Research Article ISSN 2835-6276

American Journal of Medical and Clinical Research & Reviews

Food Consumption Habits Among Black African Adolescents With Metabolic Syndrome In Lagos State, Nigeria

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Received: 11 April 2024; **Accepted:** 26 April 2024; **Published:** 05 May 2024

Citation: Bamgboye M. Afolabi. Food Consumption Habits Among Black African Adolescents With Metabolic Syndrome In Lagos State, Nigeria. AJMCRR 2024; 3(5): 1-20.

ABSTRACT

Introduction: *Metabolic syndrome (MetS), a cluster of metabolic abnormalities characterized by dyslipidemia, high blood pressure, high fasting blood glucose level and abdominal obesity is becoming a public health concern in sub-Saharan Africa. Very few studies have linked intake of certain food items to the occurrence of MetS among Nigerian adolescents despite abundance of these food items in the country during the study period.*

Objective: *This study, therefore, aimed at determining the contribution of animal protein and other food items to MetS in adolescents living in Lagos, Nigeria.*

Materials and Methods: *Six hundred and fifty adolescents (age range: 10–19 years, boys, and girls) were recruited into this cross-sectional study, though complete, analyzable data were from 624 participants. Face-to-face dietary assessments were conducted using a validated food-frequency questionnaire. Seven food groups – animal protein, green vegetables, carbohydrates, sweets, dairy products, fruits, and nuts – and physical activity level were included in the questionnaire. Anthropometric measurements were carried out for each participant. Fasting venous blood was collected for lipid profile and blood glucose assessments. Blood pressure was measured and MetS was assessed using appropriate diagnostic criteria for adolescents.*

Results: *In general, boys were slightly more likely to be high weekly consumers of animal protein (χ^2=0.008, P-value=0.93, OR=1.02, 95% CI=0.70,1.47) than girls. Specifically, boys with MetS were*

1.83 times more likely to be high consumers of animal protein (χ^2=2.47, P-value=0.12, OR=1.83, 95% CI=0.89,3.92) than those without MetS; girls with MetS were less likely to be high consumers of animal protein (χ^2=0.03, P-value=0.86, OR=0.77, 95% CI=0.25,2.40). The proportion of subjects with MetS who consumed animal protein ≤1.5 times a week (9.6%) was lower than the proportion that consumed it >3 times weekly (30.8%). High weekly consumption of sweets, fruits and high level of physical exercise conferred low probability of having MetS for the subjects.

Conclusions: *High weekly consumption of animal protein appears to be a risk factor for the development of MetS, especially among boys. Fruits and Physical activities ameliorate the chances of MetS in both genders. Adolescent nutrition platforms and regular physical exercise are essential criteria needed to address MetS among adolescents.*

Keywords: Adolescents, Black Africans, Lean, Metabolic syndrome, Nigerians, Overweight/ Obese.

