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Prevalence of Metabolic Syndrome Among Underweight, Healthy. Overweight and Obese Indigenous Sub-Sahara African Adolescents: A Comparative Analysis

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Abstract

Background and Objective: Metabolic syndrome (MetS) is a public health burden. The objective is to compare the prevalence of MetS and its components among underweight, healthy, overweight and obese adolescents in Lagos, Nigeria. ***Materials and Methods:*** This was a cross-sectional study of 624 adolescents (383 girls and 241 boys). Data collected included waist circumference (WC), blood pressure (BP), fasting plasma glucose (FPG), fasting total cholesterol (T-Chol), triglyceride (TG), low-density lipoprotein (LDL) and high-density lipoprotein (HDL). ***Results:*** In all, 108 (17.3%), 466 (74.7%), 30 (4.8%) and 20 (3.2%) subjects were underweight, healthy, overweight and obese. Obese subjects were significantly younger than the underweight (P-value=0.0003) or healthy (P-value=0.008) individuals. Waist circumference ≥90th percentile was more prevalent among obese boys (16.7%) than girls (7.1%). The prevalence of MetS was 8.3%, higher in boys (14.1%) than girls (4.7%), highest (26.7%) among the overweight and lowest (2.8%) among the underweight. High LDL-C was mostly widespread (92.5%) and systolic hypertension had the least occurrence (4.3%). Dyslipidemia, diabetic FPG, and systolic hypertension, were most prevalent among overweight subjects. Prevalence of hypertriglyceridemia (78.6%), low HDL-C (33.3%), hyperglycemia (22.2%) and systolic hypertension (33.3%) were highest in obese girls and overweight boys respectively. The risk factor for MetS of ≥3 least occurred (2.8%) among underweight subjects. ***Conclusions:*** Our results indicate that less than 5% of the adolescents were either overweight or obese but 17.3% were underweight. Cardiometabolic risk factors for MetS were more common among overweight subjects. Metabolic syndrome was more prevalent among boys (14.1%) than girls (4.7%).

Keywords: Biophysical profile; Black African Adolescents; Clinical; Metabolic Syndrome; Sub-Saharan

Abbreviations

CI=Confidence Interval; BMI=Body Mass Index; DM=Diabetes mellitus; MetS=Metabolic syndrome; BP=Blood pressure; FBG=Fasting Blood Glucose; TG=Triglyceride; T-Chol=Total cholesterol; LDL-C=Low-density lipoprotein cholesterol; HDL-C=High-density lipoprotein cholesterol; NIMR=Nigerian Institute of Medical Research; WHO=World Health Organization; SBP-Systolic Blood Pressure; DBP-Diastolic Blood Pressure.

Introduction

Although underweight in children and adolescents has long been observed in developing countries, obesity among these groups of people has gained an epidemic proportion in developed countries and is gradually widespread with increasing prevalence in developing countries [1]. Both underweight and obesity are linked with poor health consequences throughout the course of life. Sustainable Development Goat Target 2.2 addresses putting an end to “all forms of malnutrition". Earlier studies observed that obesity epidemic in childhood into adolescence often precede early onset of adulthood diseases such as Type 2 diabetes mellitus, high blood pressure, impaired lipid profile, and cardiovascular diseases, [2-4]. On the other hand, malnutrition due to suboptimal dietary intakes usually lead to high cases of anemia and micronutrient deficiencies while endocrine factors which are vital for supporting normal adolescent growth, are sensitive to undernutrition [5]. Metabolic syndrome (MetS) has long been known as a clustering of risk factors and it is characterized by three of the following: high blood pressure (HBP), diabetic fasting plasma glucose (FPG), hypertriglyceridemia (HTG), low high-density lipoprotein-cholesterol (HDL-C), elevated low-density lipoprotein-cholesterol (LDL-C) and high waist circumference (WC) [6-9]. Obesity in children or adolescents is often associated with MetS which was previously observed mostly in adults [10] and is a topic that has been widely studied [11-14]. On the other, though the prevalence of MetS in undernourished adolescents is increasing [10], few studies have focused on this potential epidemic. The occurrence of MetS is increasing in adolescents, especially in low-income countries, and childhood MetS had earlier been reported to foretell Mets and type 2 diabetes mellitus in adulthood [15, 16]. The syndrome was first demonstrated about four decades ago to result from insulin resistance in adults [17], but recent studies had suggested probable intra-uterine origin [18-20]. The pubertal stage during early adolescence is described as a critical phase of rapid growth in a person’s life where many physiological changes occur. The multiple burdens of malnutrition, metabolic syndrome, and chronic diseases are strongly linked to adolescence. However, there is an increasing prevalence of non-communicable diseases (NCDs) in low- and middle-income countries [21], which makes it necessary to study the prevalence of MetS in adolescence. Studies on MetS among indigenous Black Africans, especially adolescents are very few. One of such studies in Sudan reported an overall prevalence of MetS as 2.3% using International Diabetes Federation (IDF) criteria, significantly more prevalent among boys than girls and also more prevalent among obese adolescents than those who were overweight [22]. It is important to address the causes of increased risk for MetS early in life to prevent the development of the syndrome in adult life. In adolescents, MetS is a major risk factor for cardiometabolic disease in adulthood [23]. In sub-Saharan Africa, only a limited number of studies have investigated the association between components of MetS and either BMI-for-age percentile or waist circumference percentile among adolescents. Therefore, this study aims to (a) compare the prevalence of metabolic syndrome among undernourished, healthy, overweight and obese indigenous Nigerian adolescent boys and girls living in Lagos, Nigeria (b) to determine the prevalence and importance of different risk factors of metabolic syndrome among these adolescents and (c) evaluate the percent prevalence of MetS relative to BMI-for-age percentile and waist percentile of the study subjects.

Subjects, Materials and Methods

Study design and population: This has already been extensively described in a previous paper [24]. Briefly though, 650 adolescent secondary school students, aged 10-19 years were recruited into this cross-sectional study but complete analyzable data was available for 624 (383 girls and 241 boys). The study, which was approved by the Institutional Review Board of the Nigerian Institute of Medical Research (NIMR IRB (IRB/18/062) was conducted in Lagos, Nigeria between October 2019 and March 2020, in accordance with the Declaration of Helsinki (2000).

Sample size: The sample size was calculated for a single population with 95% confidence interval, 54 % proportion, a margin of error 5%, and allowing 12% non-response. To ensure that results of the study are representative of all Nigerian ethnic groups resident in Lagos State, the sample size would then be 650 students to cater for attrition and missing data.

Sampling technique and procedure: Simple random sampling technique was used to select 4 Local Government Areas from the 3 Senatorial Districts that comprise Lagos State and probability proportional to size (PPS) was used to select secondary schools having

different arms of classes-Year 1, 2 and 3 of Junior Secondary School (JSS) (mainly aged 10-15 years) and Year 1, 2 and 3 of Senior Secondary School (SSS) (mainly age 16-19 years), since there were many arms in either JSS or SSS. Lastly, systematic sampling technique was used to select students in selected arms of each class.

