PriMera Scientific Surgical Research and Practice
Volume 4 Issue 5 November 2024
ISSN: 2836-0028

# Correlation Between Anthropometric Indices and Components of Metabolic Syndrome Among Sub-Saharan Black African Adolescents: Gender Differentiation

**Type:** Research Article
**Received:** September 14, 2024
**Published:** October 30, 2024

**Citation:**
Bamgboye M Afolabi., et al. "Correlation Between Anthropometric Indices and Components of Metabolic Syndrome Among Sub-Saharan Black African Adolescents: Gender Differentiation". PriMera Scientific Surgical Research and Practice 4.5 (2024): 02-09.



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## Abstract

***Objective:*** The objective of this study was to evaluate independent and dual association of body mass index (BMI)-for-age percentile and waist circumference (WC) with metabolic syndrome (MetS) among sub-Saharan Black African boys and girls.

***Materials and Methods:*** A total of 624 boys and girls aged 10-19 years were included in the study. Study participants were measured for BMI-for-age percentile, WC, Systolic blood pressure (SBP), impaired or diabetic fasting blood sugar (FBS) level and elevated levels of total cholesterol (T-Chol), triglyceride (TG), low-density lipoprotein (LDL) as well as low level of high-density lipoprotein (HDL).

***Results:*** There was a significant variance (P-value=0.003) in the median BMI-for-age percentile among boys without (n=207; 23.8) and boys with (n=34; 44.2) MetS. This difference was more pronounced (P-value=0.00001) among girls without (n=365; 64.8) and those with (n=18; 82.9) MetS. A notable difference in WC (P-value=0.0004) was observed among girls without and with MetS. Positive and significant correlations between BMI-for-age percentile and SBP were noted among boys (r= +0.37, P-value<0.00001) and girls (r= +0.23, P<0.00001) without MetS, though the correlation was insignificant but still stronger among boys (r= +0.29, P-value=0.09) than girls (r= +0.11, P=0.68) with MetS. The correlation between WC and SBP was only significant among boys with MetS (r= +0.34, P-value<0.049). Stronger, negative and significant correlations were observed between BMI-for-age-percentile and FBG among girls (r= -0.67, P=0.002 for girls) than among boys (r= -0.42, P-value=0.01 for boys). Also stronger, negative and significant correlations existed between WC and FBG among girls (r= -0.62, P=0.006) than among boys (r= -0.39, P-value=0.02). Among those with MetS, the correlation between WC and TChol was stronger, positive and significant among girls (r= +0.54, P-value=0.02) but negative and insignificant among boys (r= -0.16, P-value=0.36). Both BMI-for-age percentile and WC were responsible for significant changes in FBS mostly among girls ($R^2$=0.49, F-ratio=7.29, P-value=0.006) than among boys ($R^2$=0.20, F-ratio=3.94, P-value=0.03).

***Conclusions:*** Our results indicate that, elevated SBP BMI and WC may contribute more to MetS among boys while Diabetes, BMI and WC may do so among girls in Black Africa. There appears to be different interplay between these components of MetS through different mechanisms among boys and girls.

***Keywords:*** Black African Adolescents; Body Mass Index; Sex; Metabolic Syndrome; Sub-Saharan; Waist circumference

## Introduction

Metabolic syndrome (MetS) is marked by a cluster of metabolic conditions, including obesity, disruptions in glucose metabolism, hypertension, and dyslipidemia. Together, these conditions increase the likelihood of developing diabetes mellitus and cardiovascular diseases [1, 2]. The emergence of metabolic problems in childhood is strongly linked to considerable weight gain and the early onset of obesity [3-6]. Several studies have indicated a higher prevalence of MetS among overweight and obese youth [7, 8], suggesting that excess body fat is the most significant risk factor for MetS. In terms of risk factors, gender, nutritional status, and physical activity continued to be associated with MetS in the multivariate analysis, even after adjusting for other variables. Among female adolescents, the likelihood of developing MetS was nearly 70% lower compared to males [9]. This finding supports previous research in adolescents, which has consistently shown a higher prevalence of MetS among young males [8, 10]. The increased prevalence of MetS among males could be attributed to greater deposition of abdominal fat compared to females, a condition associated with MetS components such as hyperglycemia, hypertension, and dyslipidemia [11]. Indeed, in the study, elevated blood glucose was more frequently observed among males, which might have contributed to the higher prevalence of MetS in this group, as it was the third most common component among the surveyed adolescents [12]. Previous studies have indicated that excess body fat plays a significant role in triggering MetS among the pediatric population [13-15]. Various anthropometric indicators have been proposed to assess body fat profiles. Among these, the body mass index (BMI) is the most commonly used in epidemiological surveys, providing insights into the overall quantity of body fat [16]. Additionally, waist circumference (WC), waist-height ratio (WHtR), and the conicity index (C-Index) have been suggested and effectively utilized to gauge cardiometabolic risk in young individuals, as they offer estimates of the central concentration of body fat [17, 18]. Certain aspects of metabolic homeostasis are regulated differently in males and females [19], and studies have indicated that the prevalence of various combinations of MetS factors differs by gender [20, 21]. The primary factors behind gender differences in glucose, lipid, and energy homeostasis are the "activation" effects of estrogens and androgens on their respective receptors after puberty begins. Numerous studies have shown variations in the incidence of cardiometabolic risk factors among obese children based on gender and pubertal status [22-29]. However, the combinations and interactions of the clustered MetS risk factors in the pediatric population are not yet fully understood. Limited studies in children and adolescents have investigated gender differences in metabolic risk factors for MetS [22-25]. The findings align with previous research [9], indicating no significant gender disparity in MetS prevalence [23, 24]. However, higher prevalence of certain metabolic syndrome components, such as elevated systolic blood pressure, among males compared to females was observed [9]. In the study population, obese children did not show higher rates of impaired fasting glucose in males nor a greater prevalence of insulin resistance in females [30]. Despite variations in sex hormone levels, the balance between androgens and estrogens could be crucial in the onset of metabolic syndrome, even in children and adolescents [31, 32]. The diverse influence of gender on MetS during childhood suggests that a polygenic contribution is likely significant, in addition to hormonal factors [9]. During puberty, there was an increase in the number of metabolic syndrome components observed in the population, with varying percentages noted during early and late/post-pubertal stages [9]. This highlights a heightened risk for persistence of MetS into adulthood and emphasizes the importance of promptly identifying and treating metabolic complications in pediatric obesity for both the current and future health of the child [5, 6]. Almost all studies on the issue under discussion were conducted in the developed world. Thus, there is paucity of information on the relationship between anthropometric indices and other components of MetS among Sub-Saharan Black African adolescents relative to sex differentiation. Hence, the aims of the current study were to investigate the gender-based associations between specific anthropometric indices such as Body Mass Index percentile by age and Waist circumference and components of metabolic syndrome in these adolescents.

## Materials and Methods

This was a cross-sectional, descriptive study conducted in Lagos City which has the largest population density in Nigeria, is divided into 3 Senatorial Districts and 20 Local Government Areas and located on the Southwest corner of the country, after approval from the Ethics Committee of the Nigerian Institute of Medical Research (NIMR IRB (IRB/18/062). The study, which was conducted according to the Declaration of Helsinki (2000), took place over a 6-month period from October 2019 to March 20202 after both written signed informed consent and verbal assent were given correspondingly by parents and each of the 624 enrolled participants, consisting of boys and girls aged 10-19 years. Relevant data on socio-demographic and economic characteristics were gathered from both parents and participating students and information about their dietary pattern and clinical factors were collected using a structured questionnaire during face-to-face interviews. Five milliliters of the fasting venous blood sample were collected for serum glucose and lipid profile analysis. Blood pressure, weight, height, neck, hip, and waist circumferences were measured.

The *sample size* and *sampling technique* had been extensively described in an earlier publication [33]. Briefly, the sample size was designed for a specific population with 95% confidence interval [25], 54% proportion, a margin of error 5%, and allowing for 12% non-response. To ensure that results of the study are representative of all Nigerian ethnic groups resident in Lagos State, the sample size arrived at was 650 students to cater for attrition. Participants were recruited using simple random sampling, probability proportional to size and systematic sampling technique.

*Inclusion and exclusion criteria*: These have also been earlier described (33). In brief, the main inclusion criteria involved that the participant should be resident in community of study for at least 2 years, be within the age bracket of 10-19 years, be an indigenous Nigerian, a regular student at selected secondary school, has parental approval, and gives consent. The core exclusion criteria were those on therapeutic diet or drugs, participants who were on admissions to a health facility 6 months prior to the study, those taking lipid-lowering medications, or with a history of vascular/liver/renal or other continuing illness. Further, being pregnant, suspicion of pregnancy, breastfeeding, or use of oral contraceptive were also regarded as exclusion criteria.

### *Data collection*

This part of the study has also been extensively described earlier (33). Briefly, pertinent data on the socio-demographic and economic characteristics of study participant were collected using a semi-structured questionnaire instrument. Appropriate anthropometric measurements, including body weight in kilograms, height, waist, and hip circumferences in centimeters, were evaluated by trained field workers as earlier pronounced (33). Blood pressure of each student was taken from the upper left arm, after 30 min sitting, with an aneroid sphygmomanometer for a very thin hand {SURGILAC CE 123-HS-20C. [Germany]}, automatic blood pressure monitor for moderate hand {Medical Instrument WUXI, Ltd, EN-BL-8030 [China]} or a mercury sphygmomanometer (long cuff Medical Instrument WUXI, Ltd, EN-BL-8030 [China]} machine for a very big hand). The average of the three measurements was used.

*Blood collection*: From each consenting participant, a total of 5 ml of fasting venous blood was withdrawn from ante cubital fossa of the left hand and placed into fluoride oxalate tubes for the determination of fasting blood glucose and into Lithium heparin bottles for fasting blood lipid analysis. The blood samples in each bottle were preserved at -20°C during cold-chain transportation to Nigerian Institute of Medical Research, prior to centrifuging, for the production of plasma. Randox Glucose-PAP (Randox Laboratories, UK) reagent was used for analyzing FPG and lipid profile (total cholesterol, HDL, low-density lipoprotein (LDL) and triglycerides) were measured using a photo spectrometric analyzer (BioSystems EN ISO 13485 and EN ISO 9001 standards (Barcelona, Spain).