Introduction

Increasing demands for energy proteins and micronutrients are necessary to cope with the rapid linear pubertal growth and development, change in body composition, and increased physical activity. Adequate nutrition is a key permissive factor for the normal timing and tempo of pubertal development [1]. The extreme upsurge in energy and nutrient requirements concurs with other factors that may affect adolescents' food choices, nutrient intake, and thus, nutritional status. These factors, including the quest for independence and acceptance by peers, increased mobility, greater time spent at school and/or work activities, and concern with self-image, contribute to the unpredictable and unhealthy eating behaviors that are common during adolescence [2, 3]. A poor diet may cause health problems later in life such as obesity, heart disease, or diabetes. The high prevalence of unhealthy eating behaviors can contribute to undernutrition, and this can lead to the development of eating disorders [4]. Sometimes, beliefs, culture and tradition play an important role in a family's concepts of healthy and unhealthy foods, which may or may not be accurate [5]. Unhealthy eating habits are seen in adolescents in the United States and many other countries [6-10]. Typical adolescent and high school students' eating habits include skipping meals, fast food consumption, frequent snacking, and dieting behaviors. This cohort of people consume high dense energy from saturated fat and/or added sugar, high sodium intake and have a lower intake of vitamin A, folic acid, fiber, iron, calcium, vitamin D, and zinc than is recommended [11, 12]. Worldwide, atherosclerotic cardiovascular diseases (CVDs) are becoming more common and having an earlier onset due to poor eating habits and inactivity throughout adolescent period [13]. Metabolic disorders such as Obesity, Type 2 Diabetes mellitus (T2DM), and Inflammatory Bowel Diseases are the most prevalent globally. Metabolic syndrome is a gathering of at least three of the following five medical conditions: abdominal obesity, high blood pressure, high blood sugar, high serum triglycerides, and low serum high-density lipoprotein (HDL). Metabolic syndrome is associated with the risk of developing cardiovascular disease and T2DM [14]. A systematic review with modelling analysis reports that (i) 25.8 million children and 35.5 million adolescents in 44 nations in 13 regions were living with MetS in 2020, (ii) with adult prevalence of 5.5% in high income nations, 3.9% in upper middle-income nations, 4.5% in lower middle-income nations and 7.0% in low-income nations of which sub_saharan African countries (including West Africa) are part. and (iii) three countries with the highest prevalence of MetS among adolescents were Iran with 9.0%, United Arab Emirates 9.8% and Spain 9.9%. [15]. Another study reported the prevalence of MetS among adolescent female students in intermediate and secondary schools in Saudi Arabia as 7%, among obese subjects [16]. In the same study, the prevalence of MetS among female students with normal BMI was 3.2%. In Nigeria, the overall prevalence of MetS among secondary school students was 8.3% with roughly 15%, 44% in early, mid, late adolescence and with 32% and 9% with overweight and obesity respectively [17]. Food consumption patterns among Nigerians and other Africans have been reported. However, the dietary pattern of secondary school students in Nigeria has not been fully investigated. For example, in Nigeria Olatona et al [18] reported that dietary habits and diversity of the adolescents were poor, while overweight and obesity were high. Have et al [19] concluded that the Nigerian diet is made up of chiefly cereals and other plant-based foods, while animal protein diet is eaten to a lesser extent. Data from 4609 adolescents aged 10–15 years in Burkina Faso, Ethiopia, Sudan, and Tanzania reported that there is evidence of poor-quality adolescent diets and gender and age differences in the consumption of healthy diets. Studies have also been conducted on MetS among adolescents in sub-Saharan Africa [20]. Dyslipidemia and MetS have also been reported among Nigerian adolescents [21-25]. However, very few of these studies associated dietary pattern and frequency of consumption of food to presence or absence of metabolic syndrome. Further, hardly did any one of the studies segregated the adolescent participants by sex, BMI-for-age percentile, and stage of adolescence in respect of dietary pattern and metabolic syndrome. Therefore, this study aims to estimate the association of dietary habits of boys and girls who were lean or overweight/obese and in different stages of adolescence with presence or absence of metabolic syndrome in Lagos State, Nigeria. The findings of this study will serve as a foundation to launch a plan for developing effective interventional programs for the prevention of unhealthy diet and metabolic syndrome among Nigerian adolescents.

Materials and Method

Ethical approval for this study was given by the Institutional Review Board of the Nigerian Institute of Medical Research (IRB/18/062). Documented informed consents were also obtained from parents and/or guardians prior to participants' verbal agreement. The study, carried out according to the Helsinki Declaration (2000), was cross-sectional and descriptive, and it included 650 secondary school students in Lagos State, Nigeria, within the ages of 10-19 years, from whom 613 (94.3%) complete primary data was collected. Recruitment into the study started in October 2019 while the entire study ended in March 2020.

Study site: Lagos State, with a heterogenous population of approximately 20 million is one of the 36 states in Nigeria and is located Southwest of the country right on the Atlantic Ocean coastline. The city is the economic center of the country with high -riser buildings, good road network and acceptable sewage system.

Sample size, sampling technique and procedure: This had been described in a previous publication [25]. Briefly, the sample size was designed for a single population with 95% confidence interval 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 would then be 650 students to cater for attrition and missing data. There are three Senatorial Districts – Lagos East, Lagos West and Lagos Central – with 5, 10 and 5 Local Government Areas (LGA) respectively. Participants were recruited using simple random sampling, probability proportional to size and systematic sampling technique.

Inclusion and exclusion criteria: Criteria for involvement in the study were (i) age must be between 10 and 19 years, (ii) study participant must be a registered and regular student in the school of study (iii) must be a Nigerian resident in the community of study for a minimum of 2 years. Exclusion criteria were (i) those on therapeutic diet or drugs, (ii) those who had been admitted in a health facility 6 months prior to the study (iii) pregnancy, suspected pregnancy, breastfeeding, or use of oral contraceptive (iv) Caucasians.