Inclusion criteria. Those included in the study were indigenous Nigerians resident in the community for a minimum of 2 years in the respective Local Government Areas of the study and were identified as regular students in selected secondary schools approved by the State Ministry of Education. Parental approval, using a consent form to participate in the study, was an inclusion criterion.

Exclusion criteria: These included those on admissions to a health facility in previous 6 month and on therapeutic diet or drugs; known diabetics, those taking lipid-lowering medications, or students with a history of vascular/liver/renal or other chronic illness were excluded. Pregnancy, suspected pregnancy, breastfeeding, or use of oral contraceptive were also exclusion criteria. Those who did not fast for 8 hours before bloodletting were also excluded.

Data collection: Data on socio-demographic and economic characteristics were gathered from both parents and students using a semi-structured questionnaire. Body weight, height, waist, and hip circumferences were measured by trained field workers. Weight was measured with minimal clothing (no shoes) to the nearest 0.1 kg using an electronic scale (FPG machine Model HBF-514C and DP scale HN-283), and height was measured (without participants wearing shoes) to the nearest millimeter using a portable stature meter (SURGILAC). Waist and hip circumferences were also measured to the nearest millimeter over light clothing, waist midway between the lowest rib and the iliac crest, and hip at the widest part of the buttocks. World Health Organization (WHO) AnthroPlus V1.0.4 (Geneva, Switzerland) was used to calculate BMI-for-age and height-for-age percentiles for boys and girls separately, [25]. Automatic blood pressure monitor {Medical Instrument WUXI, Ltd, EN-BL-8030 [China]} was used to measure blood pressure at the upper left arm, after each student rested in sitting position for about 30 mins. The average of the three measurements was used.

Definitions: Dyslipidemia was defined as total cholesterol ≥200 mg/dL (or ≥11.1mmol/l), LDL-C ≥ 130 mg/dL, (or ≥7.2 mmol/l), triglycerides ≥130 mg/dL (or ≥7.2 mmol/l), or HDL-C < 40 mg/dL (or <2.2 mmol/l) [26, 27]. The NHLBI criteria specifically for children and adolescents were used to identify MetS among participants aged 10 to 19 years [28]. This requires three or more of (i) waist circumference ≥0.94 m for boys and ≥0.80 m for girls; fasting plasma levels of (ii) triglycerides ≥130 mg/dL (or ≥7.2 mmol/l); (iii) HDL-cholesterol <40 mg/dL (or <2.2 mmol/l); (iv) LDL-cholesterol ≥130 mg/dL (or ≥7.2 mmol/l); (v) total cholesterol ≥200 mg/dL (or ≥11.1mmol/l); (vi) glucose ≥100mg/dL (5.6 mmol/l); (vi) pre-hypertension as BP 120-129/ <80 mmHg, stage 1 hypertension, BP 130-139/80-89, and stage 2 ≥140/90 mmHg [29]. However, for the purpose of this study, waist circumference, and fasting plasma levels of glucose, triglycerides and total cholesterol were the variables taken for the assessment of MetS. Underweight was defined as BMI <5th percentile for age, healthy weight as BMI ≥5th to <85th percentile for age, overweight as BMI ≥85th to <95th percentile and obese as BMI ≥95th percentile for age, using the BMI age chart [30].

Statistical analysis: This has also been extensively reported earlier [24]. Briefly, Excel spreadsheet was used to perform coding on data from each student for anonymity, ease of reference and avoidance of bias. Coded data were, cleaned, and cross-checked for errors and exported into NCSS version 2022 statistical software (Utah, USA). The data were analyzed descriptively obtaining frequencies and percentages, and inferentially using chi-square test to determine associations, where appropriate. The student's t-test was used to compare the means of two categorical variables and Analysis of Variance was used when comparing the means of more than 2 variables. Chi-square with Odd ratio was used, Bivariate and multivariate logistic regression analyses were also performed to test association and p-value <0.05 was considered as statistically significant. Confidence Interval (CI) in this study refers to a range of values for specific variables constructed so that this range has a specified probability of including the true value of that variable. Results of analyses were presented as Tables, Graphs, Charts or Figures.

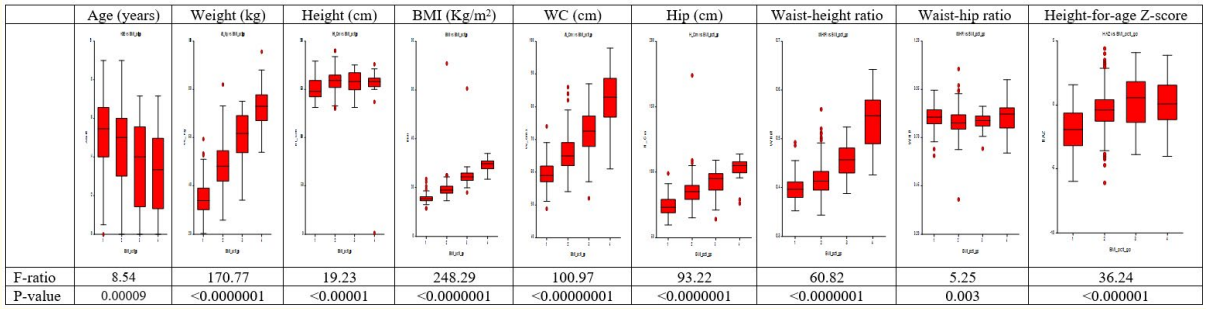
Results

Anthropometric profile-Table 1, Figure 1.