*Definitions* For the purpose of this paper,; BMI-for-age percentile was stratified into lean (<85$^{th}$ percentile) and overweight/obese (≥ 85$^{th}$ percentile). Variables were coded accordingly for ease of statistical analysis. Acceptable, borderline and high cut-off points (mg/dl) were <90, 90-129 and ≥130 for triglycerides, <170, 170-199 and ≥200 for total cholesterol, <110, 110-129 and ≥130 for low density lipoprotein-C and >45, 40-45 and <40 for high density lipoprotein-C. The World Health Organization cut-off points for FBG among adolescents was applied: low FBG=<70 mg/dL, normal FBG=70-100 mg/dL; Impaired FBG=>100-125 mg/dL and diabetic=>125 mg/dL [34]. Systolic and diastolic hypertension of the study subjects were defined as BP (mm Hg) >95$^{th}$ percentile for age, sex and height and for pre-hypertension was defined as BP (mm Hg) between 90$^{th}$ and 95$^{th}$ percentile [35].

## Results

As noted in an earlier paper [36], there was no significant difference in the means of age, weight and height or systolic blood pressure among the male and female study participating secondary school students.

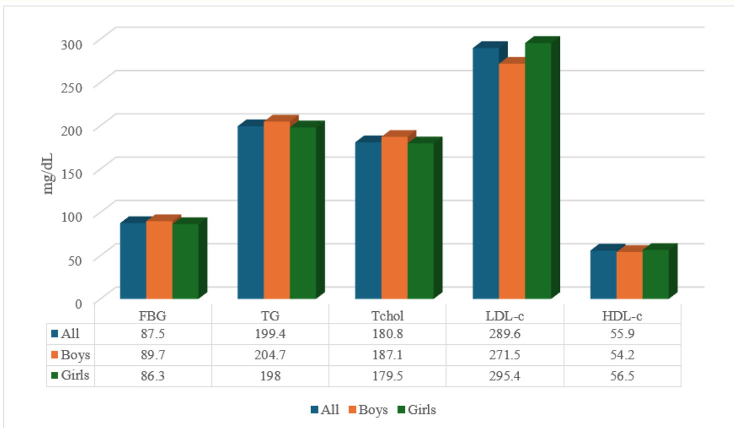
*Mean and frequency distribution of categorical components of MetS among boys and girls with and without MetS Table 1, Figure 1.*

| ***Criteria for Mets*** | ***Category*** | ***All (n=624, 100.0%)*** | | ***Metabolic syndrome*** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ***<90th percentile (n=572)*** | | | | ***≥90th percentile (n=52)*** | | | | ***<90th percentile*** | ***≥90th percentile*** | ***Mets < 90th / ≥90th percentile*** | |
| | | | | ***Gender*** | | | | | | | | ***Boys vs Girls*** | ***Boys vs Girls*** | ***Boys vs Boys*** | ***Girls vs Girls*** |
| | | | | ***Boys*** | | ***Girls*** | | ***Boys*** | | ***Girls*** | | | | | |
| | | ***Freq. (%)*** | ***Mean (±sd)*** | ***Freq. (%)*** | ***Mean (±sd)*** | ***Freq. (%)*** | ***Mean (±sd)*** | ***Freq. (%)*** | ***Mean (±sd)*** | ***Freq. (%)*** | ***Mean (±sd)*** | ***t-test (P-value)*** | | | |
| SBP (mm Hg) | All | - | 108.3 (12.4) | 207 (36.2) | 107.9 (13.9) | 365 (63.8) | 107.8 (11.4) | 34 (65.4) | 112.4 (12.9) | 18 (34.6) | 115.8 (8.3) | 0.09 (0.93) | -1.15 (0.26) | -1.86 (0.07) | -3.91 (0.0009) |
| | Low | 41 (6.6) | 83.9 (5.1) | 22 (10.6) | 84.7 (4.4) | 18 (4.9) | 82.6 (5.7) | 1 (2.9) | 89.0 (0.0) | 0 (0.0) | 0.0 (0.0) | 1.28 (0.21) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) |
| | Normal | 472 (75.6) | 106.2 (7.7) | 139 (67.2) | 105.3 (7.9) | 296 (81.1) | 106.3 (7.6) | 23 (67.6) | 106.5 (7.8) | 14 (77.8) | 112.3 (5.2) | -1.25 (0.21) | -2.71 (0.01) | -0.68 (0.50) | -4.11 (0.0008) |
| | Elevated | 84 (13.5) | 123.9 (2.9) | 34 (16.4) | 124.4 (2.8) | 43 (11.8) | 123.5 (3.0) | 5 (14.7) | 124.2 (3.5) | 2 (11.1) | 125.0 (4.2) | 1.36 (0.18) | -0.24 (0.84) | 0.12 (0.91) | -0.50 (0.70) |
| | Stage 1 | 24 (3.5) | 132.9 (2.0) | 10 (4.8) | 133.3 (1.9) | 7 (1.9) | 133.1 (2.5) | 5 (14.7) | 132.6 (1.8) | 2 (11.1) | 131.0 (1.4) | 0.18 (0.86) | 1.25 (0.31) | 0.70 (0.50) | 1.53 (0.22) |
| | Stage 2 | 3 (0.5) | 147.3 (9.3) | 2 (1.0) | 142.0 (1.4) | 1 (0.3) | 158.0 (0.0) | 0 (0.0) | 0.0 (0.0) | 0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) |
| | $\chi^2$ (P-value) / OR (95% CI) | | | | | | | | | | | 6.37 (0.01) / 1.76 (1.13, 2.74) | 2.18 (0.14) / 3.33 (0.64, 17.25) | 0.84 (0.36) / 1.45 (0.65, 3.27) | 0.95 (0.33) / 1.76 (0.56, 5.56) |
| DBP (mm Hg) | All | - | 66.2 (9.5) | 207 (36.2) | 64.7 (10.3) | 365 (63.8) | 66.8 (8.9) | 34 (65.4) | 67.4 (10.1) | 18 (34.6) | 69.5 (10.2) | -2.46 (0.01) | -0.71 (0.48) | -1.44 (0.16) | -1.10 (0.28) |
| | Low | 299 (47.9) | 58.4 (5.6) | 116 (56.0) | 57.5 (6.0) | 163 (44.7) | 59.0 (5.4) | 13 (38.2) | 57.7 (4.6) | 7 (38.9) | 60.4 (3.6) | -2.14 (0.03) | -1.45 (0.17) | -0.14 (0.89) | -0.98 (0.36) |
| | Normal | 278 (44.6) | 71.4 (3.7) | 75 (36.2) | 71.3 (3.9) | 178 (48.8) | 71.6 (3.7) | 17 (50.0) | 70.4 (3.0) | 8 (44.4) | 71.1 (3.9) | -0.57 (0.57) | -0.45 (0.66) | 1.05 (0.30) | 0.36 (0.73) |
| | Elevated | 39 (6.2) | 83.3 (2.9) | 13 (6.3) | 84.1 (3.4) | 21 (5.7) | 83.0 (2.7) | 3 (8.8) | 83.3 (3.1) | 2 (11.1) | 81.5 (0.7) | 0.99 (0.33) | 0.97 (0.42) | 0.40 (0.72) | 1.95 (0.11) |
| | Stage 1 | 8 (1.3) | 93.6 (3.4) | 3 (1.5) | 91.7 (1.2) | 3 (0.8) | 94.0 (5.3) | 1 (3.0) | 96.0 (0.0) | 1 (5.6) | 96.0 (0.0) | -0.73 (0.53) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) |
| | $\chi^2$ (P-value) / OR (95% CI) | | | | | | | | | | | 0.27 (0.60) / 1.19 (0.62, 2.30) | 0.24 (0.62) / 0.67 (0.13, 3.37) | 0.62 (0.43) / 1.59 (0.50, 5.08) | 2.66 (0.10) / 2.84 (0.77, 10.50) |
| | | Median | | Freq. (%) | Median | Freq. (%) | Median | Freq. (%) | Median | Freq. (%) | Median | Mann-Whitney U-test (P-value) | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FBG (mg/dL) | All | - | 87.5 | 207 (36.2) | 86.4 | 365 (63.8) | 83.7 | 34 (65.4) | 111.9 | 18 (34.6) | 120.7 | -0.32 (0.75) | 0.87 (0.39) | 5.69 (<0.000001) | 4.69 (<0.000001) |
| | Low | 88 (14.1) | 28.9 | 64 (30.9) | 51.4 | 129 (35.3) | 53.6 | 4 (11.8) | 64.5 | 1 (5.6) | 66.3 | 0.29 (0.77) | 0.00 (1.00) | 1.75 (0.08) | 1.39 (0.17) |
| | Normal | 344 (55.1) | 79.6 | 97 (46.9) | 88.9 | 129 (35.3) | 86.9 | 4 (11.8) | 89.8 | 4 (22.2) | 96.5 | 0.93 (0.35) | -1.44 (0.15) | 0.18 (0.85) | 2.12 (0.03) |
| | Impaired | 120 (19.2) | 109.9 | 34 (16.4) | 107.3 | 66 (18.1) | 110.1 | 14 (41.2) | 110.8 | 5 (27.8) | 113.6 | 0.57 (0.57) | 1.02 (0.31) | 0.73 (0.47) | 1.17 (0.24) |
| | Diabetic | 72 (11.5) | 149.4 | 12 (5.8) | 138.5 | 41 (11.2) | 137.8 | 12 (35.2) | 198.5 | 8 (44.4) | 229.4 | -0.54 (0.59) | 0.77 (0.44) | -3.70 (0.00005) | 3.25 (0.001) |
| | χ² (P-value) / OR (95% CI) | | | | | | | | | | | 3.39 (0.07) / 0.69 (0.46, 1.03) | 0.11 (0.74) / 1.25 (0.34, 4.58) | 40.85 (<000001) / 11.37 (4.86, 26.81) | 14.64 (0.0001) / 6.27 (2.18, 18.02) |
| TG (mg/dL) | All | - | 199.4 | 207 (36.2) | 214.5 | 365 (63.8) | 199.4 | 34 (65.4) | 165.7 | 18 (34.6) | 161.4 | 1.23 (0.22) | 0.14 (0.89) | -2.48 (0.013) | -1.58 (0.11) |
| | Low | 174 (27.9) | 119.7 | 51 (24.6) | 117.9 | 104 (28.5) | 119.1 | 12 (35.3) | 129.0 | 7 (38.9) | 133.8 | -0.81 (0.42) | 0.34 (0.74) | 0.68 (0.49) | 0.57 (0.57) |
| | Acceptable | 72 (11.5) | 172.4 | 23 (11.1) | 168.0 | 36 (9.9) | 173.5 | 12 (35.3) | 170.3 | 1 (5.6) | 131.6 | -1.63 (0.10) | -1.07 (0.28) | 0.00 (1.00) | -1.69 (0.09) |
| | High | 378 (60.6) | 239.5 | 133 (64.3) | 248.3 | 225 (61.6) | 234.4 | 10 (29.4) | 270.0 | 10 (55.6) | 213.4 | 1.59 (0.11) | 1.70 (0.09) | 0.53 (0.59) | -1.70 (0.09) |
| | χ² (P-value) / OR (95% CI) | | | | | | | | | | | 0.38 (0.54) / 1.12 (0.78, 1.59) | 3.33 (0.07) / 0.33 (0.10, 1.09) | 11.63 (0.0001) / 0.23 (0.11, 0.51) | 0.27 (0.60) / 0.78 (0.30 (2.02) |
| T-Chol (mg/dL) | All | - | 180.8 | 207 (36.2) | 177.6 | 365 (63.8) | 176.5 | 34 (65.4) | 247.7 | 18 (34.6) | 234.1 | 1.23 (0.22) | 0.14 (0.89) | -2.49 (0.01) | -1.57 (0.11) |
| | Low | 15 (2.4) | 25.6 | 6 (2.9) | 20.7 | 8 (2.2) | 20.1 | 1 (3.0) | 25.0 | 0 (0.0) | 0.0 | 1.16 (0.28) | 0.00 (0.00) | 0.00 (1.00) | 0.00 (0.00) |
| | Acceptable | 193 (30.9) | 105.8 | 72 (34.8) | 103.6 | 113 (31.0) | 107.6 | 6 (17.6) | 128.1 | 2 (11.1) | 72.1 | -0.48 (0.063) | -0.67 (0.50) | 0.06 (0.96) | -0.77 (0.44) |
| | High | 416 (66.7) | 223.4 | 129 (62.3) | 228.3 | 244 (66.8) | 216.3 | 27 (79.4) | 295.5 | 16 (88.9) | 268.3 | 2.04 (0.04) | 0.54 (0.59) | -3.18 (0.001) | -1.63 (0.10) |
| | χ² (P-value) / OR (95% CI) | | | | | | | | | | | 1.19 (0.27) / 0.82 (0.57, 1.17) | 0.72 (0.39) / 0.48 (0.09, 2.61) | 3.72 (0.05) / 2.33 (0.97, 5.61) | 3.81 (0.05) / 3.97 (0.90, 17.53) |
| LDL (mg/dL) | All | - | 289.6 | 207 (36.2) | 250.1 | 365 (63.8) | 294.5 | 34 (65.4) | 333.1 | 18 (34.6) | 298.6 | -3.73 (0.0002) | -1.45 (0.015) | 2.63 (0.009) | -0.31 (0.75) |
| | Low | 46 (7.4) | 40.4 | 20 (9.7) | 48.2 | 22 (6.0) | 39.9 | 1 (2.9) | 16.5 | 3 (16.7) | 36.4 | 0.23 (0.82) | -0.45 (0.65) | -1.49 (0.14) | 0.04 (0.97) |
| | Acceptable | 1 (0.2) | 87.8 | 1 (0.5) | 87.8 | 0 (0.0) | 0.0 | 0 (0.0) | 0 | 0 (0.0) | 0 | - | - | - | - |
| | High | 577 (92.5) | 298.7 | 186 (89.8) | 273.1 | 343 (94.0) | 301.4 | 33 (97.1) | 333.3 | 15 (83.3) | 318.5 | -3.30 (0.001) | -0.76 (0.45) | 2.23 (0.03) | 0.52 (0.60) |
| | χ² (P-value) / OR (95% CI) | | | | | | | | | | | 3.22 (0.07) / 0.57 (0.30, 1.06) | 3.06 (0.08) / 6.60 (0.63, 68.80) | 1.83 (0.18) / 3.73 (0.48, 28.65) | 3.17 (0.07) / 0.32 (0.09, 1.19) |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HDL (mg/dL) | All | - | 55.9 | 207 (36.2) | 58.3 | 365 (63.8) | 57.8 | 34 (65.4) | 35.1 | 18 (34.6) | 35.8 | 0.76 (0.45) | 0.11 (0.92) | -5.63 (<0.00001) | -3.93 (0.00009) |
| | Low | 268 (43.0) | 36.6 | 78 (38.6) | 35.6 | 151 (41.4) | 39.9 | 25 (73.5) | 25.4 | 14 (77.8) | 25.0 | -1.15 (0.25) | 0.03 (0.98) | -2.81 (0.005) | -2.32 (0.02) |
| | Acceptable | 2 (0.3) | 53.3 | 0 (0.0) | 0.0 | 1 (0.3) | 53.2 | 1 (3.0) | 53.5 | 0 (0.0) | 0.0 | - | - | - | - |
| | High | 354 (56.7) | 73.8 | 129 (61.4) | 76.5 | 213 (58.3) | 73.7 | 8 (23.5) | 54.7 | 4 (22.2) | 56.8 | 0.39 (0.70) | 1.62 (0.11) | -3.25 (0.001) | -1.62 (0.11) |
| | *$\chi^2$ (P-value) / OR (95% CI) | | | | | | | | | | | 0.75 (0.39) / 0.86 (0.60, 1.22) | 0.00 (1.00) / 0.79 (0.21, 3.05) | 15.27 (0.00009) / 4.59 (2.03, 10.35) | 9.25 (0.002) / 4.96 (1.60, 15.36) |

