighed using a Seca scale digital device according to normal procedures (WHO, 2008; FANTA, 2016).

Waist Circumference Measurement

The waist circumference was assessed using a non-elastic tape measure at the designated anatomical midpoint, with skin lightly touched but not compressed (WHO, 2019; Marfell-Jones et al., 2018). The measurement was conducted in accordance with normal protocols while wearing light garments

Hip Circumference Measurement

This was measured to the closest 0.5cm at the location of the largest circumference around the hip and buttocks. The recorder bent down to take the measurement while the responders stood. A flexible, non-stretchable measuring tape was used for this.

Waist-Hip Ratio

This study employed the waist-to-hip ratio, calculated as waist girth divided by hip girth. Men (⩾0.95cm) and females (⩾0.80cm) are at high risk, whilst men (⩽0.95cm) and females (⩽0.80cm) are at low risk. For both genders, a high waist-to-hip ratio is an indicator of central (abdominal) obesity and is associated with a higher risk of type 2 diabetes and cardiovascular disease.

Blood Pressure Measurements of Respondents

Systolic and diastolic blood pressure values were collected from participants' dominant arm using an analogue sphygmomanometer (Omron Medical, United Kingdom) after they had been seated for 10 minutes. The readings were captured to the nearest mmHg, following the guidelines outlined by the American Heart Association (Whelton et al., 2021). The analogue sphygmomanometer was used with a suitable-sized cuff, and readings were taken by trained personnel to ensure accurate measurements (Pickering et al., 2020). One reading was taken per participant.

Specimen Collection and Biochemical Parameters

During the sensitisation and awareness meeting, participants were requested to undergo a 10-12-hour overnight fast before specimen collection by trained professionals (laboratory scientists) using a multi-sample needle from the cubital fossa, following proper antiseptic preparation of the venepuncture site (Centers for Disease Control and Prevention, 2022). Blood samples were collected into microcentrifuge tubes (plain and anticoagulant) and stored in an ice pack flask from the field within 2 hours, then brought to the laboratory within 4 kilometres and centrifuged at 4000 rpm for 5 minutes (Clinical and Laboratory Standards Institute, 2020). The supernatant was then collected and stored at -20°C for a maximum of three weeks (World Health Organization, 2021) prior to laboratory analysis.

Determination of fasting blood glucose (Tietz, 1995)

To quantify fasting blood glucose, the analysis utilised a 5mL blood sample that was placed in a sodium fluoride test tube. Three test tubes (blank, test sample, and standard) were prepared and labelled respectively. Reagents and samples were equilibrated to room temperature. Micro-pipetting added 10 µL of distilled water, the test sample, and the standard to the respective tubes. Mono reagent (1.0mL) was then added, mixed, and incubated (37°C, 5 minutes). Absorbance was measured calorimetrically (520nm) against the reagent blank.

Calculation

$$\frac{\text{Absorbance of test}}{\text{Absorbance of standard}} \times \frac{100\text{mg/dl}}{1} = \text{mg/dl glucose}$$

Determination of Serum Lipid Profile

To assess fasting lipid profiles, 1 µL of supernatant from approximately 5 mL of venous blood was carefully placed in plain tubes, properly labelled, and promptly transported to the laboratory for analysis of triglycerides, total cholesterol, HDL-C, and LDL.

Determination of serum Triglycerides (TG) utilised the method described by (Fossati and Prencipe, 1982).

Determination of serum total cholesterol (TC) followed the method prescribed by Allain et al. (1974).

Determination of serum low density lipoprotein (LDL) followed the method prescribed by Sachiko (1997).

Determination of serum High Density Lipoprotein (HDL) was done following the method described by Burstein et al. (1980).

Results

Data were obtained from 247 boys and 153 girls.

Anthropometric characteristics of respondents

Table 1 below shows that 1.3% and 4.4% of respondents aged 10-14 years were severely stunted and moderately stunted, respectively, while 15.8% and 40.9% of respondents aged 15-19 years were severely stunted and moderately stunted, respectively. These results show that among the females between 10-14 years, 1.8% were moderately stunted and severely underweight, 8.8% and 5.3% were moderately overweight and severely obese, respectively, while between 15-19 years, 6.8% and 22% were severely and moderately stunted, 3.4% and 13.6% were severely and moderately underweight, respectively.