Variables	***BMI-for-age percentile***											
	Group 1 (underweight)*			***Group 2 (healthy weight)***			***Group 3 (overweight)***			***Group 4 (Obese)****		
	All	***Boys***	***Girls***	***All***	***Boys***	***Girls***	***All***	***Boys***	***Girls***	***All***	***Boys***	***Girls***
	(n=108, 17.3%)	***(n=56, 51.9%)***	***(n=52, 48.1%)***	***(n=466, 74.7%)***	***(n=170, 36.5%)***	***(n=296, 63.5%)***	***(n=30, 4.8%)***	***(n=9, 30.0%)***	***(n=21, 70.0%)***	***(n=20, 3.2%)***	***(n=6, 30.0%)***	***(n=14, 70.0%)***
Age (yrs)	15.4 (2.0)	15.6 (2.1)	15.1 (1.9)	14.7 (2.1)	14.7 (2.2)	14.7 (2.0)	13.6 (2.3)	13.1 (2.5)	13.8 (2.3)	13.3 (2.1)	13.4 (2.4)	13.3 (2.0)
t-test (P-value)		1.30 (0.20)			0.00 (1.00)			-0.72 (0.48)			0.09 (0.93)	
Weight (kg)	34.7 (6.8)	34.7 (7.3)	34.6 (6.3)	48.4 (8.9)	49.0 (10.4)	48.1 (7.9)	60.6 (10.8)	55.7 (14.2)	62.7 (8.6)	73.2 (10.4)	70.9 (14.5)	74.2 (8.5)
t-test (P-value)		0.08 (0.94)			0.97 (0.33)			-1.37 (0.20)			-0.52 (0.62)	
Height (cm)	150.0 (10.4)	149.2 (10.7)	151.0 (10.2)	158.5 (10.1)	160.6 (12.5)	157.3 (8.3)	157.3 (11.2)	156.7 (14.2)	157.6 (10.1)	150.5 (36.0)	159.5 (4.9)	146.7 (42.3)
t-test (P-value)		-0.89 (0.37)			3.07 (0.002)			-0.17 (0.87)			1.11 (0.28)	
BMI (kg/ m^2)	15.6 (1.7)	15.6 (1.5)	15.5 (1.9)	19.2 (3.2)	19.1 (4.4)	19.3 (2.1)	25.3 (7.1)	22.9 (2.3)	26.4 (8.2)	29.5 (2.4)	28.3 (3.3)	30.0 (1.9)
t-test (P-value)		0.30 (0.76)			-0.56 (0.58)			-1.80 (0.08)			-1.18 (0.28)	
WC (cm)	59.2 (4.1)$	59.8 (4.3)	58.7 (3.8)	65.7 (5.0)$$	65.9 (5.2)	65.6 (4.8)	72.0 (7.4)$$$	68.9 (8.3)	73.3 (6.8)	82.4 (9.2)$$$$	82.9 (11.0)	82.1 (8.8)
t-test (P-value)		1.74 (0.09)			0.62 (0.54)			-1.40 (0.18)			0.16 (0.88)	
Hip (cm)	74.0 (7.1)	72.9 (6.6)	75.2 (7.5)	84.7 (8.8)	82.8 (10.5)	85.7 (7.5)	92.0 (10.7)	85.6 (12.1)	94.8 (9.0)	102.7 (10.1)	104.1 (6.3)	102.1 (11.5)
t-test (P-value)		-1.69 (0.09)			-3.17 (0.001)			-205 (0.06)			0.50 (0.62)	
Waist-Height ratio	0.40 (0.03)	0.40 (0.03)	0.39 (0.02)	0.42 (0.03)	0.41 (0.3)	0.42 (0.03)	0.46 (0.04)	0.44 (0.04)	0.46 (0.04)	0.54 (0.06)	0.55 (0.07)	0.53 (0.05)
t-test (P-value)		2.05 (0.04)			-3.46 (0.0006)			-1.26 (0.23)			0.63 (0.55)	
Waist-Hip ratio	0.80 (0.06)	0.82 (0.06)	0.78 (0.06)	0.78 (0.06)	0.80 (0.06)	0.77 (0.06)	0.78 (0.05)	0.81 (0.04)	0.77 (0.05)	0.81 (0.09)	0.80 (0.10)	0.81 (0.08)
t-test (P-value)		3.46 (0.0008)			5.20 (<0.000001)			2.32 (0.03)			-0.22 (0.83)	
HAZ	-1.96 (1.58)	-2.41 (1.54)	-1.47 (1.49)	-0.39 (1.47)	-0.48 (1.7)	-0.36 (1.33)	0.31 (2.19)	-0.12 (2.94)	0.49 (1.83)	0.27 (1.92)	0.13 (2.51)	0.33 (1.72)
t-test (P-value)		-3.22 (0.002)			-0.79 (0.43)			0.58 (0.58)			-0.18 (0.86)	

**There was no significant difference in the proportion of boys and girls that were malnourished or obese. (χ^2=3.20, P-value=0.07, OR=2.51, 95% CI=0.90, 7.03). Further, boys were approximately 2½ times more likely to be malnourished than girls. Obese adolescents (n=20, 3.2%) were significantly younger than the malnourished (P-value-0.0003) and the healthy (P-value-0.008).*

Table 1: Anthropometric characteristics of study subjects by BMI-for-age percentile groups.



	Age (years)	Weight (kg)	Height (cm)	BMI (Kg/m²)	WC (cm)	Hip (cm)	Waist-height ratio	Waist-hip ratio	Height-for-age Z-score
F-ratio	8.54	170.77	19.23	248.29	100.97	93.22	60.82	5.25	36.24
P-value	0.00009	<0.0000001	<0.00001	<0.0000001	<0.00000001	<0.0000001	<0.0000001	0.003	<0.000001

Figure 1: Box plot showing analysis of variance (ANOVA) in the means of age (years), weight (kg), height (cm), BMI (Kg/m^2), Waist circumference (cm), hip circumference (cm), waist-height ratio, waist-hip ratio and height-for-age Z-score (y-axis) of all malnourished, ideal (healthy), overweight and obese (x-axis) adolescents in the study.

A description of the anthropometric profile of the study subjects is as shown in Table 1. The majority (74.7%) of the subjects had healthy weight while 17.3%, 4.8% and 3.2% were malnourished, overweight and obese. Overall, obese adolescents (n=20, 3.2%) were significantly younger than the malnourished (P-value-0.0003) and the healthy (P-value-0.008). The means (±sd) of age (years), weight (kg), height (cm) and BMI (Kg/m^2) of the study participants were 14.7 (2.1), 47.4 (11.6), 156.7 (12.3) and 19.2 (4.2) with no significant variation in age, weight and height among boys and girls. However, girls had a significantly higher BMI (19.5±4.1 vs 18.5±4.5) compared to boys (P-value=0.01). There were significant differences in the anthropometric indices among the underweight, normal weight, overweight and obese subjects.

Cardiometabolic risk factors for Metabolic Syndrome as defined by the presence of three of five known risk factors among study subjects-Table 2 and Figure 2.

Risk factor for MetS		***Total***			***BMI-for-age percentile***											
		<5th (Underweight)			***5th - <85th (Healthy weight)***			***85th - <95th (Overweight)***			***≥95th (Obese)***					
All		***Boys***	***Girls***	***All***	***Boys***	***Girls***	***All***	***Boys***	***Girls***	***All***	***Boys***	***Girls***	***All***	***Boys***	***Girls***	
624 (100.0)		241 (36.8)	383 (63.2)	108 (17.3)	56 (51.9)	52 (48.1)	466 (74.7)	170 (36.5)	296 (63.5)	30 (4.8)	9 (30.0)	21 (70.0)	20 (3.2)	6 (30.0)	14 (70.0)	
Systolic hypertension	Freq. (%)	27 (4.3)	17 (7.1)	10 (2.6)	2 (1.9)	2 (3.6)	0 (0.0)	18 (3.9)	12 (7.1)	6 (2.0)	5 (16.7)	3 (33.3)	2 (9.5)	2 (10.0)	0 (0.0)	2 (14.3)
	Mean (±sd)	134.5 (5.6)	134.1 (3.4)	135.2 (8.3)	133.5 (1.5)	133.5 (2.1)	0 (0.0)	135.4 (6.6)	134.8 (3.8)	136.8 (10.6)	132.0 (1.4)	132.0 (1.7)	132.0 (1.4)	133.5 (4.9)	0 (0.0)	133.5 (4.9)
Diastolic Hypertension	Freq. (%)	8 (1.3)	4 (1.7)	4 (1.0)	2 (1.9)	1 (1.8)	1 (1.9)	5 (1.1)	2 (1.2)	3 (1.0)	1 (3.3)	1 (11.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Mean (±sd)	93.6 (3.4)	92.8 (2.4)	94.5 (4.4)	91.5 (0.7)	91.0 (0.0)	92.0 (0.0)	94.0 (4.1)	92.0 (1.4)	95.3 (5.0)	96.0 (0.0)	96.0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Fasting FPG ≥125.0 mg/dL	Freq. (%)	72 (11.5)	24 (10.0)	48 (12.5)	14 (13.0)	6 (10.7)	8 (15.4)	51 (10.9)	16 (9.4)	35 (11.8)	5 (16.7)	2 (22.2)	3 (14.3)	2 (10.0)	0 (0.0)	2 (14.3)
	Median	149.4	158.4	142.6	144.9	166.7	136.3	149.6	158.4	149.2	145.2	176.8	135.0	141.5	0	141.5
Fasting TG ≥130.0 mg/dL	Freq. (%)	378 (60.6)	143 (59.3)	235 (61.4)	66 (61.1)	37 (66.1)	29 (55.8)	277 (59.4)	98 (57.6)	179 (60.5)	21 (70.0)	5 (55.6)	16 (76.2)	14 (70.0)	3 (50.0)	11 (78.6)
	Median	239.5	248.7	231.2	235.0	235.0	233.1	238.9	252.4	228.6	234.2	234.2	236.7	265.5	227.6	280.2