***Table 1:*** Median, Mean and frequency distribution of categorical components of MetS among boys and girls with and without metabolic syndrome.




Mann-Whitney U-test (P-value) of median values of FBG, TG, T-Chol, LDLc and HDL-c between boys and girls were 0.66 (0.51), 0.69 (0.49), 0.84 (0.40), 3.03 (0.002) and -0.58 (0.56) respectively. Significant difference was observed only in the different values of LDL-c among boys and girls in the study.

***Figure 1:*** Median values of biochemical components of Metabolic Syndrome among all study participants segregated by sex.

The categories of SBP, DBP, FBG, TG, T-Chol, LDL and HDL are illustrated in Table 1. The prevalence of systolic hypertension, (elevated: n=5, 14.7%; Stage 1: n=5, 14.7%: Stage 2: n=0, 0.0%) was higher among MetS-positive (29.4%) than among MetS-negative (22.2%) boys (elevated: n=34, 16.4%; Stage 1: n=10, 4.8%; Stage 2: n=2, 1.0%). Among MetS-positive girls, the prevalence of systolic hypertension, (elevated: n=2, 11.1%; Stage 1: n=2, 11.1%; Stage 2: n=0, 0.0%) was 22.2% compared to MetS-negative girls in which the prevalence (elevated: n=43, 11.8%; Stage 1: n=7, 1.9%; Stage 2: n=1, 0.3%) was 14.0%. Overall, the mean (±SD) SBP (mm Hg) of MetS-positive (115.8±8.3) and MetS-negative (107.8±11.4) girls were notably different (t-test=-3.91, P-value=0.0009). Boys with high SBP were about 1½ more likely ($\chi^2$=0.84, P-value=0.36, OR=1.45, 95% CI=0.65. 3.27) to present with the syndrome than those with normal SBP and girls with high SBP were approximately twice as likely to have MetS than those with normal SBP ($\chi^2$=0.95, P-value=0.33, OR=1.76, 95% CI=0.56. 5.56). In the same manner, the prevalence of diastolic hypertension was higher among girls with (16.9%) than without (6.6%) and among boys with (11.8%) than without (7.7%) MetS. Boys with high DBP were over 1½ more likely to present with MetS compared to boys with normal DBP ($\chi^2$=0.62, P-value=0.43, OR=1.59, 95% CI=0.50. 5.08) while girls with high DBP were approximately thrice as likely to have MetS than those with normal DBP ($\chi^2$=2.66, P-value=0.10, OR=2.84, 95% CI=0.77. 10.50). The prevalence of impaired and diabetic FBG was higher among MetS-positive boys (76.5%) and girls (72.2%) than among MetS-negative boys (22.2%) and girls (29.3%). Boys with impaired and diabetic FBG, were over 11 times more likely to be MetS-positive ($\chi^2$=40.85, P-value<0.000001. OR=11.4, 95% CI=4.86. 26.81) than boys without the syndrome while girls with it were over 6 times as likely to be

MetS-positive compared with those without the syndrome ($\chi^2$=14.64, P-value=0.0001, OR=6.27, 95% CI=2.18. 18.02). The prevalence of hyper-triglyceride was higher (55.6%) among MetS-positive girls than among their male counterparts (29.4%). The Table also shows a significant variation (Mann-U-test=-2.49, P-value=0.01) in the frequency of T-Chol among boys with (65.4%) than those without (36.2%) MetS. The prevalence of high T-Chol was significantly higher (Mann-U-test=-3.18, P-value=0.001) in boys with (79.4%) than those without (62.3%) the syndrome. MetS-positive girls had a higher prevalence of T-Chol (88.9%) than girls (66.8%) without or even boys (79.4%) with the syndrome. Among those with high level of T-Chol, girls were approximately four times more likely to suffer from the syndrome ($\chi^2$=3.81, P-value=0.05, OR=3.97, 95% CI=0.90. 17.53), and boys were about 2½ times more likely to suffer from it ($\chi^2$=3.72, P-value=0.05, OR=2.33, 95% CI=0.97. 5.61) than those with normal T-Chol levels. The prevalence of elevated LDL level was higher among MetS-positive (97.1%) than MetS-negative boys (89.8%) but was higher among MetS-negative (94.0%) than MetS-positive (83.3%) girls. Further boys with high LDL were about 4 times as likely to suffer from the syndrome compared to boys with normal LDL level ($\chi^2$=1.83, P-value=0.18, OR=3.73, 95% CI=0.48. 28.65).The mean LDL-c (mg/dL) was significantly higher (Mann-Whitney U-test = 2.63; P-value = 0.009) among boys with (333.1) compared to boys without (250.1) but not among girls with (298.6) compared to girls without (294.5) the syndrome. The prevalence of low HDL level was most apparent also in MetS-positive (73.5%) than MetS-negative (38.6%) boys and much more so in MetS-positive (77.8%) than MetS-negative (41.4%) girls. Among those with low concentration of HDL, the odds of being afflicted with the syndrome was 4.59 among boys ($\chi^2$=15.27, P-value=0.00009), OR=4.59, 95% CI=2.03, 10.35) and approximately 5.0 among girls ($\chi^2$=9.25, P-value=0.002, OR=4.96, 95% CI=1.60. 15.36). Thus, among boys, impaired and diabetic FBG was the dominant likelihood of MetS (OR=11.37) followed by low HDL (OR=4.59), LDL (OR=3.73), T-Chol (OR=2.33), Diastolic hypertension (OR=1.59), Systolic hypertension (OR=1.45) and TG (OR=0.23). Among girls however, impaired and diabetic FBG was also the dominant likelihood of MetS (OR=6.27) followed by low HDL (OR=4.96), T-Chol (OR=3.97), Diastolic hypertension (OR=2.84), Systolic hypertension (OR=1.76), TG (OR=0.78) and LDL (OR=0.32).