Questionnaire: A part of the study involved administration of questionnaire of which responses to food frequency such as age, sex and weekly consumption of specified food items are relevant to this paper.

Measurements: Determination of Metabolic syndrome (MetS) has already been established in a previous paper [25]. Briefly, to ascertain whether a student had or did not have MetS, anthropometric measurements such as body weight (to the nearest 0.1 kg, with minimal clothing and no shoes), height, and waist circumferences were taken by trained field workers. 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 [26]. Systolic and diastolic blood pressures (left upper arm) and pulse rate were measured after 30 min sitting using automatic blood pressure monitor and the average of three consecutive measurements, with an interval of 5-10 minutes between each measurement, was used. After overnight fasting, 5 ml of venous blood was taken and separated into fluoride oxalate tubes for fasting blood glucose (FBG) analysis, and into Lithium heparin tubes for lipids analyses – total cholesterol, triglyceride, high-density lipoprotein (HDL) and low-density lipoprotein (LDL).

Data analysis: NCSS Statistical Software (2022) Kaysville, Utah, USA, ncss.com/software/ncss. was used for data analyses. Before analysis, normality of the data distribution for continuous measures was verified by Kolmogorov-Smirnov Normality test. Failure of the test resulted in the use of Mann-Whitney U-test and Kruskal-Wallis one-way ANOVA for the assessment of the differences between 2 and 3 medians respectively. Independent Student's t-tests were used to identify differences in anthropometric measurements. Descriptive statistics were performed to determine differences between boys and girls, early and late adolescence and between lean and overweight/ obese study subjects. Those with MetS were categorized as Target group and those without as Not Target group. Linear logistic regression was performed on STATA 13, using the presence of MetS – defined as cMetS 90% – as dependent variables and scores calculated from the lifestyle questionnaire as predictor variables. Responses to each food frequency question were computed and the

75% percentiles were used as cutoff points for low and high values to which the numerals 0 and 1 were assigned, respectively. A P-value of <0.05 was taken as significant. Results were presented in Tables, graphs, and figures.

Results

Anthropometric and clinical characteristics of study subjects (Table 1).

A total of 650 students were recruited into the study but only 613 (94.3%) completed the food frequency questionnaire for analysis among who 236 (38.5%) were boys and 377 (61.5%) girls. Overall, 297 (48.5%) were in early and 316 (51.5%) in late adolescence, 563 (91.8%) were lean and 50 (8.2%) were overweight/obese (boys: n=15 or 6.4%; girls: n=35 or 9.3%). There was no significant difference in the means of age (14.8±2.2 vs 14.6±2.1 years; t-test=1.10, P-value=0.27), weight (46.5±12.4 vs 47.9±11.1 kg; t-test= -1.4, P-value=0.16) and height (157.7±12.9 vs 156.0±11.9 cm; t-test=1.6, **P -value=0.10**) of boys and girls respectively. However, the mean BMI (kg/m^2) of girls (19.5±4.1) was significantly higher (t-test= -2.21, **P-value=0.03**) than that of boys (18.7±4.5). Whereas no notable variation was observed in the mean SBP of males and females, there was a significant variation (t-test= -2.31, **P-value=0.02**) in the mean DBP.

Table 1. Anthropometric and clinical characteristics of study participants.

Variable	Unit		All (n=613, 100.0%)	Boys (n=236, 38.5%)	Girls (n=377, 61.5%)	t-test (P-value)
Age	years	Mean (±sd)	14.7 (2.1)	14.8 (2.2)	14.6 (2.1)	1.1 (0.27)
Weight	kilogram		47.4 (11.6)	46.5 (12.4)	47.9 (11.1)	-1.4 (0.16)
Height	centimeter		156.7 (12.3)	157.7 (12.9)	156.0 (11.9)	1.6 (0.10)
BMI	kilogram/m^2		19.2 (4.3)	18.7 (4.5)	19.5 (4.1)	-2.21 (0.03)
Systolic BP	mm Hg		108.2 (12.4)	108.5 (13.9)	108.1 (11.4)	0.37 (0.71)
Diastolic BP	mm Hg		66.2 (1.8)	65.0 (10.4)	66.9 (9.1)	-2.31 (0.02)
BMI-for-age percentile	Lean	Freq. (%)	563 (91.8)	221 (93.6)	342 (90.7)	1.66 (0.20)* 1.51 (0.80, 2.83)!
	Overweight./ Obese		50 (8.2)	15 (6.4)	35 (9.3)	
Stage of adolescence	Early		297 (48.5)	109 (46.2)	188 (49.9)	0.78 (0.38)* 0.86 (0.62, 1.20)!
	Late		316 (51.5)	127 (53.8)	189 (50.1)	