Fasting T-Chol ≥200 mg/dL	Freq. (%)	264 (42.3)	106 (44.0)	158 (41.3)	41 (38.0)	25 (44.6)	16 (30.8)	201 (43.1)	108 (63.5)	75 (25.3)	15 (50.0)	3 (33.3)	12 (57.1)	7 (35.0)	3 (50.0)	4 (28.6)
	Median	223.4	280.8	258.4	259.3	282.8	242.0	265.9	252.3	280.7	295.8	373.8	284.0	266.7	266.7	274.1
Fasting LDL-C ≥130.0 mg/dL	Freq. (%)	577 (92.5)	219 (90.9)	358 (93.5)	101 (93.5)	51 (91.1)	50 (96.1)	428 (91.9)	155 (91.2)	273 (92.3)	30 (100.0)	9 (100.0)	21 (100.0)	18 (90.0)	4 (66.7)	14 (100.0)
	Median	295.7	290.0	302.1	280.7	265.5	292.5	296.4	290.8	307.9	298.6	306.0	295.7	331.0	271.5	331.0
Fasting HDL-C <40 mg/dL	Freq. (%)	154 (24.7)	67 (27.8)	87 (22.7)	18 (16.7)	11 (19.6)	7 (13.5)	123 (26.4)	52 (30.6)	71 (24.0)	8 (26.7)	3 (33.3)	5 (23.8)	5 (25.0)	1 (16.7)	4 (28.6)
	Median	26.8	26.7	27.1	29.1	29.2	28.9	26.7	26.6	27.9	23.1	21.2	23.2	27.1	36.8	24.2
Waist circumference ≥90th pctl		56 (9.0)	20 (8.3)	36 (9.4)	9 (8.3)	5 (8.9)	4 (7.7)	42 (9.0)	17 (10.0)	25 (8.4)	3 (10.0)	0 (0.0)	3 (14.3)	2 (10.0)	1 (16.7)	1 (7.1)
Dyslipidemia		53 (8.5)	26 (10.8)	27 (7.1)	9 (8.3)	7 (12.5)	2 (3.9)	38 (8.2)	18 (10.6)	20 (6.8)	2 (6.7)	0 (0.0)	2 (9.5)	4 (20.0)	1 (16.7)	3 (21.4)
Metabolic syndrome		52 (8.3)	34 # (14.1)	18 # (4.7)	3 (2.8)*	3 (5.4)	0 (0.0)	36 (7.7)	25 (14.7)	11 (3.7)	8 (26.7)	5 (55.6)	3 (14.3)	5 (25.0)*	1 (16.7)	4 (28.6)
Number of risk factors for MetS	≥3	58 (9.3)	22 (9.1)	36 (9.4)	6 (5.6)	4 (7.1)	2 (3.8)	27 (5.8)	10 (5.9)	17 (5.7)	15 (50.0)	7 (77.8)	8 (38.1)	10 (50.0)	1 (16.7)	9 (64.3)
	2	202 (32.4)	77 (32.0)	125 (32.6)	32 (29.6)	18 (32.1)	14 (26.9)	155 (33.3)	56 (32.9)	99 (33.5)	9 (30.0)	1 (11.1)	8 (38.1)	6 (30.0)	2 (33.3)	4 (28.6)
	1	272 (43.6)	111 (46.1)	161 (42.0)	58 (53.7)	28 (20.0)	30 (57.7)	205 (44.0)	79 (46.5)	126 (42.6)	5 (16.7)	1 (11.1)	4 (19.0)	4 (20.0)	3 (50.0)	1 (7.1)
	0	92 (14.7)	31 (12.9)	61 (15.9)	12 (11.1)	6 (10.7}	6 (11.5)	79 (16.9)	25 (14.7)	54 (18.2)	1 (3.3)	0 (0.0)	1 (4.8)	0 (0.0)	0 (0.0)	0 (0.0)

** χ^2=10.68, P-value=0.001, OR=11.67, 95% CI: 2.53, 53.89, RR= 9.00, 95% CI=2.33, 34.70; # χ^2=17.11, P-value=0.00004, OR=3.33, 95% CI: 1.83, 6.05, RR= 3.00, 95% CI=1.74, 5.19.*

Table 2: Clinical and biochemical risk factors for Metabolic Syndrome as defined by the presence of three of five known risk factors among study subjects.

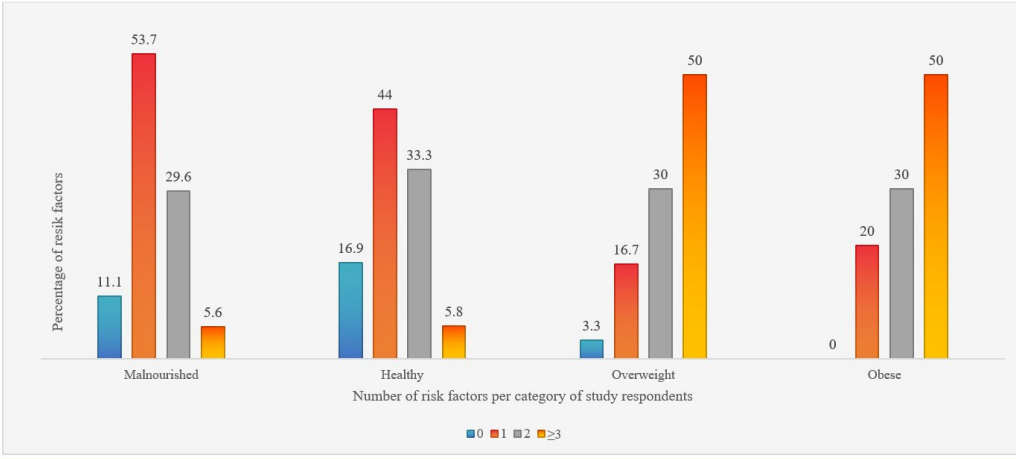


Figure 2: Prevalence of risk factors for metabolic syndrome relative to category of BMI-for-age percentile of study subjects.