Table 1. Anthropometric characteristics of respondents (N= 363)

Height-for-Age (Stunting)				
	Males		Females	
Categories	10-14	15-19	10-14	15-19
N*	103	144	57	59
<-3SD (Severely stunted)	1.9	19.4	0	6.8
<-2SD (Moderately stunted)	5.8	48.6	1.8	22
Mean	0.21	2.05	0.85	1.12
SD	1.63	1.05	1.56	1.09
Total	103	144	57	59
BMI-for-Age (Underweight/ Overweight)				
	Males		Females	
	10-14	15-19	10-14	15-19
<-3SD (Severe underweight)	2.9	8.3	1.8	0
<-2SD (Moderate underweight)	10.7	35.4	8.8	3.4
<+1SD (Normal)	12.6	0	14	13.6
<+2SD (Moderate overweight)	0	0	8.8	1.7
<+3SD (Obese)	0	0	5.3	0
Mean	0.48	1.63	0.1	0.84
SD	1.21	1.09	1.58	1.08

SD-standard deviation, BMI-Body Mass Index, Height-for-Age-stunting, BMI-for-Age; underweight or overweight

* The sample size was 400, but this table was generated using WHO Anthroplus software where outlying or skewed results were removed automatically, giving 363 respondents.

The Pearson correlation coefficient for all the MetS components and anthropometric parameters for male within 10-14 years is presented below. The result showed that fasting blood sugar (FBS) had a significantly (p≤0.005) negative correlation with WHR(r = -.317, p≤0.005). SBP significantly (p≤0.001) correlated negatively with LDL (r = -0.533, p≤0.001) and TCH (r = -0.422, p≤0.001). For females within 10-14 years is presented below showed that WC had a positive and significant (p≤0.005) association with MetS components like TRIG (r = 0.358, p≤0.005) and TCH (r =0.333, p≤0.005.

Pearson's correlation coefficient for all the MetS components and anthropometric parameters for males within 15-19 years is presented in table below. WC associated with SBP (r= 0.241, p≤0.001) and LDL (r= 0.242, p≤0.005). There was a negative but significant (p≤0.005) association between WHR and SBP(r = -0.154, p≤0.005) DBP(r = -0.195, p≤0.001) while for female within 15-19 years showed WHR was negatively associated with DBP (r = -0.288, p≤0.005).

Table 2a. Correlation between anthropometric parameters and metabolic syndrome components for males 10-14 years

	Variable	1	2	3	4	5	6	7	8
Male	1.WC(cm)	1							
10-14	2.WHR(cm)	.504**	1						
	3.SBP(mmHg)	-0.027	-0.154	1					
	4.DBP(mmHg)	-0.092	-0.122	.813**	1				
	5. FBS(mmol/L)	-0.18	-.317*	0.184	0.133	1			
	6.HDL(mmol/L)	0.011	0.125	-0.146	-0.147	-0.017	1		
	7.LDL(mmol/L)	0.094	0.22	-.533**	-.490**	-0.109	-0.072	1	
	8.TRIG(mmol/L)	0.02	0.09	0.025	-0.169	-0.038	0.257	-0.102	1
	9.TCH(mmol/L)	0.07	0.242	-.422**	-.497**	-0.132	.584**	.603**	.488**

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). WC: Waist circumference; WHR: Waist: hip ratio; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FBS: Fasting blood sugar; HDL: High density lipoprotein; LDL: Low density lipoprotein; TRIG: Triglycerides; TCH: Total cholesterol.