*=χ^2, != Odds ratio (95% Confidence Interval)

Weekly consumption of various food items relative to gender, BMI, and Stage of adolescence. (Table 2).

A large proportion of the study subjects reported low weekly consumption of animal protein (448, 73.%), green vegetables (457, 74.6%), carbohydrate (454, 74.1%), sweets (448, 73.1%), dairy products

(452, 73.7%), fruits (458, 74.7%) and nuts (454, 74.1%). In general, level of physical activities was also low (421, 68.7%). In general, except in physical activities only among boys and girls, there was no statistically significant difference regarding consumption of identified food items when the subjects were segregated by BMI-for-age or stage of adolescence. The probability of high consumption of animal protein (OR=1.02, 95% CI=0.70, 1.47), green vegetables (OR=1.07, 95% CI=0.74, 1.56), dairy products (OR=1.11, 95% CI=0.77, 1.61) and nuts (OR=1.07, 95% CI=0.74, 1.54) was higher among boys compared to girls. On the contrary, the probability of high weekly consumption of carbohydrates (OR=0.89, 95% CI=0.61, 1.29) and sweets (OR=0.88, 95% CI=0.61, 1.28) was lesser in boys compared to girls. Boys were also less likely to engage in high physical exercise compared to girls (OR=1.61, 95% CI=0.43, 0.88). Lean subjects were slightly more likely to report high weekly consumption of animal protein (OR=1.52, 95% CI=0.74, 3.11), green vegetables (OR=1.09, 95% CI=0.55, 2.14), sweets (OR=1.05, 95% CI=0.54, 2.03), dairy products (OR=1.14, 95% CI=0.58, 2.24), fruits (OR=1.22, 95% CI=0.61, 2.44) and nuts (OR=1.65, 95% CI=0.79, 3.49). Surprisingly, high level of physical activity was less likely among lean adolescents (OR=0.72, 95% CI=0.40, 1.32) when compared to overweight/obese subjects. Compared to those in late adolescence, subjects in early adolescents were, less likely to be high consumers of animal protein (OR=0.91, 95% CI=0.63, 1.30), green vegetables (OR=0.77, 95% CI=0.53, 1.11), carbohydrates (OR=0.84, 95% CI=0.59, 1.21), sweets (OR=0.82, 95% CI=0.57, 1.17), dairy products (OR=0.97, 95% CI=0.67, 1.39), fruits (OR=0.93, 95% CI=0.65, 1.34) and nuts (OR=0.93, 95% CI=0.65, 1.34).

Table 2. Weekly consumption of various food items relative to gender, BMI, and Stage of adolescence.

	Weekly consumption	All	Gender		BMI		Stage of adolescence	
			Boys	Girls	Lean	O/O	Early	Late
Animal protein	High	165 (26.9)	64 (27.1)	101 (26.8)	155 (27.5)	10 (20.0)	77 (25.9)	88 (27.8)
	Low	448 (73.1)	172 (72.9)	276 (73.2)	408 (72.5)	40 (80.0)	220 (74.1)	228 (72.2)
χ^2 (P-value)			0.008 (0.93)		1.32 (0.25)		0.29 (0.59)	
OR (95% CI)			1.02 (0.70, 1.47)		1.52 (0.74, 3.11)		0.91 (0.63, 1.30)	
Green vegetables	High	156 (25.4)	62 (26.3)	94 (24.9)	144 (25.6)	12 (24.0)	68 (22.9)	88 (27.8)
	Low	457 (74.6)	174 (73.7)	283 (75.1)	419 (74.4)	38 (76.0)	229 (77.1)	228 (72.2)
χ^2 (P-value)			0.14 (0.71)		0.06 (0.81)		1.98 (0.16)	
OR (95% CI)			1.07 (0.74, 1.56)		1.09 (0.55, 2.14)		0.77 (0.53, 1.11)	
Carbohydrate	High	159 (25.9)	58 (24.6)	101 (26.8)	144 (25.6)	15 (30.0)	72 (24.2)	87 (27.5)
	Low	454 (74.1)	178 (75.4)	276 (73.2)	419 (74.4)	35 (70.0)	225 (75.8)	229 (72.5)
χ^2 (P-value)			0.37 (0.54)		0.47 (0.49)		0.86 (0.35)	
OR (95% CI)			0.89 (0.61, 1.29)		0.80 (0.43, 1.51)		0.84 (0.59, 1.21)	
Sweets	High	165 (26.9)	60 (25.4)	105 (27.8)	152 (27.0)	13 (26.0)	74 (24.9)	91 (28.8)
	Low	448 (73.1)	176 (74.6)	272 (72.2)	411 (73.0)	37 (74.0)	223 (75.1)	225 (71.2)
χ^2 (P-value)			0.43 (0.51)		0.02 (0.88)		1.17 (0.28)	
OR (95% CI)			0.88 (0.61, 1.28)		1.05 (0.54, 2.03)		0.82 (0.57, 1.17)	