Table 2 and Figure 2 present various risk factors for and prevalence of MetS relative to sex-specific BMI-for-age percentile of the study subjects. The prevalence of underweight was higher in boys (51.9%) than girls (48.1%) but the prevalence of overweight and obesity was higher in girls (70.0% each) than boys (30% each). The most prevalent cardiometabolic risk factor for MetS was high LDL-C (92.5%) with an overall median of 295.7 mg/dL, more prevalent among girls (93.5%) than boys (90.5%). All (100.0% prevalence) overweight subjects had high LDL-C levels, while 93.5% underweight, 91.9% healthy weight and 90.0% obese subjects respectively presented with LDL-C of 280.7 mg/dL, 296.4 mg/dL, and 331.0 mg/dL respectively, the latter (highest value) being observed among obese subjects. Hypertriglyceridemia was moderately widespread (60.6%) with a median of 239.5 mg/dL, mainly among girls (614%) more than boys (59.3%) and equally distributed among overweight (70.0%) and obese (70.0%) but mainly among overweight (76.2%) and obese (78.6%) girls. Hypertriglyceridemia was moderately low among the underweight (61.1%) and lowest (59.4%) among those with healthy weight. Elevated level of fasting T-Chol was reasonably widespread (42.3%) among all the subjects with a median value of 223.4 mg/dl., mainly among boys (prevalence: 44.0%; median: 280.8 mg/dL) than among girls (prevalence: 41.3%; median: 258.4 mg/dL); most prevalent among healthy weight subjects (prevalence = 43.1%; median = 265.9 mg/dL), especially in boys (prevalence = 63.5%; median = 252.3 mg/dL) than girls (prevalence = 25.3%; median =280.7 mg/dL) and least among obese subjects (prevalence = 35.0%; median =266.7 mg/dL). The overall median value of fasting high HDL-C was 26.8 mg/dL which was more widespread in boys (prevalence = 27.8%; median = 26.7 mg/dL) than girls (prevalence = 22.7%; median = 27.1 mg/dL)-most widespread among overweight subjects (prevalence = 26.7%; median = 23.1 mg/dL), especially in boys (prevalence = 33.3%; median = 21.2 mg/dL).

Among all the study subjects, the prevalence of systolic hypertension was 4.3% which was higher among boys (7.1%) than girls (2.6%). The prevalence of systolic hypertension in the underweight, healthy weight, overweight and obese subjects was 1.9%, 3.9%, 16.7% and 10.0% respectively, higher in boys than girls except among the obese subjects in which systolic hypertension was higher in girls than among boys. Dyslipidemia and MetS were more widespread (20.0% and 25.0%) among obese subjects, especially among the girls (21.4% and 28.6%), however ≥3 risk factors for MetS was equally distributed among overweight (50.0%) and obese (50.0%) subjects, higher in overweight boys (77.8%) than girls (38.1%) but higher in obese girls (64.3%) than boys (16.7%).

Mean and median distribution of metabolic risk factors among adolescents with and without metabolic syndrome relative to BMI-for-age percentile, Table 3.

Risk factors for MetS	Stage of MetS		Statistics	All (n=624)	Underweight (n=108)	Healthy (n=466)	Overweight (n=30)	Obese (n=20)	F-ratio	P-value
Systolic hypertension	*All*		Freq. (%)	*27 (4.3)*	*2 (1.9)*	*18 (3.9)*	*5 (16.7)*	*2 (10.0)*	*0.59*	*0.79*
			Mean (±sd)	*134.5 (5.6)*	*133.5 (2.1)*	*135.4 (6.6)*	*132.0 (1.4)*	*133.5 (4.9)*		
	Metabolic syndrome	*<90th pctl*	Freq. (%)	*20 (74.1)*	*1 (50.0)*	*14 (77.8)*	*4 (80.0)*	*1 (50.0)*	*0.19*	*0.99*
			Mean (±sd)	*135.4 (6.3)*	*135.0 (0.0)*	*136.3 (7.2)*	*131.8 (1.51)*	*137.0 (0.0)*		
		≥90th pctl	Freq. (%)	*7 (25.9)*	*1 (50.0)*	*4 (22.2)*	*1 (26.7)*	*1 (50.0)*	*0.70*	*0.60*
			Mean (±sd)	*132.1 (1.8)*	*132.0 (0.0)*	*132.5 (2.1)*	*133.0 (0.0)*	*130.0 (0.0)*		
	t-test (P-value)			*2.16 (0.045)*	*0.00 (0.00)*	*1.73 (0.10)*	*0.00 (0.00)*	*0.00 (0.00)*	-	
Diastolic hypertension	*All*		*Freq. (%)*	*8 (1.3)*	*2 (1.9)*	*5 (1.1)*	*1 (3.3)*	*0 (0.0)*	*0.36*	*0.87*
			Mean (±sd)	*93.6 (3.4)*	*91.5 (0.7)*	*94.0 (4.1)*	*96.0 (0.0)*	*0 (0.0)*		
	Metabolic syndrome	*<90th pctl*	*Freq. (%)*	*6 (75.0)*	*2 (100.0)*	*4 (80.0)*	*0 (0.0)*	*0 (0.0)*	-	-
			Mean (±sd)	*92.8 (3.7)*	*91.5 (0.7)*	*93.5 (4.5)*	*0 (0.0)*	*0 (0.0)*		
		≥90th pctl	*Freq. (%)*	*2 (25.0)*	*0 (0.0)*	*1 (20.0)*	*0 (0.0)*	*0 (0.0)*	-	-
			Mean (±sd)	*96.0 (0.0)*	*0 (0.0)*	*90.0 (0.0)*	*0 (0.0)*	*0 (0.0)*		
	t-test (P-value)			*-2.12 (0.09)*	-	*0.0 (0.0)*	-	-	-	