*Descriptive statistics of BMI-for-age percentile and waist circumference of boys and girls relative to component of MetS Table 2.*

| Components of MetS | Category | Boys | | | Girls | | | Boys | | | Girls | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MetS<90th percentile | | | | | | MetS≥90th percentile | | | | | | MetS<90th vs MetS≥90th percentile | | | |
| | | | | | | | | | | | | | | BMI-for-age pctl | | WC (cm) | |
| | | Freq. (%) | BMI-for-age pctl. | WC (cm) | Freq. (%) | BMI-for-age pctl. | WC (cm) | Freq. (%) | BMI-for-age pctl. | WC (cm) | Freq. (%) | BMI-for-age pctl. | WC (cm) | Boys vs Boys | Girls vs Girls | Boys vs Boys | Girls vs Girls |
| | | | Median | | | Median | | | Median | | | Median | | Mann-Whitney U-test (P-value) | | | |
| | All | 207 (36.2) | 23.8 | 64.0 | 365 (63.8) | 34.3 | 64.8 | 34 (65.4) | 44.2 | 66.0 | 18 (34.6) | 82.9 | 71.0 | -2.92 (0.003) | 4.43 (0.00001) | 1.99 (0.046) | 3.66 (0.0003) |
| SBP | Low | 22 (10.6) | 2.4 | 58 | 18 (4.9) | 14.6 | 58.3 | 1 (2.9) | 95.5 | 62.0 | 0 (0.0) | 0 | 0 | 1.67 (0.10) | - | 1.07 (0.28) | - |
| | Normal | 139 (67.2) | 23.0 | 63.5 | 296 (73.7) | 33.6 | 64.0 | 23 (67.6) | 31.0 | 66.0 | 14 (77.8) | 82.9 | 71.0 | 1.60 (0.11) | 4.15 (0.00003) | 0.80 (0.42) | 3.29 (0.001) |
| | Elevated | 34 (16.4) | 35.3 | 68.5 | 43 (11.8) | 56.6 | 69.0 | 5 (14.7) | 70.9 | 72.0 | 2 (11.1) | 49.3 | 66.5 | 1.55 (0.12) | -0.28 (0.78) | 1.30 (0.19) | -0.50 (0.62) |
| | Stage 1 | 10 (4.8) | 50.8 | 69.0 | 7 (1.9) | 82.8 | 72.0 | 5 (14.7) | 67.3 | 71.0 | 2 (11.1) | 92.9 | 79.5 | 0.74 (0.46) | 1.17 (0.24) | 0.37 (0.71) | 0.74 (0.46) |
| | Stage 2 | 2 (1.0) | 45.5 | 64.5 | 1 (0.3) | 8.8 | 60.0 | 0 (0.0) | 0.0 | 0.0 | 0 (0.0) | 0.0 | 0.0 | - | - | - | - |
| DBP | Low | 116 (56.0) | 20.4 | 62.0 | 163 (44.7) | 25.8 | 63.0 | 13 (38.2) | 26.1 | 65.0 | 7 (38.9) | 53.8 | 70.0 | 1.62 (0.11) | 2.88 (0.004) | 1.17 (0.24) | 3.41 (0.0001) |
| | Normal | 75 (36.2) | 35.6 | 67.0 | 178 (48.8) | 38.5 | 66.0 | 17 (50.0) | 42.6 | 66.0 | 8 (44.4) | 91.0 | 75.0 | 0.90 (0.37) | 3.35 (0.0008) | 0.07 (0.95) | 1.99 (0.047) |
| | Elevated | 13 (6.3) | 42.1 | 67.0 | 21 (5.7) | 58.6 | 70.9 | 3 (8.8) | 92.6 | 73.0 | 2 (11.1) | 60.4 | 74.0 | 2.09 (0.04) | 0.55 (0.59) | 1.75 (0.08) | 0.00 (1.00) |
| | Stage 1 | 3 (1.5) | 19.4 | 65.0 | 3 (0.8) | 41.0 | 66.0 | 1 (2.9) | 93.4 | 67.0 | 1 (5.6) | 85.9 | 72.0 | 1.34 (0.18) | 1.34 (0.18) | 0.45 (0.65) | 1.34 (0.18) |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FBS | Low | 29 (14.0) | 37.8 | 64.0 | 58 (15.6) | 32.1 | .64.5 | 1 (2.9) | 67.3 | 71.0 | 0 (0.0) | 0.0 | 0.0 | 0.98 (0.33) | - | 1.56 (0.12) | - |
| | Normal | 132 (63.8) | 24.6 | 64.4 | 200 (54.8) | 34.1 | 65.0 | 7 (20.6) | 80.7 | 69.0 | 5 (27.8) | 96.6 | 81.0 | 2.37 (0.02) | 3.01 (0.003) | 1.17 (0.24) | 3.04 (0.002) |
| | Im-paired | 34 (16.4) | 7.0 | 62.0 | 67 (18.4) | 37.3 | 65.0 | 14 (41.2) | 47.3 | 67.5 | 5 (27.8) | 85.9 | 76.0 | 3.36 0.0008) | 3.16 (0.002) | 2.99 (0.003) | 2.33 (0.02) |
| | Diabetic | 12 (5.8) | 19.1 | 63.0 | 40 (11.1) | 32.7 | 64.0 | 12 (35.3) | 11.7 | 62.5 | 8 (44.4) | 49.3 | 68.0 | -0.69 (0.49) | 1.33 (0.18) | -0.03 (0.98) | 1.44 (0.15) |
| TG | Low | 51 (24.6) | 26.8 | 63.0 | 104 (28.5) | 30.0 | 64.0 | 12 (35.3) | 64.5 | 71.5 | 7 (38.9) | 79.4 | 68.0 | 2.75 (0.006) | 2.74 (0.006) | 2.31 (0.02) | 1.15 (0.25) |
| | Ade-quate | 23 (11.1) | 28.8 | 66.0 | 36 (9.9) | 25.0 | 63.0 | 12 (35.3) | 41.2 | 66.0 | 1 (5.6) | 50.2 | 67.0 | 1.37 (0.17) | 0.75 (0.45) | 0.31 (0.75) | 1.08 (0.28) |
| | High | 133 (64.3) | 22.5 | 64.0 | 225 (61.6) | 37.1 | 65.0 | 10 (29.4) | 16.1 | 64.0 | 10 (55.5) | 97.7 | 75.5 | 0.31 (0.75) | 3.53 (0.0004) | -0.32 (0.75) | 3.70 (0.0002) |
| T-Chol | Low | 6 9 (2.9) | 18.7 | 62.0 | 8 (2.2) | 43.6 | 61.0 | 1 (2.9) | 63.7 | 63.0 | 0 (0.0) | 0.0 | 0.0 | 1.00 (0.32) | - | 1.05 (0.29) | - |
| | Ade-quate | 72 (34.8) | 26.1 | 65.0 | 113 (31.0) | 34.3 | 65.0 | 6 (17.7) | 18.6 | 65.0 | 2 (11.1) | 72.0 | 72.5 | 0.00 (1.00) | 1.45 (0.15) | -0.01 (0.99) | 0.34 (0.73) |
| | High | 129 (62.3) | 23.0 | 64.0 | 244 (66.8) | 34.1 | 65.0 | 27 (79.4) | 45.8 | 66.0 | 16 (88.9) | 82.9 | 71.0 | 3.01 (0.003) | 4.16 (0.00003) | 2.15 (0.03) | 3.61 (0.0003) |
| LDL | Low | 20 (9.6) | 25.8 | 65.0 | 22 (6.0) | 30.6 | 64.0 | 1 (2.9) | 25.7 | 62.0 | 3 (16.7) | 80.2 | 71.0 | 0.00 (1.00) | 2.09 (0.04) | -0.75 (0.45) | 0.97 (0.33) |
| | Ade-quate | 1 (0.5) | 1.4 | 58.0 | 0 (0.0) | 0.0 | 0.0 | 0 (0.0) | 0.0 | 0.0 | 0 (0.0) | 0.0 | 0.0 | - | - | - | - |
| | High | 186 (89.9) | 23.7 | 64.0 | 343 (94.0) | 34.6 | 65.0 | 33 (97.1) | 45.8 | 66.0 | 15 (83.3) | 85.9 | 71.0 | 2.96 (0.003) | 4.00 (0.00006) | 2.10 (0.04) | 3.58 (0.0003) |
| HDL | High | 78 (37.7) | 21.5 | 62.0 | 151 (41.4) | 30.8 | 64.0 | 25 (73.6) | 61.6 | 66.0 | 14 (77.8) | 85.7 | 71.5 | 2.92 (0.003) | 4.13 (0.00004) | 2.57 (0.01) | 2.83 (0.005) |
| | Ade-quate | 0 (0.0) | 0.0 | 0.0 | 1 (0.3) | 17.3 | 74.0 | 1 (2.9) | 14.0 | 57.0 | 0 (0.0) | 0.0 | 0.0 | - | - | - | - |
| | Low | 129 (62.3) | 25.4 | 65.8 | 213 (58.3) | 33.8 | 64.0 | 8 (23.5) | 38.4 | 66.5 | 4 (22.2) | 53.9 | 69.0 | 0.95 (0.34) | 1.74 (0.08) | 0.92 (0.36) | 2.00 (0.046) |

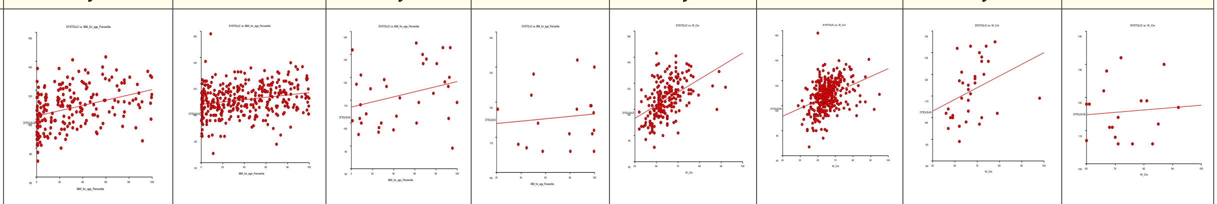
Shapiro-Wilk W Test-value=0.92; P-value <0.00001. Decision: Reject normality.