Dairy products	High	161 (26.3)	65 (27.5)	96 (25.5)	149 (26.5)	12 (24.0)	77 (25.9)	84 (26.6)
	Low	452 (73.7)	171 (72.5)	281 (74.5)	414 (73.5)	38 (76.0)	220 (74.1)	232 (73.4)
χ² (P-value)			0.32 (0.57)		0.14 (0.70)		0.03 (0.85)	
OR (95% CI)			1.11 (0.77, 1.61)		1.14 (0.58, 2.24)		0.97 (0.67, 1.39)	
Fruits	High	155 (25.3)	58 (24.6)	97 (25.7)	144 (25.6)	11 (22.0)	73 (24.6)	82 (25.9)
	Low	458 (74.7)	178 (75.4)	280 (74.3)	419 (74.4)	39 (78.0)	224 (75.4)	234 (74.1)
χ² (P-value)			0.10 (0.75)		0.31 (0.58)		0.15 (0.70)	
OR (95% CI)			0.94 (0.65, 1.37)		1.22 (0.61, 2.44)		0.93 (0.65, 1.34)	
Nuts	High	159 (25.9)	63 (26.7)	96 (25.5)	150 (26.6)	9 (18.0)	75 (25.2)	84 (26.6)
	Low	454 (74.1)	173 (73.3)	281 (74.5)	413 (73.4)	41 (82.0)	222 (74.8)	232 (73.4)
χ² (P-value)			0.11 (0.74)		1.78 (0.18)		0.14 (0.71)	
OR (95% CI)			1.07 (0.74, 1.54)		1.65 (0.79, 3.49)		0.93 (0.65, 1.34)	
Physical exercise*	High	192 (31.3)	59 (25.0)	133 (35.3)	173 (30.7)	19 (38.0)	99 (33.3)	93 (29.4)
	Low	421 (68.7)	177 (75.0)	244 (64.7)	390 (69.3)	31 (62.0)	198 (66.7)	223 (70.6)
χ² (P-value)			7.12 (0.007)		1.13 (0.29)		1.08 (0.30)	
OR (95% CI)			0.61 (0.43, 0.88)		0.72 (0.40, 1.32)		1.20 (0.85, 1.69)	

*Number of times per week.

Metabolic syndrome and weekly consumption of various food items relative to gender, BMI, and Stage of adolescence (Table 3a-c).

There were no significant differences in the proportion of subjects with high weekly consumption of any of the food items, regardless of their MetS status. However, those with weekly high consumption of animal protein (17, 32.7%) and green vegetables (16, 30.8%) were approximately 1.4 and 1.3 times, more likely to be in the target group (OR=1.36, 95% CI=0.74, 2.49) and (OR=1.34, 95% CI=0.72, 2.48) respectively. High weekly consumption of fruits and high level of weekly physical activities protected subjects from being in the target group (Table 3a). Boys in the target group were approximately 1.8, 1.7, 1.6, 1.5 and 1.8 times more likely to be high consumers of animal protein, green vegetables, carbohydrates, dairy products, and high level of physical exercise compared to boys in the non-target group. On the contrary girls that reported weekly high consumption of animal protein, green vegetables, carbohydrates, sweets, dairy products, fruits, and high level of physical exercise were less likely (approximately 0.8, 0.9, 0.5, 0.7, 0.6, 0.6 and 0.2 times) to be in the target group (Table 3b).