Table 2b. Correlation between anthropometric parameters and metabolic syndrome components for females 10-14 years

	Variable	1	2	3	4	5	6	7	8
Female	1.WC(cm)	1							
10-14	2.WHR(cm)	.402**	1						
	3.SBP(mmHg)	-0.001	-0.296	1					
	4.DBP(mmHg)	-0.109	-0.184	.821**	1				
	5. FBS(mmol/L)	-0.025	0.045	.613**	.673**	1			
	6.HDL(mmol/L)	0.075	-0.057	.413**	.330*	0.277	1		
	7.LDL(mmol/L)	0.092	0.076	-0.292	-0.176	-0.137	-0.281	1	
	8.TRIG(mmol/L)	.358*	.508**	0.021	-0.033	0.164	.305*	0.009	1
	9.TCH(mmol/L)	.333*	0.294	-0.066	-0.106	0.034	0.273	.644**	.604**

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). WC: Waist circumference; WHR: Waist: hip ratio; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FBS: Fasting blood sugar; HDL: High density lipoprotein; LDL: Low density lipoprotein; TRIG: Triglycerides; TCH: Total cholesterol

Table 2c. Correlation between anthropometric parameters and metabolic syndrome components for males 15-19 years

	Variable	1	2	3	4	5	6	7	8
Male	1.WC(cm)	1							
15-19	2.WHR(cm)	.276*	1						
	3.SBP(mmHg)	0.105	-.277*	1					
	4.DBP(mmHg)	0.019	-.319**	.723**	1				
	5. FBS(mmol/L)	-0.06	0.092	0.016	0.089	1			
	6.HDL(mmol/L)	-0.142	-0.171	-0.157	-0.21	0.028	1		
	7.LDL(mmol/L)	.242*	0.095	0.082	-0.121	-.325**	0.104	1	
	8.TRIG(mmol/L)	0.212	-0.076	-0.088	-0.221	-0.057	.345**	0.096	1
	9.TCH(mmol/L)	0.197	-0.035	-0.012	-0.226	-0.221	.599**	.790**	.537**

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). WC: Waist circumference; WHR: Waist: hip ratio; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FBS: Fasting blood sugar; HDL: High density lipoprotein; LDL: Low density lipoprotein; TRIG: Triglycerides; TCH: Total cholesterol

Table 2d. Correlation between anthropometric parameters and metabolic syndrome components for females 15-19 years

	Variable	1	2	3	4	5	6	7	8
Females	1.WC(cm)	1							
15-19	2.WHR(cm)	.579**	1						
	3.SBP(mmHg)	0.019	-0.213	1					
	4.DBP(mmHg)	-0.186	-0.304	.751**	1				
	5. FBS(mmol/L)	-0.244	0.044	0.313	0.274	1			
	6.HDL(mmol/L)	-0.02	-0.296	0.093	0.137	0.163	1		
	7.LDL(mmol/L)	0.115	0.04	-.332*	-0.204	-0.311	-0.183	1	
	8.TRIG(mmol/L)	0.091	-0.006	-0.088	-0.042	-0.157	-0.017	0.151	1
	9.TCH(mmol/L)	0.213	0.014	-0.252	-0.197	-0.288	0.153	.623**	.634**

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). WC: Waist circumference; WHR: Waist: hip ratio; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FBS: Fasting blood sugar; HDL: High density lipoprotein; LDL: Low density lipoprotein; TRIG: Triglycerides; TCH: Total cholesterol

Metabolic syndrome components of respondents by age and sex

Table 3a shows the mean, standard deviation, and cut-off values for the MetS components of the respondents by sex, and Table 3b, by age. Mean values were within the normal cut-off ranges for MetS components considered in this research for both sexes (except HDL for females) and for both age groups. Maximum values for each parameter were higher than the cut-off values except for systolic blood pressure in age (10-14) years, which was within the cut-off value.

Table 3a. Mean values for metabolic syndrome components of respondents by sex

MetS Components	N	Cut-off values	Mean± SD	N	Cut-off values	Mean± SD
	Male			Female		
WC	273	⩾94cm	69.0 ± 6.67	127	⩾80cm	73.3 ± 7.73
SBP	273	⩾ 130mmHg	98.5 ± 11.3	127	⩾ 130mmHg	98.2 ± 14.8
DBP	273	⩾80mmHg	66.0 ± 10.3	127	⩾80mmHg	66.1 ± 11.8
FBS	119	⩾5.6mmol/L	4.86 ± 0.83	83	⩾5.6mmol/L	4.85 ± 0.8
HDL	119	<1.03mmol/L	1.07 ± 0.31	83	<1.29mmol/L	1.08 ± 0.47
LDL	119	>2.8mmol/L	1.21 ± 0.5	83	>2.8mmol/L	1.68 ± 0.62
TRIG	119	⩾1.7mmol/L	1.22 ± 0.5	83	⩾1.7mmol/L	1.51 ± 0.52
TCH	119	>4.4mmol/L	2.91 ± 0.68	83	>4.4mmol/L	3.4 ± 0.74