Diabetic Fasting PG	*All Median*		*Freq. (%)*	*72 (11.5)*	*14 (13.0)*	*51 (10.9)*	*5 (16.7)*	*2 (10.0)*	*0.02*	*1.00*
			149.4	*144.7*	*149.6*	*145.2*	*141.5*			
	Metabolic syndrome	*<90th pctl*	*Freq. (%)*	*52 (72.2)*	*12 (85.7)*	*37 (72.5)*	*1 (20.0)*	*2 (100.0)*	*0.04*	*1.00*
			Median	*138.0*	*138.4*	*146.6*	*134.1*	*141.5*		
		≥90th pctl	*Freq. (%)*	*20 (27.8)*	*2 (14.3)*	*14 (27.5)*	*4 (80.0)*	*0 (0.0)*	*-*	*-*
			Median	*199.7*	*198.5*	*210.5*	*161.3*	*0 (0.0)*		
	Mann-Whitney U-test (P-value)			*5.07 (<0.00001)*	*2.19 (0.03)*	*4.69 (<0.000001)*	*-1.41 (0.16)*	*-*	*-*	
High Fasting TG	*All Median*		*Freq. (%)*	*378 (60.6)*	*66 (61.1)*	*277 (59.4)*	*21 (70.0)*	*14 (70.0)*	*0.02*	*1.00*
			239.5	*235*	*238.9*	*234.2*	*265.5*			
	Metabolic syndrome	*<90th pctl*	*Freq. (%)*	*358 (94.7)*	*64 (97.0)*	*266 (96.0)*	*18 (85.7)*	*10 (71.4)*	*0.01*	*1.00*
			Median	*240.2*	*234.9*	*240.2*	*243.9*	*265.5*		
		≥90th pctl	*Freq. (%)*	*20 (5.3)*	*2 (3.0)*	*11 (4.0)*	*3 (14.3)*	*4 (28.6)*	*-*	*-*
			Median	*230.3*	*317.7*	*231.3*	*209.4*	*253.4*		
	Mann-Whitney U-test (P-value)			*-0.72 (0.47)*	*1.38 (0.17)*	*-0.71 (0.48)*	*-1.51 (0.13)*	*-0.21 (0.83)*	*-*	
High Fasting T-Chol	*All Median*		*Freq. (%)*	*416 (66.7)*	*74 (68.5)*	*308 (66.1)*	*20 (66.7)*	*7 (35.0)*	*0.02*	*1.00*
			223.4	*208.7*	*226.3*	*231.8*	*266.7*			
	Metabolic syndrome	*<90th pctl*	*Freq. (%)*	*373 (89.7)*	*72 (97.3)*	*278 (90.3)*	*13 (65.0)*	*4 (57.1)*	*1.22*	*0.22*
			Median	*219.1*	*204.9*	*219.9*	*272.1*	*238.5*		
		≥90th pctl	*Freq. (%)*	*43 (10.3)*	*2 (2.7)*	*30 (9.7)*	*7 (35.0)*	*3 (42.9)*	*1.73*	*0.08*
			Median	*295.5*	*475.3*	*291.9*	*188.6*	*371.4*		
	Mann-Whitney U-test (P-value)			*3.49 (0.0005)*	*2.23 (0.03)*	*3.36 (0.0008)*	*-1.47 (0.14)*	*2.12 (0.03)*	*-*	
High Fasting LDL-C	*All Median*		*Freq. (%)*	*577 (92.5)*	*101 (93.5)*	*428 (91.8)*	*30 (100.0)*	*18 (90.0)*	*0.04*	*1.00*
			295.7	*280.7*	*296.4*	*298.6*	*331.0*			
	Metabolic syndrome	*<90th pctl*	*Freq. (%)*	*529 (91.7)*	*98 (97.0)*	*396 (92.5)*	*22 (73.3)*	*13 (72.2)*	*0.02*	*1.00*
			Median	*292.4*	*273.7*	*294.8*	*292.6*	*335.8*		
		≥90th pctl	*Freq. (%)*	*48 (8.3)*	*3 (3.0)*	*32 (7.5)*	*8 (26.7)*	*5 (27.8)*	*-*	*-*
			Median	*326.2*	*346.2*	*334.6*	*298.6*	*326.2*		
	Mann-Whitney U-test (P-value)			*1.67 (0.09)*	*1.53 (0.13)*	*1.55 (0.12)*	*-0.28 (0.78)*	*-0.15 (0.88)*	*-*	
Low Fasting HDL-C	*All Median*		*Freq. (%)*	*154 (24.7)*	*18 (16.7)*	*123 (26.4)*	*8 (26.7)*	*5 (25.0)*	*0.00*	*1.00*
			25.1	*29.1*	*26.7*	*23.1*	*27.1*			
	Metabolic syndrome	*<90th pctl*	*Freq. (%)*	*122 (79.2)*	*16 (88.9)*	*101 (82.1)*	*4 (50.0)*	*1 (20.0)*	*0.00*	*1.00*
			Median	*27.9*	*29.1*	*27.6*	*26.1*	*29.5*		
		≥90th pctl	*Freq. (%)*	*32 (20.8)*	*2 (11.1)*	*22 (17.9)*	*4 (50.0)*	*4 (80.0)*	*-*	*-*
			Median	*23..6*	*23.6*	*24.6*	*22.1*	*24.2*		
	Mann-Whitney U-test (P-value)			*-1.79 (0.07)*	*0.00 (1.00)*	*-1.76 (0.08)*	*0.58 (0.56)*	*0.71 (0.48)*	*-*	

Table 3: Mean and median distribution of metabolic risk factors among adolescents with and without metabolic syndrome relative to BMI-for-age percentile.

Although there was a significant difference (P=0.045) in the systolic blood pressure (mm Hg) of hypertensive subjects with (n=7, 132.1±1.8) and without (135.4±6.3) MetS, such significance was not apparent when subjects were grouped into underweight, healthy weight, overweigh and obese. Diabetic FPG was significantly higher (P<0.03) among MetS-positive (n=2, 198.5 mg/dL) than among MetS-negative (n=12, 138.4 mg/dL) underweight subjects but much more so (P<0.000001) among MetS-positive (n=14, 210.5 mg/dL) than among MetS-negative (n=37, 146.6 mg/dL) healthy weight subjects. Risk factors ≥3 were least common (5.6%) among underweight subjects but most widespread (50.0% each) among the overweight and the obese. Only 14.7% of the study subjects had no risk factor for MetS, especially girls (15.9%) compared to boys (12.9%).