Table 3. Weekly consumption of various food items by all subjects (a) with or without metabolic syndrome relative to gender (b), BMI-for-age percentile (c), and Stage of adolescence (d).

Weekly consumption	Category	MetS		χ² (P-value)	OR	95% CI
		≥90 pctl	<90 pctl			
		Gender, BMI-for-age percentile and Stage of adolescence				
Animal protein	High	17 (32.7)	148 (26.4)	0.96 (0.33)	1.36	0.74, 2.49
	Low	35 (67.3)	413 (73.6)			
Green vegetables	High	16 (30.8)	140 (25.0)	0.85 (0.36)	1.34	0.72, 2.48
	Low	36 (69.2)	421 (75.0)			

Carbohydrate	High	14 (26.9)	145 (28.9)	0.03 (0.87)	1.06	0.56, 2.01
	Low	38 (73.1)	416 (74.1)			
Sweets	High	13 (25.0)	152 (27.1)	0.11 (0.90)	0.90	0.47, 1.73
	Low	39 (75.0)	409 (72.9)			
Dairy products	High	15 (28.8)	146 (26.0)	0.20 (0.66)	1.15	0.61, 2.16
	Low	37 (71.2)	415 (74.0)			
Fruit	High	11 (21.1)	144 (25.7)	0.51 (0.47)	0.78	0.39, 1.55
	Low	41 (78.9)	417 (74.3)			
Nuts	High	15 (28.8)	144 (25.7)	0.25 (0.62)	1.17	0.63, 2.20
	Low	37 (71.2)	417 (74.3)			
Physical exercise	High	14 (26.9)	178 (31.7)	0.51 (0.47)	0.79	0.42, 1.50
	Low	38 (73.1)	383 (68.3)			

Gender, BMI-for-age percentile and Stage of adolescence											
		Boys		χ² (P-value)	OR	95% CI	Girls		χ² (P-value)	OR	95% CI
		≥90 pctl	<90 pctl				≥90 pctl	<90 pctl			
Animal protein	High	13 (38.2)	51 (25.2)	2.47 (0.12)	1.83	0.89, 3.92	4 (22.2)	97 (27.0)	0.03 (0.86)	0.77	0.25, 2.40
	Low	21 (61.8)	151 (74.8)				14 (77.8)	262 (73.0)			
Green vegetables	High	12 (35.3)	50 (24.7)	1.66 (0.20)	1.66	0.77, 3.59	4 (22.2)	90 (25.1)	0.00 (1.00)	0.85	0.27, 2.66
	Low	22 (64.7)	152 (75.3)				14 (77.8)	269 (74.9)			
Carbohydrate	High	11 (32.3)	47 (23.3)	1.29 (0.26)	1.58	0.72, 3.47	3 (16.7)	98 (27.3)	0.52 (0.47)	0.53	0.15, 1.88
	Low	23 (67.7)	155 (76.7)				15 (83.3)	261 (72.7)			
Sweets	High	9 (26.5)	51 (25.2)	0.02 (0.88)	1.07	0.47, 2.43	4 (22.2)	101 (28.1)	0.08 (0.78)	0.73	0.23, 2.27
	Low	25 (73.5)	151 (74.8)				14 (77.8)	258 (71.9)			
Dairy products	High	12 (35.3)	53 (26.2)	1.19 (0.28)	1.53	0.71, 3.31	3 (16.7)	93 (25.9)	0.36 (0.55)	0.57	0.16, 2.02
	Low	22 (64.7)	149 (73.8)				15 (83.3)	266 (74.1)			
Fruit	High	8 (23.5)	50 (24.7)	0.02 (0.88)	0.94	0.40, 2.20	3 (16.7)	94 (26.2)	0.39 (0.53)	0.56	0.16, 1.99
	Low	26 (76.5)	152 (75.3)				15 (83.3)	265 (73.8)			
Nuts	High	10 (29.4)	53 (26.2)	0.15 (0.70)	1.17	0.53, 2.61	5 (27.8)	91 (25.3)	0.00 (1.00)	1.13	0.39, 3.26
	Low	24 (70.6)	149 (73.8)				13 (72.2)	268 (74.7)			
Physical exercise	High	12 (35.3)	47 (23.3)	2.24 (0.13)	1.80	0.83, 3.91	2 (11.1)	131 (36.5)	3.79 (0.05)	0.22	0.05, 0.96
	Low	22 (64.7)	155 (76.7)				16 (88.9)	228 (63.5)			