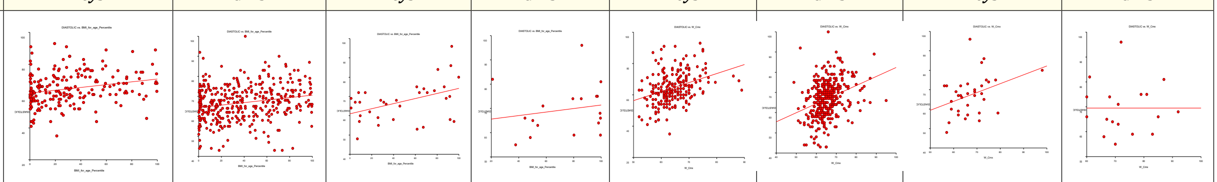
***Table 2:*** Descriptive statistics of BMI-for-age percentile and waist circumference of boys and girls in the study relative to categorical components of Metabolic syndrome.

- ***All study subjects***: In all, BMI-for-age was significantly higher (Mann-Whitney U-test= -2.92, P-value=0.003) among MetS-positive (median=44.2) compared to MetS-negative (median=23.8) boys and much more so (Mann-Whitney U-test= -4.43, P-value=0.00001) among girls with (median=82.9) compared to girls without (median=34.3) MetS. Likewise, WC was notably higher (Mann-Whitney U-test=1.99, P-value=0.046) among MetS-positive (median=66.0) than among MetS negative (median=64.0) boys and also significantly higher (Mann-Whitney U-test=3.66, P-value=0.0003) among MetS-positive (median=71.0) than among MetS negative (median=64.8) girls.
- ***BMI-for-age percentile and WC relative to different categories of SBP***: One subject, a boy with low SBP, was MetS-positive. Among girls with normal SBP, BMI-for-age was significantly higher (Mann-Whitney U-test=4.15, P-value=0.00003) among Mets-positive (median=82.9) compared to MetS-negative (median=33.6) girls. A noteworthy WC (Mann-Whitney U-test= 3.29, P-value=0.001) was also observed among Mets-positive (median=71.0) compared to MetS-negative (64.0) girls.
- ***BMI-for-age percentile and WC relative to different categories of DBP (not a component of MetS): MetS-***positive girls with low DBP had a significantly higher (Mann-Whitney U-test=4.15, P-value=0.004) BMI-for-age (median=53.8) than Mets-negative girls (median=25.8) and a significantly higher (Mann-Whitney U-test=4.15, P-value=0.004) WC (median=70.0 cm) than MetS-negative girls (median=63.0cm). Among those with elevated DBP, BMI-for-age percentile of MetS-positive boys (median=92.6) was significantly higher (Mann-Whitney U-test=2.09, P-value=0.04) than that of MetS-negative boys (median=42.1).
- ***BMI-for-age percentile and WC relative to different categories of FBG***: Discrepancies were observed in the BMI-for age per-

centile and in the WC of boys and girls with normal and impaired FBG. Among those with normal FBG, the BMI-for age (median=80.7) in MetS-positive boys was significantly higher (Mann-Whitney U-test=2.37, P-value=0.02) than that among MetS-negative boys (median=24.6) and the BMI-for age (median=96.6) in MetS-positive girls was also significantly higher (Mann-Whitney U-test=, P-value=0.02 and among girls with (median=96.6 cm) than girls without (34.1 cm) MetS. Statistically significant difference (Mann-Whitney U-test=3.04, P-value=0.002) in WC was observed only among girls with MetS (median=81.0 cm) compared to girls without MetS (65.0 cm). Among those with impaired FBG, there were notable variations (Mann-Whitney U-test=3.36, P-value=0.0008) in the BMI-for-age of MetS-positive (median=47.3) and MetS-negative (median=7.0) boys and in the BMI-for-age of MetS-positive (median=85.9) and MetS-negative (median=37.3) girls. Notable differences were also observed in the WC of MetS-positive (median=67.5 cm) and MetS-negative (median=62.0) boys (Mann-Whitney U-test=3.16, P-value=0.002), and more so in the WC of MetS-positive (median=76.0 cm) and MetS-negative (median=65.0) girls (Mann-Whitney U-test=2.33, P-value=0.02).

- ***BMI-for-age percentile and WC relative to different categories of TG, T-Chol, LDL and HDL***: At low TG level, significant variation (MWU-test = 2.75, P-value=0.006) was observed in the BMI-for-age percentile of MetS-positive (median=71.5 mg/dL) and MetS-negative boys (median=26.8 mg/dL) and similar variation for girls. Significant variation was observed in only WC for boys. At high TG level, notable variations occurred in the BMI-for-age percentile of only girls with (median=97.5) and median=37.1) and in the WC of those with (median=75.5 cm) and without (65.0 cm) MetS. At high levels of T-Chol, LGL and HDL, significant variations in BMI-for-age percentile and WC were observed among boys and girls with and without MetS.
- ***Correlation between BMI-for-age percentile, WC, SBP and DBP in boys and girls, Figures 2 a-b***

| | *Correlation between SBP and BMI-for-age percentile* | | | | *Correlation between SBP and Waist circumference (cm)* | | | |
|---|---|---|---|---|---|---|---|---|
| | *MetS<90th pctl* | | *MetS≥90th pctl* | | *MetS<90th pctl* | | *MetS≥90th pctl* | |
| | *Boys* | *Girls* | *Boys* | *Girls* | *Boys* | *Girls* | *Boys* | *Girls* |
| |  | | | | | | | |
| r | +0.37 | +0.23 | +0.29 | +0.11 | +0.49 | +0.36 | +0.34 | +0.08 |
| T-value | 5.69 | 4.45 | 1.73 | 0.42 | 7.66 | 7.33 | 2.05 | 0.33 |
| P-value | <0.00001 | <0.00001 | 0.09 | 0.68 | <0.00001 | <0.00001 | 0.049 | 0.75 |
| 95% CL | 0.25, 0.48 | 0.13, 0.32 | -0.05, 0.57 | -0.38, 0.55 | 0.36, 0.57 | 0.27, 0.46 | 0.002, 0.608 | -0.40, 0.53 |
| (a) | | | | | | | | |

| | *Correlation between DBP and BMI-for-age percentile* | | | | *Correlation between DBP and Waist circumference (cm)* | | | |
|---|---|---|---|---|---|---|---|---|
| | *MetS<90th pctl* | | *MetS≥90th pctl* | | *MetS<90th pctl* | | *MetS≥90th pctl* | |
| | *Boys* | *Girls* | *Boys* | *Girls* | *Boys* | *Girls* | *Boys* | *Girls* |
| |  | | | | | | | |
| r | +0.24 | +0.21 | +0.44 | +0.18 | +0.35 | +0.32 | +0.36 | +0.001 |
| T-value | 3.58 | 4.03 | 2.78 | 0.74 | +5.39 | 6.37 | 2.26 | 0.005 |
| P-value | 0.0004 | 0.0001 | 0.009 | 0.47 | <0.000001 | <0.000001 | 0.03 | 1.00 |
| 95% CL | 0.11, 0.37 | 0.11, 0.30 | 0.12, 0.69 | -0.31, 0.60 | 0.23, 0.47 | 0.22, 0.41 | 0.04, 0.63 | -0.47, 0.47 |
| (b) | | | | | | | | |

***Figures 2a-b:*** Scatterplot and Pearson's correlation coefficient (r) of (a) Systolic Bood Pressure (mmHg) and (b) Diastolic Blood Pressure (mm Hg) with BMI-for-age percentile and Waist circumference (cm).

The correlations between BMI-for-age and SBP among boys and girls with MetS were insignificant. However, there was marginally significant correlation (r=+0.34, T-value=2.05, P-value=0.049, 95% CI: 0.002, 0.608) between WC and SBP only among MetS-positive boys. There was a strong positive correlation (r=+0.44, T-value=2.78 P-value=0.009, 95% CI: 0.12, 0.69) between BMI-for-age percentile and DBP among MetS-positive boys and still a positive but weaker correlation (r=+0.36, T-value=2.26, P-value=0.03, 95% CI: 0.04, 0.63) between WC an DBP in the same group of boys

- ***Correlation between BMI-for-age percentile, WC and FBG in boys and girls, Figure 3.***

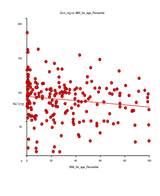
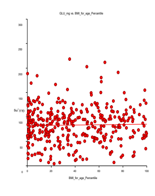
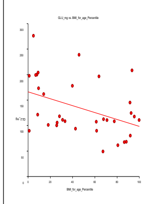
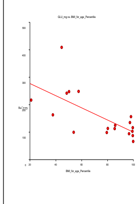
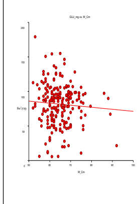
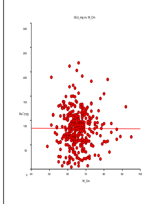
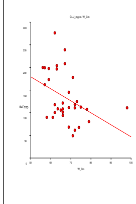
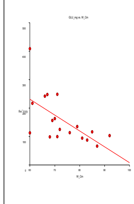
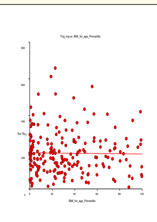
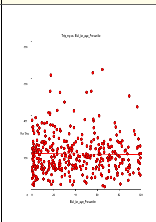
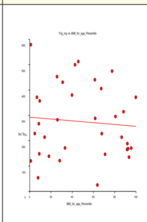
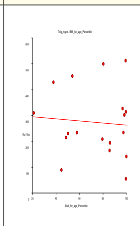
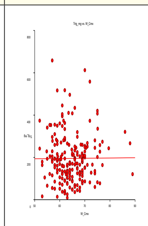
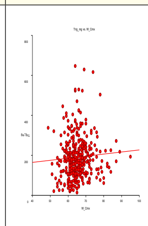
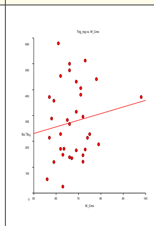
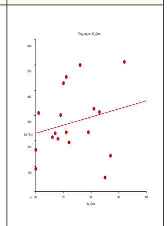
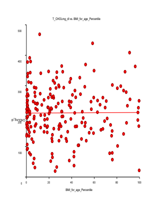
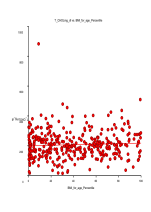
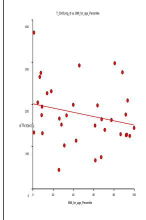
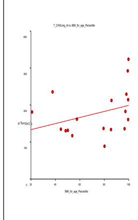
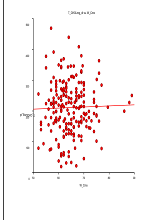
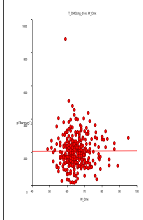
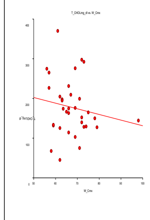
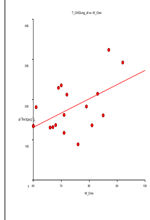
| | ***Correlation between FBS and BMI-for-age percentile*** | | | | ***Correlation between FBS and Waist circumference (cm)*** | | | |
|---|---|---|---|---|---|---|---|---|
| | ***MetS<90th pctl*** | | ***MetS≥90th pctl*** | | ***MetS<90th pctl*** | | ***MetS≥90th pctl*** | |
| | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** |
| |  |  |  |  |  |  |  |  |
| R | -0.15 | +0.03 | -0.42 | -0.67 | -0.07 | -0.004 | -0.39 | -0.62 |
| T-value | 2.18 | 0.51 | 2.61 | 3.63 | 0.94 | 0.08 | 2.40 | 3.15 |
| P-value | 0.03 | 0.61 | 0.01 | 0.002 | 0.35 | 0.94 | 0.02 | 0.006 |
| 95% CL | -0.28, -0.01 | -0.08, 0.13 | -0.66, -0.09 | -0.87, -0.30 | -0.20, 0.07 | -0.11, 0.10 | -0.64, -0.06 | -0.84, -0.21 |