Discussion

To the authors' knowledge, this is the first Nigerian study, determining the prevalence of metabolic syndrome among underweight, healthy weight, overweight and obese adolescents in Nigeria, possibly in Africa. In this study, the prevalence of MetS and of its risk factors among these four groups of adolescents was also assessed. The current study showed that the overall prevalence of MetS, observed to be 8.3%, is higher than the 2.3% reported from Turkey [31], the 3.3% reported from an Iranian study [32], remarkably higher in overweight (26.7%) and obese (25.0%) adolescents than among the healthy weight (7.7%) and least, as expected, among the underweight (2.8%). Among the healthy weight in this study, MetS prevalence of 7.7% higher than the 2.7% reported in the same area [33] and the 0% reported from Morocco [34]. Considering gender consequence, the overall prevalence of MetS was significantly higher among boys than girls (14.1% vs. 4.7%), consistent with reports from other parts of the world such as Latin America [35], USA [36], Iran [37] and United Arab Emirate [38], but in disparity with an Indian study [39]. Differences in maturation rate between boys and girls and variances in sex hormones-testosterone and sex hormone-binding globulin, abundantly produced in puberty,-may be responsible for the higher prevalence of MetS among boys than in girls [40, 41]. Other possible explanation for such variation may be the preference for male child, parental literacy level and position of the child and weaning nutritional diet. The prevalence of overweight and obesity were 3.2% and 4.8% respectively, far lower than the 31.8%, and 28.7% reported by Birken et al in Canada [42] or the combined 44.%. for overweight and obese reported in a Moroccan study [34]. The prevalence of underweight was higher in boys while that of overweight and obesity were higher in girls, which is discordant with the study of Arum et al in India that reported obesity as being higher in boys than in girls [43]. In addition, obese and overweight children were significantly younger than the underweight and the healthy, suggesting the possibility of familial or hereditary obesity among study subjects. The prevalence of MetS among the overweight and obese in this study is similar to the 24.1% pooled prevalence in the overweight and obese adolescents as reported by IDF, but distant from the 36.5% and 56.3% posted by ATP III and de Ferranti respectively [44]. The prevalence of low HDL-C in this study is consistent with what other studies reported [45, 46] but inconsistent with the report from Tunisia [47]. Cho submitted that the standard HDL behavior is the elimination of cholesterol from atherosclerotic lesions, and the deleting oxidized species in LDL, to widen the removal of β-amyloid plaque and inhibit α-synuclein aggregation in the brain to attenuate Alzheimer's disease and Parkinson's disease, respectively [45]. Over the years, many studies have viewed low plasma concentration of HDL-C as a strong and independent cardiovascular disease (CVD) risk factor [48, 49]. A study compared HDL-C level in teenagers (10-19 years old) between boys and girls to appreciate the reason why women have a higher HDL-C level and a longer life span than men in adulthood and later life [50]. That study stated that HDL-C level quickly declines among boys in their pubertal period (14 and 15 years old) and that the lowest HDL-C level at 15 years of age remained at 19 years of age in the male group; stays almost stationary at a lower level for the life expectancy of men compared to women. This lowered HDL-C during the pubertal age occurred only in the male group, though the explanation for this is unclear. Probably the cholesterol from HDL-critical for spermatogenesis and steroidogenesis in the male reproduction system, including Sertoli cells, are required for sperm production. Further, Bartlett et al reported that increased risk of CVD associated with low HDL-C is most evident in the presence of higher levels of other lipids or lipoproteins [46]. Findings from this study show noteworthy differences in the mean values of hypertensive blood pressure and in the median values of diabetic FPG and T-Chol among adolescents with and without MetS but no significant variation in the median values of low HDL-C, high LDL-C and in hypertriglyceridemia among those with and without MetS, a conflicting finding from what other studies reported [51, 52]. Hypertension has been closely associated with MetS which has been linked with aldosterone production, LDL-C and dysfunctional HDL-C [53]. Friedman

et al reported that obesity is associated with notably detrimental risk parameters for cardiovascular disease in school aged children and that this was also the case for overweight children, although the effect was not as strong as for obese children [54]. Although interpreted variously, the occurrence of hypertension, a fundamental apparatus seems to be vasculopathy, resulting in narrowed lumen caused by accumulation of atherosclerotic plaque. Hypertriglyceridemia, more prevalent among boys than girls, was also observed in the study population, which could serve as an important biomarker of CVD risk [46] and it has been reported that increased TG and LDL-C substantially elevates CVD risk, consistent with prior studies demonstrating a 30-60% increase in CVD risk when LDL-C exceeded 130 mg/dL [55]. A main limitation of this study is its cross-sectional nature. As such findings in this study should be verified by future longitudinal surveys.

Conclusion/Recommendation

This study illustrates that MetS among adolescents is an emerging public health challenge in Nigeria. The prevalence is significantly higher among the overweight and obese population but still exists among underweight and healthy subjects exposing the double health burden of malnutrition in Nigeria. Thus, further studies are required to be undertaken to detect all potential factors, including genetic and hereditary investigations. Decision makers should promote schemes such as school-based interventions on lifestyle modifications to possibly prevent MetS in Nigeria.

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Conflict of interest

All authors declare no conflict of interest.

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Authors Contribution

SH, BMA, OA, BMA engaged in conception and design of the study, BMA, SH engaged in analysis and interpretation of data; BMA, SH drafted the article, OA, BMA revised it critically for important intellectual content; BMI, SH did the final revision of the version to be published.

References

1. Phelps NH., et al. "Worldwide trends in underweight and obesity from 1990 to 2022: a pooled analysis of 3663 population-representative studies with 222 million children, adolescents, and adults"'. The Lancet 403.10431 (2024): 1027-1050.
2. Cook S., et al. "Prevalence of metabolic syndrome phenotype in adolescents". Arch Pediatr Adolesc Med 157 (2003): 821-27.
3. Steinberger J. "Diagnosis of the metabolic syndrome in children". Curr Opin Lipidol 14 (2003): 555-9.
4. Zambon MP., et al. "Clinical and laboratory characteristics of obese children and adolescents". Rev Paul Pediatria25 (2007): 27-32.
5. Christian P and Smith ER. "Adolescent Undernutrition: Global Burden, Physiology, and Nutritional Risks". Ann Nutr Metab 72.4 (2018): 316-328.
6. Veugelers PJ and Fitzgerald AL. "Prevalence of and risk factors for childhood overweight and obesity". CMAJ 173 (2005): 607-13.
7. Silveira D., et al. "Risk factors for overweight among Brazilian adolescents of low-income families: a case-control study". Public

Health Nutr 9 (2005): 421-8.