Lean subjects in the target group were about 1.5 times more likely to be high weekly consumers of animal protein (OR=1.52, 95% CI=0.77, 3.01) and of green vegetables (OR=1.50, 95% CI=0.75, 3.00) compared to those without MetS. Overweight/obese subjects in the target group were approximately 1.3 and 0.93 more likely to be high weekly consumers of animal protein (OR=1.29, 95% CI=0.28, 5.94) and green vegetables (OR=0.93, 95% CI=0.21, 4.15) compared to those without MetS. High weekly consumption of sweets and fruits seemed to protect lean (OR=0.93, 95% CI=0.44, 1.95 and OR=0.86, 95% CI=0.40, 3.05) and overweight/obese (OR=0.81, 95% CI=0.18, 3.56 and OR=0.57, 95% CI=0.11, 1.87) adolescents from MetS. High level of physical exercise also likely exerted this effect on the lean (OR=0.76, 95% CI=0.36, 1.60) and overweight/obese (OR=0.65, 95% CI=0.17, 2.51) subjects (Table 3c). Early adolescents in the target group were about 1.5 and 2.2 times more likely to be high weekly consumers of animal protein (OR=1.50, 95% CI=0.61, 3.61) and green vegetables (OR=2.2, 95% CI=0.91, 5.22) compared with their counterpart in the non-target group. High weekly consumption of carbohydrate (OR=0.80, 95% CI=0.29, 2.25), dairy products (OR=0.7, 95% CI=0.26, 2.03), and fruits

(OR=0.6, 95% CI=0.20, 1.79) were protective against MetS among those in early adolescence while green vegetable (OR=0.9, 95% CI=0.35, 2.08), sweets, (OR=0.8, 95% CI=0.33, 1.98), fruits (OR=0.9, 95% CI=0.39, 2.32), and physical exercise (OR=0.5, 95% CI=0.18, 1.34), were protective against MetS among those in late adolescence (Table 3d).

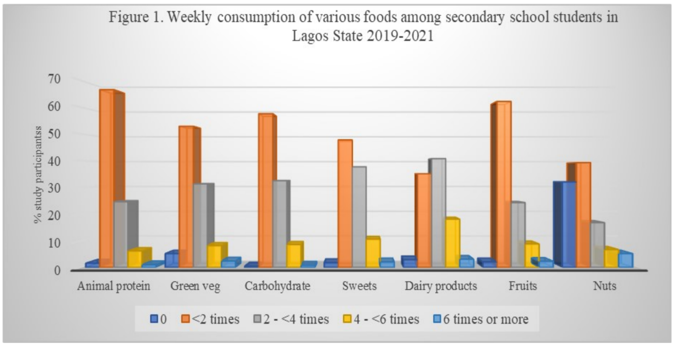
Gender, BMI-for-age percentile and Stage of adolescence											
		Lean		χ² (P-value)	OR	95% CI	Overweight/Obese		χ² (P-value)	OR	95% CI
		≥90 pctl	<90 pctl				≥90 pctl	<90 pctl			
Animal protein	High	14 (35.9)	141 (26.9)	1.47 (0.23)	1.5	0.77, 3.01	3 (23.1)	7 (18.9)	0.00 (1.00)	1.29	0.28, 5.94
	Low	25 (64.1)	383 (73.1)				10 (76.9)	30 (81.1)			
Green vegetables	High	13 (33.3)	131 (25.0)	1.32 (0.25)	1.5	0.75, 3.00	3 (23.1)	9 (24.3)	0.00 (1.00)	0.93	0.21, 4.15
	Low	26 (66.7)	393 (75.0)				10 (76.9)	28 (75.7)			
Carbohydrate	High	12 (30.8)	132 (25.2)	0.59 (0.44)	1.3	0.65, 2.68	2 (15.4)	13 (35.1)	0.97 (0.32)	0.34	0.06, 1.75
	Low	27 (69.2)	392 (74.8)				11 (84.6)	24 (64.9)			
Sweets	High	10 (25.6)	142 (27.1)	0.04 (0.84)	0.9	0.44, 1.95	3 (23.1)	10 (27.0)	0.00 (1.00)	0.81	0.18, 3.56
	Low	29 (74.4)	382 (72.9)				10 (76.9)	27 (73.0)			
Dairy products	High	12 (30.8)	137 (26.1)	0.40 (0.53)	1.2	0.62, 2.55	3 (23.1)	9 (24.3)	0.00 (1.00)	0.93	0.21, 4.15
	Low	27 (69.2)	387 (73.9)				10 (76.9)	28 (75.7)			
Fruit	High	9 (23.1)	135 (25.8)	0.14 (0.71)	0.8	0.40, 1.87	2 (15.4)	11 (84.6)	0.08 (0.78)	0.57	0.11, 3.05
	Low	30 (76.9)	389 (74.2)				9 (24.3)	28 (75.7)			
Nuts	High	12 (30.8)	138 (26.3)	0.36 (0.55)	1.2	0.61, 2.52	3 (23.1)	6 (16.2)	0.02 (0.89)	1.55	0.33, 7.36
	Low	27 (69.2)	386 (73.7)				10 (76.9)	31 (83.8)			
Physical exercise	High	10 (25.6)	163 (31.1)	0.51 (0.48)	0.7	0.36, 1.60	4 (30.8)	15 (40.5)	0.09 (0.77)	0.65	0.17, 2.51
	Low	29 (74.4)	361 (68.9)				9 (69.2)	22 (59.5)			