***Figure 3:*** Scatterplot and Pearson's correlation coefficient of Fasting Blood Sugar (mg/dL), BMI-for-age percentile and waist circumference (cm) by sex.

A strong but negative correlation was found between BMI-for-age percentile and FBG among MetS-positive boys (r=-0.42, T-value=2.61, P-value=0.01, 95% CI: -0.66, -0.09) and still stronger but negative correlation (r=-0.67, T-value=3.63, P-value=0.002, 95% CI: -0.87, -0.30) among MetS-positive girls. Also, there was a negative relatively strong and significant correlation between WC and FBG among MetS-positive boys (r=-0.39, T-value=2.40, P-value=0.02, 95% CI: -0.64, -0.06) and still stronger, negative and significant correlation (r=-0.63, T-value=3.15, P-value=0.006, 95% CI: -0.84, -0.21) among MetS-positive girls.

- ***Correlation between BMI-for-age percentile, WC and TG and T-Chol in boys and girls, Figures 4a-b.***

| | ***Correlation between TG and BMI-for-age percentile*** | | | | ***Correlation between TG and Waist circumference (cm)*** | | | |
|---|---|---|---|---|---|---|---|---|
| | ***MetS<90th pctl*** | | ***MetS≥90th pctl*** | | ***MetS<90th pctl*** | | ***MetS≥90th pctl*** | |
| | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** |
| |  |  |  |  |  |  |  |  |
| r | -0.02 | -0.02 | -0.08 | -0.08 | +0.006 | +0.06 | +0.15 | +0.23 |
| T-value | 0.22 | 0.37 | 0.48 | 0.32 | 0.08 | 1.23 | 0.85 | 0.94 |
| P-value | 0.83 | 0.71 | 0.64 | 0.76 | 0.94 | 0.22 | 0.40 | 0.36 |
| 95% CL | -0.15, 0.12 | -0.12, 0.08 | -0.41, 0.26 | -0.53, 0.40 | -0.13, 0.14 | -0.04, 0.17 | -0.20, 0.46 | -0.27, 0.63 |
| (a) | | | | | | | | |

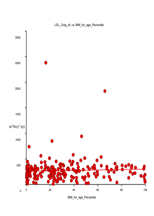
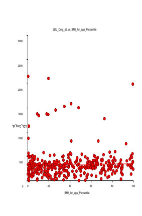
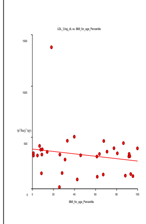
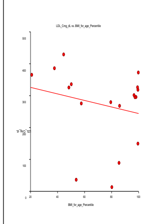
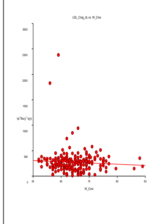
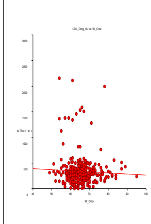
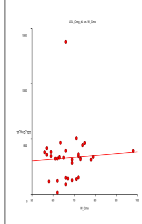
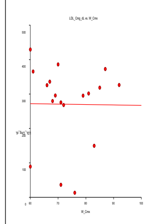
| | ***Correlation between TChol and BMI-for-age percentile*** | | | | ***Correlation between TChol and Waist circumference (cm)*** | | | |
|---|---|---|---|---|---|---|---|---|
| | ***MetS<90th pctl*** | | ***MetS≥90th pctl*** | | ***MetS<90th pctl*** | | ***MetS≥90th pctl*** | |
| | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** |
| |  |  |  |  |  |  |  |  |
| r | +0.007 | +0.06 | -0.24 | +0.24 | +0.03 | +0.002 | -0.16 | +0.54 |
| T-value | 0.10 | 1.19 | 1.39 | 1.46 | 0.38 | 0.04 | 0.94 | 2.56 |
| P-value | 0.92 | 0.23 | 0.17 | 0.16 | 0.71 | 0.97 | 0.36 | 0.02 |
| 95% CL | -0.13, 0.14 | -0.04, 0.16 | -0.53, 0.11 | -0.15, 0.70 | -0.11, 0.16 | -0.10, 0.10 | +0.48, 0.18 | 0.10, 0.80 |

(b)

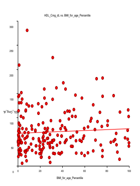
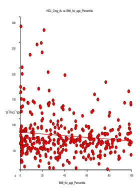
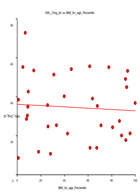
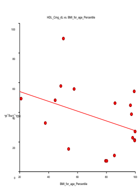
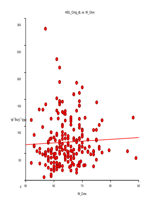
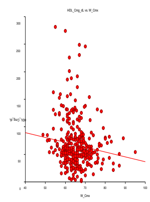
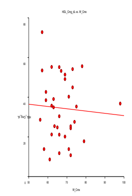
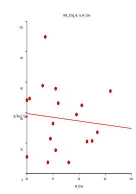
***Figures 4a-b:*** Scatterplot and Pearson's correlation coefficient of (a) TG and (b) T-Chol (mg/dL) with BMI-for-age percentile and waist circumference (cm).

As shown in Figure 3a, the correlation between BMI-for-age or WC with TG was not significant in both boys and girls with MetS Only among MetS-positive girls was there any evidence of strong, positive and significant correlation (r=+0.54, T-value=2.56, P-value=0.02, 95% CI: 0.10, 0.80) between WC and T-Chol.

- ***Correlation between BMI-for-age percentile, WC and LDL and HDL in boys and girls, Figures 5a-b.***

| | ***Correlation between LDL and BMI-for-age percentile*** | | | | ***Correlation between LDL and Waist circumference (cm)*** | | | |
|---|---|---|---|---|---|---|---|---|
| | ***MetS<90th pctl*** | | ***MetS≥90th pctl*** | | ***MetS<90th pctl*** | | ***MetS≥90th pctl*** | |
| | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** |
| |  |  |  |  |  |  |  |  |
| r | +0.05 | +0.02 | -0.18 | -0.22 | -0.07 | -0.05 | +0.06 | -0.009 |
| T-value | 0.67 | 0.40 | 0.03 | 0.92 | 0.94 | 0.91 | 0.33 | 0.04 |
| P-value | 0.50 | 0.69 | 0.31 | 0.37 | 0.35 | 0.36 | 0.74 | 0.97 |
| 95% CL | -0.09, 0.18 | -0.08, 0.12 | -0.49, 0.17 | -0.63, 0.27 | -0.20, 0.07 | -0.15, 0.06 | -0.29, 0.39 | -0.17, 0.46 |

(a)

| | ***Correlation between HDL and BMI-for-age percentile*** | | | | ***Correlation between HDL and Waist circumference (cm)*** | | | |
|---|---|---|---|---|---|---|---|---|
| | ***MetS<90th pctl*** | | ***MetS≥90th pctl*** | | ***MetS<90th pctl*** | | ***MetS≥90th pctl*** | |
| | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** | ***Boys*** | ***Girls*** |
| |  |  |  |  |  |  |  |  |
| r | +0.07 | -0.12 | -0.07 | -0.39 | 0.04 | -0.13 | -0.06 | -0.11 |
| T-value | 0.95 | 2.31 | 0.39 | 1.71 | 0.68 | 2.54 | 0.33 | 0.43 |
| P-value | 0.34 | 0.02 | 0.70 | 0.11 | 0.50 | 0.01 | 0.74 | 0.67 |
| 95% CL | -0.07, 0.20 | -0.22, -0.02 | -0.39, 0.26 | -0.73, 0.09 | -0.09, 0.18 | -0.23, -0.03 | -0.39, 0.28 | -0.55, 0.38 |
| (b) | | | | | | | | |

***Figures 5a-b:*** Scatterplot and Pearson's correlation coefficient of (a) LDL (mg/dL) and (b) HDL (mg/dL) with BMI-for-age percentile and waist circumference (cm).

There was no evidence of any significant correlation between either BMI-for-age percentile or WC with either LDL or HDL.