MetS: metabolic syndrome; WC: waist circumference; FBS: Fasting blood sugar; HDL: high density lipoprotein; LDL: low density lipoprotein; TRIG: Triglycerides

Table 3b. Mean metabolic syndrome components of respondents by age group

MetS Components	Age	N	Mean± SD	Age	N	Mean± SD
	(10-14)			(15-19)		
WC (cm)		166	69.28±8.29		234	71.1±6.41
SBP (mmHg)		166	95.6±13.6		234	100±11.3
DBP (mmHg)		166	64.8±11.9		234	66.9±9.71
FBS (mmol/L)		93	4.76±0.84		109	4.93±0.79
HDL (mmol/L)		93	1.04±0.41		109	1.11±0.35
LDL (mmol/L)		93	1.47±0.65		109	1.34±0.54
TRIG (mmol/L)		93	1.4±0.52		109	1.28±0.53
TCH (mmol/L)		93	3.18±0.75		109	3.05±0.73

WC: Waist circumference; WHR: Waist: hip ratio; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FBS: Fasting blood sugar; HDL: High density lipoprotein; LDL: Low density lipoprotein; TRIG: Triglycerides; TCH: Total cholesterol

The Prevalence of Metabolic Syndrome

Table 4 shows the prevalence of MetS components by age group and sex. The result showed an overall MetS prevalence of 3.0% among adolescents in the Gusau urban area. The prevalence of WC was 13.6% and 15.4% for females aged 10-14 and 15-19 years, respectively, while that of SBP (0.7%) was found only in males aged 15-19 years. DBP was within the range (1.2-4.1%), FBS (4.5-17.9%), while HDL (18.3-75.0%) had the highest prevalence among metabolic syndrome components for both ages and gender. DBP (1.3%) in males 15-19 years, FBS (17.9%) in females 15-19 years, HDL (75.0%) and LDL (6.8%) in females 10-14years, TRIG (35.9%) in females 15-19 years, while TCH (9.1%) in females 10-15 years as the highest limit respectively. Female participants had a high case rate of MetS of 6.0%, compared with 0.8% among male participants.

Table 4. Prevalence of metabolic syndrome components by age group and sex

Proportions above/below cut-off point for each component (%)										
Age/sex	**WC**	**SBP**	**DBP**	**FBS**	**HDL**	**LDL**	**TRIG**	**TCH**	**MetS**	
(10-14) Males	2.0	-	4.1	16.3	55.1	-	24.5	2.0	2.0	
Females	13.6	-	-	4.5	75.0	6.8	29.5	9.1	6.8	
(15-19) Males	-	0.7	1.3	7.2	18.3	0.7	7.2	2.0	-	
Females	15.4	-	1.2	17.9	59.0	5.1	35.9	5.1	5.1	
Males	0.8	0.8	3.4	16.0	46.2	0.8	19.3	3.4	0.8	
Females	14.5	-	1.2	10.8	67.5	6.0	32.5	7.2	6.0	**3.0**

WC: Waist circumference; WHR: Waist: hip ratio; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FBS: Fasting blood sugar; HDL: High density lipoprotein; LDL: Low density lipoprotein; TRIG: Triglycerides; TCH: Total cholesterol; MetS: metabolic syndrome.

The Metabolic Syndrome Component Counts of Respondents

Table 5 shows the MetS component counts by age group and sex. Among females aged 10-14 years, 6.8% of respondents had at least three MetS parameters, while 4.5% of those aged 15-19 years had at least four MetS parameters, irrespective of waist circumference. MetS components were observed in about 6.8% of respondents aged 10-14 years and 2.6% of respondents aged 15-19 years.