8. Reaven GM. "The metabolic syndrome: is this diagnosis necessary?". Am J Clin Nutr 83 (2006): 1237-47.
9. Eisenmann JC. "On the use of continuous metabolic syndrome score in pediatric research". Cardiovasc Diabetol 7 (2008): 1-6.
10. Ford ES and Chaoyang L. "Defining the metabolic syndrome in children and adolescents: will the real definition please stand up?". J Pediatr 152 (2008): 160-4.
11. Al-Hamad D and Raman V. "Metabolic syndrome in children and adolescents". Transl Pediatr 6.4 (2017): 397-407.
12. Mehrkash M., et al. "Obesity and Metabolic Syndrome among a Representative Sample of Iranian Adolescents". The Southeast Asian journal of tropical medicine and public health 43.3 (2012): 756-763.
13. Gobato AO., et al. "Metabolic syndrome and insulin resistance in obese adolescents". Rev Paul Pediatr 32.1 (2014): 55-62.
14. Engin A. "The Definition and Prevalence of Obesity and Metabolic Syndrome". Advances in Experimental Medicine and Biology, Springer, Cham 960 (2017).
15. Aung K., et al. "Risk of developing diabetes and cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese individuals". The Journal of Clinical Endocrinology and Metabolism 99 (2014): 462-468.
16. Bitew ZW., et al. "Metabolic syndrome among children and adolescents in low- and middle-income countries: a systematic review and meta-analysis". Diabetol Metab Syndr 12 (2020): 93.
17. Grabia M., et al. "Prevalence of Metabolic Syndrome in Children and Adolescents with Type 1 Diabetes Mellitus and Possibilities of Prevention and Treatment: A Systematic Review". Nutrients 13.6 (2021): 1782.
18. Aronis Konstantinos N., et al. "A brief history of insulin resistance: from the first insulin radioimmunoassay to selectively targeting protein kinase C pathways". Metabolism-Clinical and Experimental 61.4 (2012): 445-449.
19. Chopra AK. "Metabolic Syndrome or Insulin Resistance: Evolution, Controversies and Association with Cardiovascular Disease Risk". Indian Journal of Clinical Cardiology 1.2 (2020): 77-85.
20. Xu D and Hu W. "Fetal Origin of Metabolic Syndrome". In: Wang, H., Chen, L., Xu, D. (eds) Fetal Origin of Diseases. Springer, Singapore (2024).
21. Xita N and Tsatsoulis A. "Fetal origins of the metabolic syndrome". Ann N Y Acad Sci 1205 (2010): 148-55.
22. Simmons RK., et al. "The Metabolic Syndrome: Useful Concept or Clinical Tool? Report of a WHO Expert Consultation". Diabetologia 53 (2010): 600-605.
23. Elfaki FA., et al. "Prevalence of Metabolic Syndrome among Early Adolescents in Khartoum State, Sudan". Int. J. Environ. Res. Public Health 19.22 (2022): 14876.
24. DeBoer MD. "Assessing and managing the metabolic syndrome in children and adolescents". Nutrients 11 (2019): 1788.
25. Afolabi BM and Holdbrooke SJ. "Obesity, Dyslipidemia and other Risks Factors for Metabolic Syndrome among Indigenous Black African Secondary School Students in Lagos, Nigeria". Qeios ID: S522VG (2023).
26. World Health Organization. AnthroPlus V1.04. WHO (2014).
27. American Heart Association. Cholesterol Statistics. http://www.americanheart.org/presenter.jhtml?identifier=536
28. National Cholesterol Education Program (NCEP). Expert Panel on Blood Cholesterol Levels in Children and Adolescents: Highlight of the reports of the Expert Panel. Pediatrics (2012).
29. NHLBI. Obesity Education Initiative. The practical guide: Identification, Evaluation, and Treatment of Overweight and Obesity in Adults. National Institute for Health, Bethseda MD, USA. (NIH Publication Number 004084) nhlbi.nih.gov (2021).
30. Lande MB and Batisky DL. "New American Academy of Pediatrics Hypertension Guideline". Hypertension 73.1 (2019): 31-32.
31. CDC. Growth Chart Training. BMI-for-age as a screening measure (2024). www.cdc.gov/growth-chart-training/hcp/using bmi/screening-measure.html
32. Cizmecioglu PM., et al. "Prevalence of Metabolic Syndrome in Schoolchildren and Adolescents in Turkey: A Population-Based Study". J. Pediatr. Endocrinol. Metab 22 (2011): 703-714.
33. Mehrkash M., et al. "Obesity and Metabolic Syndrome Among a Representative Sample of Iranian Adolescents". The Southeast Asian journal of tropical medicine and public health 43.3 (2012): 756-763.

34. Moronkola OA., et al. "Risk Factors of Metabolic Syndrome among Normal Weight Adolescents in Lagos, Nigeria". West Afr J Med 41.1 (2024): 74-81.
35. Hamrani A., et al. "Prevalence of Metabolic Syndrome and its Individual Components among Moroccan Adolescents: The Role of Overweight-Obesity and Excess Body Fat". J Metabolic Synd 2 (2013): 129.
36. Reina SA., et al. "Metabolic Syndrome in Hispanic Youth: Results from the Hispanic Community Children's Health Study/Study of Latino Youth". Metab Syndr Relat Disord 15.8 (2017): 400-406.
37. Fitzpatrick SL., et al. "Metabolic syndrome risk profiles among African American adolescents: national health and nutrition examination survey, 2003-2010". Diabetes Care 36.2 (2013): 436-42.
38. Alireza A., et al. "Metabolic syndrome in Iranian Youths; A Population-based study on Junior and High Schools Students in Rural and Urban Areas". J Diabet Res (2013): 738485.
39. Mehairi AE., et al. "Metabolic syndrome among Emirati adolescents: a school-based study". PLoS One 8 (2013): e56159.
40. Tandon N., et al. "Prevalence of metabolic syndrome among urban Indian adolescents and its relation with insulin resistance (HOMA-IR)". J Pediatr Endocrinol Metab 26 (2013): 1123-30.
41. Mehmet Agirbasli., et al. "Sex Hormones and Metabolic Syndrome in Children and Adolescents". Metabolism 58.9 (2009): 1256-62.
42. Hillman JB and Biro FM. "Dynamic Changes of Adiposity During Puberty: Life May Not Be Linear". J. Adolesc. Health 47 (2010): 322-323.
43. Birken CS., et al. "Determining rates of overweight and obese status in children using electronic medical records: Cross-sectional study". Can Fam Physician 63.2 (2017): e114-e122.
44. Arum P, Perwiraningrum DA and Werdiharini AE. "Overweight and Obesity in Adolescence as A Risk Factor of Metabolic Syndrome". The First International Conference of Food and Agriculture (2020).
45. Bitew ZW., et al. "Metabolic syndrome among children and adolescents in low- and middle-income countries: a systematic review and meta-analysis". Diabetol Metab Syndr 12 (2020): 93.
46. Cho KH. "The Current Status of Research on High-Density Lipoproteins (HDL): A Paradigm Shift from HDL Quantity to HDL Quality and HDL Functionality". Int J Mol Sci 23.7 (2022): 3967.
47. Bartlett J., et al. "Is Isolated Low High-Density Lipoprotein Cholesterol a Cardiovascular Disease Risk Factor? New Insights from the Framingham Offspring Study". Circ Cardiovasc Qual Outcomes 9.3 (2016): 206-212.
48. Regaieg S., et al. "Prevalence of Metabolic Syndrome and Its Components among Overweight and Obese Secondary School Adolescent in SFAX, Tunisia". International Journal of Clinical Nutrition 3.1 (2015): 1-6.
49. Sheridan S, Pignone M and Mulrow C. "Framingham-based tools to calculate the global risk of coronary heart disease: a systematic review of tools for clinicians". J Gen Intern Med 18 (2003): 1039-52.
50. Toth PP., et al. "High-density lipoproteins: a consensus statement from the National Lipid Association". J Clin Lipidol 7 (2013): 484-525.
51. Gorman BK and Read J. "Why men die younger than women". Geriatr. Aging 10 (2007): 179-181.
52. Cho YK and Jung CH. "HDL-C and Cardiovascular Risk: You Don't Need to Worry about Extremely High HDL-C Levels". J Lipid Atheroscler 10.1 (2021): 57-61.
53. Han BH., et al. "Impact of Mean and Variability of High-Density Lipoprotein-Cholesterol on the Risk of Myocardial Infarction, Stroke, and Mortality in the General Population". Journal of the American Heart Association 9.7 (2020): e015493.
54. Grundy SM. "Metabolic syndrome update". Trends Cardiovasc. Med 26 (2016): 364-373.
55. Friedemann C., et al. "Cardiovascular disease risk in healthy children and its association with body mass index: systematic review and meta-analysis". BMJ 345 (2012): e4759.
56. National Cholesterol Education Program Expert Panel on Detection Evaluation and Treatment of High Blood Cholesterol in Adults Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Circulation 106 (2002): 3143-421.

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