Table 3 presents a multivariate regression analysis between each component of MetS as dependent variable and BMI-for-age percentile and WC as predictor variables for boys. Among MetS-positive boys, BMI-for-age percentile, and WC accounted for an insignificant 13.0% variation in SBP (mm Hg) (R2=0.13, P-value=0.12), and none was a significant predictor (coef=0.05, T-stat=0.61, P-value=0.55; coef=0.41, T-stat=1.20, P-value=0.24 respectively) in the variations of SBP. The two were also not predictor variables for the variations in DBP. Incidentally, Among MetS-positive boys, both BMI and WC accounted for a significant 20.0% variations observed in the FBG (R2=0.20, F-ratio=3.94, P-value=0.03) though individually, and neither was a substantial predictor (coef=-0.47, T-stat=-1.40, P-value=0.17; 95% CI=-1.15, 0.21; coef=-1.42, T-stat=-1.02, P-value=0.31, 95% CI =-4.26, 1.41 respectively) in the variations of FBG.

| ***Predictor variables*** | ***Dependent variable=SBP*** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***MetS<90th percentile*** | | | | | ***MetS≥90th percentile*** | | | | |
| | ***$R^2$= 0.24*** | | ***F-ratio= 32.95*** | | ***P-value <0.00001*** | ***$R^2$= 0.13*** | | ***F-ratio= 2.24*** | | ***P-value= 0.12*** |
| | Regression Coefficient | Standard Error | T-Statistic to Test H0: β(i)=0 | P-value | 95% Confidence Interval | Regression Coefficient | Standard Error | T-Statistic to Test H0: β(i)=0 | P-value | 95% Confidence Interval |
| Intercept | 52.83 | 9.26 | 5.70 | <0.000001 | 34.57, 71.09 | 82.41 | 20.83 | 3.96 | 0.0004 | 39.92, 124.89 |
| BMI-for-age percentile | 0.08 | 0.04 | 2.41 | 0.017 | 0.02, 0.15 | 0.05 | 0.08 | 0.61 | 0.55 | -0.12, 0.22 |
| Waist circumference (cm) | 0.81 | 0.15 | 5.39 | <0.000001 | 0.51, 1.11 | 0.41 | 0.34 | 1.20 | 0.24 | -0.29, 1.11 |
| | Dependent variable=DBP | | | | | | | | | |
| | $R^2$= 0.12 | | F-ratio= 13.53 | | P-value<0.00001 | $R^2$= 0.21 | | F-ratio= 4.17 | | P-value= 0.02 |
| Intercept | 35.14 | 7.37 | 4.78 | <0.000001 | 20.62, 49.67 | 48.53 | 15.48 | 3.13 | 0.004 | 16.96, 80.10 |
| BMI-for-age percentile | 0.03 | 0.03 | 1.25 | 0.21 | -0.02, 0.09 | 0.10 | 0.06 | 1.65 | 0.11 | -0.02, 0.22 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Waist circumference (cm) | 0.44 | 0.12 | 3.68 | 0.0003 | 0.20, 0.68 | 0.21 | 0.25 | 0.82 | 0.42 | -0.31, 0.73 |
| | Dependent variable=FBS | | | | | | | | | |
| | $R^2$=0.02 | | F-ratio= 2.39 | | P-value =0.09 | $R^2$= 0.20 | | F-ratio=3.94 | | P-value=0.03 |
| Intercept | 81.91 | 22.61 | 3.62 | 0.0004 | 37.33, 126.49 | 251.91 | 84.88 | 2.97 | 0.006 | 78.81, 425.02 |
| BMI-for-age percentile | -0.17 | 0.09 | -1.97 | 0.05 | -0.34, 0.0003 | -0.47 | 0.33 | -1.40 | 0.17 | -1.15, 0.21 |
| Waist circumference (cm) | 0.08 | 0.37 | 0.21 | 0.94 | -0.65, 0.80 | -1.42 | 1.39 | -1.02 | 0.31 | -4.26, 1.41 |
| | Dependent variable=TG | | | | | | | | | |
| | $R^2$=0.0001 | | F-ratio= 0.014 | | P-value = 0.99 | $R^2$= 0.06 | | F-ratio= 1.01 | | P-value=0.38 |
| Intercept | 219.29 | 64.56 | 3.40 | 0.0008 | 92.00, 346.58 | 246.21 | 119.24 | 2.05 | 0.05 | 3.02, 489.40 |
| BMI-for-age percentile | 0.04 | 0.24 | 0.16 | 0.88 | -0.44, 0.52 | -0.39 | 0.47 | -0.83 | 0.41 | -1.35, 0.57 |
| Waist circumference (cm) | -0.15 | 1.04 | -0.14 | 0.89 | -2.21, 1.92 | -0.74 | 1.95 | -0.38 | 0.71 | -4.73, 3.24 |
| | Dependent variable=T-Chol | | | | | | | | | |
| | $R^2$=0.002 | | F-ratio=0.24 | | P-value =0.78 | $R^2$= 0.05 | | F-ratio=0.84 | | P-value=0.44 |
| Intercept | 255.12 | 87.82 | 2.90 | 0.004 | 81.96, 428.28 | 8.46 | 240.04 | 0.03 | 0.97 | -481.10, 498.03 |
| BMI-for-age percentile | 0.05 | 0.33 | 0.16 | 0.87 | -0.60, 0.71 | -1.06 | 0.94 | -1.13 | 0.27 | -2.99, 0.86 |
| Waist circumference (cm) | -0.95 | 1.43 | -0.66 | 0.51 | -3.76, 1.87 | 4.73 | 3.93 | 1.20 | 0.24 | -3.29, 12.75 |
| | Dependent variable= LDL | | | | | | | | | |
| | $R^2$= 0.02 | | F-ratio=1.63 | | P-value = 0.20 | $R^2$= 0.08 | | F-ratio=1.37 | | P-value=0.27 |
| Intercept | 547.13 | 172.94 | 3.16 | 0.002 | 206.15, 888.11 | -74.40 | 367.20 | -0.20 | 0.84 | -823.30, 674.50 |
| BMI-for-age percentile | 0.94 | 0.65 | 1.44 | 0.15 | -0.34, 2.23 | -2.33 | 1.44 | -1.62 | 0.12 | -5.28, 0.61 |
| Waist circumference (cm) | -4.70 | 2.81 | -1.67 | 0.10 | -10.24, 0.84 | 7.70 | 6.02 | 1.28 | 0.21 | -4.57, 19.97 |
| | Dependent variable=HDL | | | | | | | | | |
| | $R^2$= 0.005 | | F-ratio= 0.54 | | P-value = 0.58 | $R^2$= 0.008 | | F-ratio= 0.12 | | P-value= 0.88 |
| Intercept | 53.46 | 32.64 | 1.64 | 0.10 | -10.90, 117.81 | 44.60 | 27.63 | 1.61 | 0.12 | -11.75, 100.94 |
| BMI-for-age percentile | 0.07 | 0.12 | 0.58 | 0.56 | -0.17, 0.31 | -0.01 | 0.11 | -0.11 | 0.92 | -0.23, 0.21 |
| Waist circumference (cm) | 0.23 | 0.53 | 0.44 | 0.66 | -0.81, 1.28 | -0.14 | 0.45 | -0.31 | 0.76 | -1.06, 0.78 |

***Table 3:*** Multivariate regression analysis with each component of metabolic syndrome as dependent variable and BMI-for-age percentile and waist circumference as predictor variables among boys.

None of the anthropometric indices was a predictor of any of the lipids studied.

Table 4 introduces a multivariate regression analysis between each component of MetS as dependent variable and BMI-for-age percentile and WC as predictor variables for girls. Among MetS-positive girls, BMI-for-age percentile, and WC accounted for an insignificant 1.0% variation in SBP (mm Hg) (R2=0.01, F-ratio=0.08, P-value=0.92), and none was a significant predictor (coef=0.03, T-stat=0.26, P-value=0.80; coef=0.01, T-stat=0.04, F-ratio=0.97, P-value=0.97 respectively) in the variations of SBP. The two were also not predictor variables for the variations in DBP. Incidentally, both BMI and WC accounted for a significant 49.0% variations observed in the FBG (R2=0.49, F-ratio=7.29, P-value=0.006) though individually, and neither forecasted (coef=-1.54, T-stat=-1.80, P-value=0.09; 95% CI=--3.38, 0.29; coef=-2.58, T-stat=-1.10, P-value=0.29, 95% CI =-7.58, 2.43 respectively) the variations in FBG. Similarly, none of the two anthropometric indices was a predictor of any of the lipids studied among girls.