Table 6 shows the proportions by sex and age group with high waist circumference with or without other components

Table 5. Metabolic Syndrome component counts by age group and sex

		Metabolic Syndrome Component Counts						
Sex	**Age**	0/5	1/5	2/5	3/5	4/5	5/5	Total
Male	10 – 14	10 (20.4)	28 (57.1)	10 (20.4)	1 (2.0)	0 (0.0)	0 (0.0)	49 (24.3)
	15 – 19	26 (37.1)	32 (45.7)	11 (15.7)	1 (1.4)	0 (0.0)	0 (0.0)	70 (34.7)
Female	10 – 14	5 (11.4)	24 (54.5)	10 (22.7)	3 (6.8)	2 (4.5)	0 (0.0)	44 (21.8)
	15 – 19	7 (17.9)	16 (41.0)	12 (30.8)	2 (5.1)	1 (2.6)	1 (2.6)	39 (19.3)

Table 6. Proportions with High Waist Circumference with or without other Components

Sex	Age	WC Only	WC +1 MetSC	WC +2 MetSC	WC +3> MetSC	Total
Male	10 – 14	1 (2.0)	1 (2.0)	0 (0.0)	0 (0.0)	49 (24.3)
	15 – 19	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	70 (34.7)
Female	10 – 14	6 (13.6)	2 (4.5)	3 (6.8)	0 (0.0)	44(21.8)
	15 – 19	6 (15.4)	4 (10.3)	1 (2.6)	1 (2.6)	39 19.3)
	Total				202(100.0)	

WC: waist circumference; MetSC: metabolic syndrome component

Discussion

We found that stunting was more common among male respondents. This difference may be linked to genetic and hormone differences in these genders, as gender has long been identified as a factor that contributes to vital roles in the nutritional status of apparently healthy adolescents (Abubakar et al., 2024; Spear, 2002) and (WHO, 2022).

The prevalence of severe underweight was also higher among males. This may similarly be due to genetic and hormonal differences (Gizaw et al. (2022), on the nutritional status of adolescent females in Ethiopia, where underweight was more common in older adolescents (15–19 years) than younger ones (10–14 years).

BMI-for- age showed that females within 10-14 years had a higher frequency of overweight and obesity compared to males of the same age. This may be consistent with the fact that women are known to have more abdominal fat than men; this might be explained by physical and genetic differences between the genders. According to Barquera et al. (2022), this can also result from respondents' dietary and lifestyle choices. This research adds to the evidence that teenage malnutrition is a serious health issue in developing countries like Nigeria and other sub-Saharan African nations.

In our sample of adolescents in the Gusau urban area, the

overall prevalence of MetS among adolescents aged 10–19 years was 3.0%. This is lower than the 8.3% overall prevalence reported by Bamgboye and Susan (2024) on the burden of dyslipidaemia and MetS among Secondary School Students in Lagos, Nigeria, and higher than the 1.4% reported by Lwabukunaw (2021) on early clinical markers of MetS among secondary school adolescents in Dares Salaam, Tanzania, and the 2.3% reported by Elfaki et al. (2022) among early adolescents in Khartoum State, Sudan, but it is within the 2.5–12.1% estimated global prevalence for MetS. This may be because some researchers use different classification techniques for MetS determination, and because the respondents in this study were apparently healthy, but this may not be the case in other studies.

Males between the ages of 15-19 years had higher systolic blood pressure, higher diastolic blood pressure, and higher fasting blood sugar than females, while beneficial high-density lipoprotein cholesterol (HDL) was lower in females 10-14 years as was the prevalence of other MetS components, including triglycerides, total cholesterol, and low-density lipoprotein. The prevalence of MetS was thus highest in females aged 10-14 years, linked to their high prevalence of overweight.

This is comparable to findings from Mohammed et al. (2022) study in school-age children and adolescents in Addis Ababa. Munku et al. (2024) also found HDL levels to be higher than 33.5% in males and 49.8% in females. BP in women often starts earlier in life and increases more quickly than in men (Ji et al., 2020).