| ***Predictor variables*** | ***Dependent variable=SBP*** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***MetS<90th percentile*** | | | | | ***MetS≥90th percentile*** | | | | |
| | ***$R^2$= 0.13*** | | ***F-ratio= 27.04*** | | ***P-value <0.00001*** | ***$R^2$= 0.01*** | | ***F-ratio= 0.08*** | | ***P-value= 0.92*** |
| | ***Regression Coefficient*** | ***Standard Error*** | ***T-Statistic to Test H0: β(i)=0*** | ***P-value*** | ***95% Confidence Interval*** | ***Regression Coefficient*** | ***Standard Error*** | ***T-Statistic to Test H0: β(i)=0*** | ***P-value*** | ***95% Confidence Interval*** |
| Intercept | 68.08 | 6.43 | 10.59 | <0.00001 | 55.43, 80.72 | 112.60 | 18.36 | 6.13 | <0.00001 | 73.46, 151.74 |
| BMI-for-age percentile | 0.01 | 0.02 | 0.56 | 0.58 | -0.03, 0.06 | 0.03 | 0.12 | 0.26 | 0.80 | -0.22, 0.28 |
| Waist circumference (cm) | 0.60 | 0.10 | 5.71 | <0.00001 | 0.39, 0.80 | 0.01 | 0.32 | 0.04 | 0.97 | -0.67, 0.69 |
| | Dependent variable=DBP | | | | | | | | | |
| | $R^2$= 0.10 | | F-ratio= 15.29 | | P-value <0.00001 | $R^2$= 0.07 | | F-ratio= 0.53 | | P-value= 0.60 |
| Intercept | 40.96 | 5.12 | 8.00 | <0.00001 | 30.89, 51.02 | 79.17 | 21.96 | 3.60 | 0.003 | 32.36, 125.97 |
| BMI-for-age percentile | 0.01 | 0.02 | 0.76 | 0.45 | -0.02, 0.05 | 0.14 | 0.14 | 1.03 | 0.32 | -0.15, 0.44 |
| Waist circumference (cm) | 0.39 | 0.08 | 4.63 | <0.00001 | 0.22, 0.55 | -0.28 | 0.38 | -0.73 | 0.48 | -1.09, 0.63 |
| | Dependent variable=FBG | | | | | | | | | |
| | $R^2$= 0.001 | | F-ratio= 0.23 | | P-value = 0.80 | $R^2$= 0.49 | | F-ratio= 7.29 | | P-value= 0.006 |
| Intercept | 91.94 | 22.04 | 4.17 | <0.00001 | 48.60, 135.28 | 460.68 | 135.42 | 3.40 | 0.004 | 172.04, 749.32 |
| BMI-for-age percentile | 0.05 | 0.08 | 0.67 | 0.50 | -0.10, 0.21 | -1.54 | 0.86 | -1.80 | 0.09 | -3.38, 0.29 |
| Waist circumference (cm) | -0.16 | 0.36 | -0.45 | 0.66 | -0.87, 0.55 | -2.58 | 2.35 | -1.10 | 0.29 | -7.58, 2.43 |
| | Dependent variable=TG | | | | | | | | | |
| | $R^2$= 0.004 | | F-ratio= 0.81 | | P-value = 0.44 | $R^2$= 0.29 | | F-ratio= 3.12 | | P-value= 0.07 |
| Intercept | 223.69 | 54.33 | 4.12 | <0.00001 | 116.84, 330.53 | -95.25 | 117.04 | -0.81 | 0.43 | -344.70, 154.21 |
| BMI-for-age percentile | 0.24 | 0.19 | 1.24 | 0.22 | -0.14, 0.62 | -0.19 | 0.74 | -0.26 | 0.80 | -1.77, 1.39 |
| Waist circumference (cm) | -0.40 | 0.89 | -0.45 | 0.65 | -2.14, 1.34 | 3.93 | 2.03 | 1.93 | 0.07 | -0.40, 8.26 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dependent variable=T-Chol | | | | | | | | | |
| | $R^2$= 0.006 | | F-ratio= 1.10 | | P-value = 0.33 | $R^2$= 0.17 | | F-ratio= 1.54 | | P-value= 0.26 |
| Intercept | 104.75 | 62.49 | 1.68 | 0.09 | -18015, 227.64 | -132.49 | 269.47 | -0.49 | 0.63 | -706.85, 441.87 |
| BMI-for-age percentile | -0.25 | 0.22 | -1.13 | 0.26 | -0.69, 0.19 | -2.50 | 1.71 | -1.46 | 0.16 | -6.14, 1.15 |
| Waist circumference (cm) | 1.46 | 1.02 | 1.44 | 0.15 | -0.54, 3.47 | 8.07 | 4.68 | 1.72 | 0..10 | -1.90, 18.03 |
| | Dependent variable= LDL | | | | | | | | | |
| | $R^2$= 0.007 | | F-ratio= 1.23 | | P-value = 0.29 | $R^2$= 0.10 | | F-ratio= 0.80 | | P-value= 0.47 |
| Intercept | 579.96 | 166.32 | 3.47 | 0.0006 | 249.89, 904.04 | 141.47 | 251.90 | 0.56 | 0.58 | -395.45, 678.38 |
| BMI-for-age percentile | 0.71 | 0.29 | 1.19 | 0.23 | -0.46, 1.87 | -2.02 | 1.60 | -1.26 | 0.23 | -5.42, 1.39 |
| Waist circumference (cm) | *4.11 | 2.71 | -1.51 | 0.13 | -9.45, 1.23 | 3.80 | 4.37 | 0.87 | 0.40 | -5.52, 13.11 |
| | Dependent variable=HDL | | | | | | | | | |
| | $R^2$= 0.02 | | F-ratio= 3.26 | | P-value = 0.04 | $R^2$= 0.21 | | F-ratio= 2.05 | | P-value= 0.16 |
| Intercept | 100.42 | 24.90 | 4.03 | 0.0001 | 51.45, 149.39 | 17.65 | 42.72 | 0.41 | 0.69 | -73.42, 108.71 |
| BMI-for-age percentile | -0.11 | 0.09 | -1.28 | 0.20 | -0.29, 0.06 | -0.53 | 0.27 | -1.97 | 0.07 | *1.11, 0.04 |
| Waist circumference (cm) | -0.44 | 0.41 | -1.08 | 0.28 | -1.24, 0.36 | 0.79 | 0.74 | 1.07 | 0.30 | -0.79, 2.37 |

***Table 4:*** Multivariate regression analysis with each component of metabolic syndrome as dependent variable and BMI-for-age percentile and waist circumference as predictor variables among girls.

## Discussion

The rise of the worldwide occurrence of non-communicable diseases (NCDs) like hypertension and diabetes highlights the importance of grasping the significance of preexisting conditions, especially MetS which is considered as the primary forerunner and a major risk element for high blood pressure and diabetes [37], both of which play a significant role in global morbidity and mortality. The conventional elements of MetS include elevated SBP, impaired or diabetic FBG, high levels of TG, T-Chol, LDL and low level of HDL.

Findings in this study show that, comparing boys and girls in the category of those without the syndrome, the overall prevalence of high blood pressure (22.2% vs 14.0%) consisting of elevated systolic blood pressure (16.4% vs 11.8%), Stage 1 (4.8% vs 1.9%) and Stage 2 (1.0% vs 0.3%) hypertension respectively, was higher among boys than among girls. The average prevalence of elevated systolic BP reported here (16.4% for boys and 11.8% for girls =14.1%) is slightly higher than what Atoh et al [38] earlier reported for both boys and girls in another study conducted in the same area. In the category of those with the syndrome, boys were over three times more likely to present with high blood pressure than girls. The reason for this may be linked to sex hormones, diet or physical activities or a combination of these. For example, studies have confirmed a connection between hypertension, insulin resistance, hyperglycemia, and hyperinsulinemia [39-43] and that high level of insulin is associated with elevated concentrations of plasmatic catecholamines, irrespective of plasmatic glucose levels [44, 45]. Studies have also confirmed that the metabolism of sodium and water, triggered by insulin, during reabsorption at proximal renal tubules can result in hypertension [46]. Foods rich in fructose could also induce hypertension, as observed in animal studies [47] and hyper-activity of the sympathetic nervous system is also noted to induce hypertension in sucrose-fed mice [48, 49]. Thus, an elevated blood pressure may be a response to dietary variations that lead to insulin resistance and hyperinsulinemia [47]. Be that as it may, Rowe et al [44] noted that regular physical exercise can reduce blood pressure values in those with primary hyperinsulinemia. Further, that significantly higher proportion of boys consume animal proteins more than girls, but lower proportion consume green vegetables, fruits and nuts [50] may explain gender-based differences in blood pressure shown in this study.

Another key finding was that the prevalence of impaired/diabetic FBG among boys and girls without MetS was 22.2% and 29.3% respectively while among those with MetS, it was 76.5% and 72.2% respectively. Further, boys and girls with impaired/diabetic were 11.4 and 6.3 times respectively more likely to present with Mets, than those with normal FBG, supporting the findings that adolescent girls have a lower odd of suffering from impaired/diabetic FBG [51] and that the prime factor in the development of MetS is probably impaired and/or diabetic FBG, though this has to be verified. The prevalence of impaired/diabetic FBG among those without MetS in this study was higher than the 12.3% and 8.4% reported among adolescent boys and girls in India [52], the 9.4% reported in another Nigerian study [53] but within the 4-23% reported among adolescents in US [54]. Impaired/diabetic FBG was the component of MetS with the highest probability of being MetS-positive among boys and girls, though high level of LDL has the highest prevalence among boys and girls respectively. Evolving data suggesting a role for adipokine dysregulation, inflammation, and abnormalities in gut microbiota, immune dysregulation have emerged as important pathophysiological factors [55] though earlier studies suggest that a vicious cycle is created when insulin resistance in fat tissues triggers impairment of insulin-mediated inhibition of lipolysis, leading to a rise in circulating free fatty acids (FFAs) which invariably worsens insulin resistance by causing adjustments in the insulin signaling cascade in different organs [56, 57]. Whether these vicious cycles are influenced by male and female hormones is still debatable and should be further explored.

Among those with MetS, the prevalence of hypertriglyceridemia in this study was higher among girls (55.6%) than among boys (29.4%), with the concomitant probability of developing MetS being higher among girls (0.78) than boys (0.23). Earlier studies have shown that hypertriglyceridemia contributes to dyslipidemia in Africans with metabolic syndrome, but its contribution seems to be less frequent than reduced HDL-C as demonstrated in Botswana (14%) [58] and Nigeria (Uyo: 17.3%) [59], and Lagos: 25%) [60]. Contrary to the finding of Ahmad et al (2011) that reported HDL-cholesterol as the most common occurrence (87.6% of the subjects) [61], the most common occurrence of MetS element in this study was LDL-cholesterol. The observed difference may be due to discrepancies in diet, environment or physical exercise. It may, remotely be due to genetic variations.

Surprisingly, WC, not BMI-for-age percentile significantly correlated more with SBP and DBP among MetS-positive boys, not girls, though both BMI-for-age percentile and WC showed strongly significant but negative correlations with FBG in the disease group. This result possibly aligns with the report of Perng et al [62] that changes in sex steroid hormone and lipid metabolism may be implicated in the connection between adolescence and future metabolic risk in males. There was hardly any other significant correlation between BMI-for-age, WC and any of the lipids except what was observed between TChol and WC among MetS-positive girls. This this lack of correlation may depict genetic origin of dyslipidemia among the study subjects. This disturbing lipid profiles of adolescent boys and girls in this study may, in future, translate to atherogenic dyslipidemia which may probably contribute to the gradual and insidious progress of complications such as coronary artery disease, stroke and end stage renal disease. Studies have shown the contribution of systolic/diastolic hypertension, hypertriglyceridemia, low HDL-c, and anthropometric indices such as elevated BMI and WC with insulin resistance [63-68]. Even though these components have close biochemical relations, and usually overlap, very few studies have examined the intricate interactions between them regarding the onset of insulin resistance [69, 70], especially in sub-Saharan Africa.

### *Study limitations*

This study has potential limitations which require elaboration. This study was cross-sectional and did not permit creating a causal relationship between both anthropometric and biochemical components of MetS. Further, measurement of blood concentration of insulin was not considered in the study. Glucose Tolerance Test, Hb1A test and Post Prandial Blood Sugar (PPBS) test were not carried out. The strength of the study was that it used a relatively large survey data of adolescents at a local level.

## Conclusion

There are definite variations in the prevalence of different components of metabolic syndrome when this disease is considered among boys and girls. Systolic hypertension was more prevalent among boys with Mets than among girls. Metabolic syndrome (MetS) has dangerous effects as far as personal health is concerned, with increasing prevalence nowadays among youth in Africa and a significant impact on overall healthcare systems necessitating countermeasures as early as possible. It is advisable that policymakers at Federal and State levels should consider implementing MetS prevention programs in the school environment, covering a large number of children. Such programs should raise awareness on the disease and further promote knowledge and alertness of a healthy living, specifically focusing on adjusting to a healthy diet and improving physical activity. Students at both primary and secondary levels of education should be screened periodically for elevated blood pressure, dysglycemia and dyslipidemia. Individuals with cluster of cardio-metabolic risk factors should be treated as early as possible.

Author Contributions BMA, SJH and OOO conceptualized and designed the study. IOU, MTS, RNE and FG carried out the analyses and interpreted the data and drafted the article. AO and AA critically reviewed the article.

***Compliance with Ethical Standards***

***Conflict of interest***: The authors declare that they have no conflict of interests.

***Funding***: None.

***Data***: Available on request.

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