The mean and standard deviation were within the normal cut-off ranges for MetS components by gender. Waist circumference (WC) was elevated by +1 SD in some female respondents; high WC is associated with type 2 diabetes mellitus and related metabolic disorders, including their components. This finding might be attributed to genetics, typical hormonal fluctuations, or the low physical activity culturally instilled in females in northern Nigeria. The average results here were lower than those for obesity and MetS among marginalised school-going teenagers in Karachi, Pakistan (Hina et al. 2024). The technique used to gather the data, as well as the lifestyle and behavioural habits of men and women, might be the cause of this.

The mean and standard deviation of the MetS components among respondents, by age, also fell within the cut-off limits. The components of the MetS tend to increase with age, and indeed, higher values for SBP, DBP, FBS, and HDL were observed among respondents aged 15-19. However, LDL, TRIG, and TCH were higher in respondents aged 10-14 years. These findings are comparable to those of Amutha et al. (2024) on dietary intake, obesity, and metabolic risk factors among children and adolescents. The authors of that study noted that MetS and its components are a newly emerging field of study among adolescents.

In our data, waist-hip ratio (WHR) significantly ($p \leqslant 0.005$) correlated negatively with fasting blood glucose (FBS) and positively with DBP; this was attributed to excess fat (Viscarra and Sul, 2020). This relationship indicates links between anthropometric parameters and the onset of metabolic disorders in humans. Females 10–14 had a waist circumference (WC) that correlated significantly ($p \leqslant 0.005$) but moderately with TRIG and TCH. WHR was significantly ($p \leqslant 0.001$) and strongly correlated with TRIG, which may be due to high dietary consumption of fat (Viscarra and Sul, 2020).

Among males aged 15–19, WC had a positive, significant ($p \leqslant 0.001$) correlation with SBP and LDL. WHR was significantly ($p \leqslant 0.005$) negatively correlated with SBP and DBP ($p \leqslant 0.001$). However, WHR was negatively correlated with DBP. This study found a strong, positive correlation between systolic and diastolic blood pressure and WC and WHR, all of which are potentially linked to obesity. These results are comparable to those of Kuciene and Dulskiene (2019), who similarly found a positive association between systolic and diastolic blood pressure and BMI, WC, and WHR in Lithuanian adolescents. Likewise, research on secondary school children and adolescents in Brazil (Cheah et al., 2018) and Malaysia (Burgos et al., 2013) revealed that WC and WHR were associated with high blood pressure in children and may serve as markers for those at risk of hypertension. Blood pressure and visceral fat, as determined by waist circumference, tend to be highly associated (Burgos et al., 2013).

Conclusions

Based on the findings of this study, stunting and underweight were high in the older age group (15-19) of adolescent males, while obesity and MetS were higher in adolescent females 10-19. Malnutrition is high among the studied adolescents by age and gender; hence, the high prevalence of lower HDL, triglycerides, and total cholesterol in females, and a 3.0% prevalence of MetS. Waist circumference correlated positively with triglycerides and total cholesterol level, and waist-hip-ratio correlated positively with triglycerides in females aged 10-14 years. This study has provided baseline prevalence data on MetS among adolescents in an underserved Nigerian urban area. Its findings imply that these adolescents are at risk of MetS.

Recommendations

Nutrition and health-related programs should be organised by schools in collaboration with stakeholders in the state ministries of education and health, targeting adolescents in urban areas such as ours. Their parents need to be focused on and improve the eating and exercise habits if the country is to avoid a large-scale epidemic of MetS in the future.

Nutrition intervention is a complex phenomenon and cannot be solved with one specific approach; hence a multi-dimensional and coordinated effort is needed by all stakeholders to ameliorate poor dietary and exercise habits, high prevalence of low high-density lipoprotein, MetS, and obesity in adolescent females and males, respectively, as seen in the present study.

Author Contributions

JFI, OOO, SAS and AAA contributed to the study. Data collection tools were designed by IJF, OOO and SSA. Initial analysis and

coding were conducted by IJF. IJF wrote the first draft of the manuscript with routine critical reviews by OOO, SSA and AAA. All authors have read and approved the final version of the paper and its submission and have given consent for publication.

Declaration of Generative AI and AI-Assisted Technologies in Scientific Writing

Nothing to disclose.

Acknowledgements

None

Data Availability Statement

All relevant data are available within the manuscript

Funding

None

Conflict of Interest

The authors declare that they have no conflicts of interest.

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