Gender, BMI-for-age percentile and Stage of adolescence											
		Early		χ² (P-value)	OR	95% CI	Late		χ² (P-value)	OR	95% CI
		≥90 pctl	<90 pctl				≥90 pctl	<90 pctl			
Animal protein	High	8 (33.3)	69 (25.3)	0.74 (0.39)	1.5	0.61, 3.61	9 (32.1)	79 (27.4)	0.28 (0.60)	1.3	0.54, 0.89
	Low	16 (66.7)	204 (74.7)				19 (67.9)	209 (72.6)			
Green vegetables	High	9 (37.5)	59 (21.6)	3.14 (0.08)	2.2	0.91, 5.22	7 (25.0)	81 (28.1)	0.12 (0.73)	0.9	0.35, 2.08
	Low	15 (62.5)	214 (78.4)				21 (75.0)	207 (71.9)			
Carbohydrate	High	5 (20.8)	67 (24.5)	0.16 (0.68)	0.8	0.29, 2.25	9 (32.1)	78 (27.1)	0.33 (0.57)	1.3	0.55, 2.94
	Low	19 (79.2)	206 (75.5)				19 (67.9)	210 (72.9)			
Sweets	High	6 (25.0)	68 (24.9)	0.00 (0.99)	1.0	0.38, 2.63	7 (25.0)	84 (29.2)	0.22 (0.64)	0.8	0.33, 1.98
	Low	18 (75.0)	205 (75.1)				21 (75.0)	204 (70.8)			
Dairy products	High	5 (20.8)	72 (26.4)	0.35 (0.55)	0.7	0.26, 2.03	10 (35.7)	74 (25.7)	1.31 (0.25)	1.6	0.71, 3.64
	Low	19 (79.2)	201 (73.6)				18 (64.3)	214 (74.3)			
Fruit	High	4 (16.7)	69 (25.3)	0.48 (0.49)	0.6	0.20, 1.79	7 (25.0)	75 (26.0)	0.01 (0.90)	0.9	0.39, 2.32
	Low	20 (93.3)	204 (74.7)				21 (75.0)	213 (74.0)			
Nuts	High	6 (25.0)	69 (25.3)	0.00 (0.98)	1.0	0.38, 2.58	9 (32.1)	75 (26.0)	0.49 (0.49)	1.3	0.58, 3.10
	Low	18 (75.0)	204 (74.7				19 (67.9)	213 (74.0)			
Physical exercise	High	9 (37.5)	90 (33.0)	0.20 (0.65)	1.2	0.51, 2.89	5 (17.9)	88 (30.6)	1.42 (0.23)	0.5	0.18, 1.34
	Low	15 (62.5)	183 (67.0)				23 (82.1)	200 (69.4)			

Metabolic syndrome is defined by cMetS score ≥90% among all study subjects.

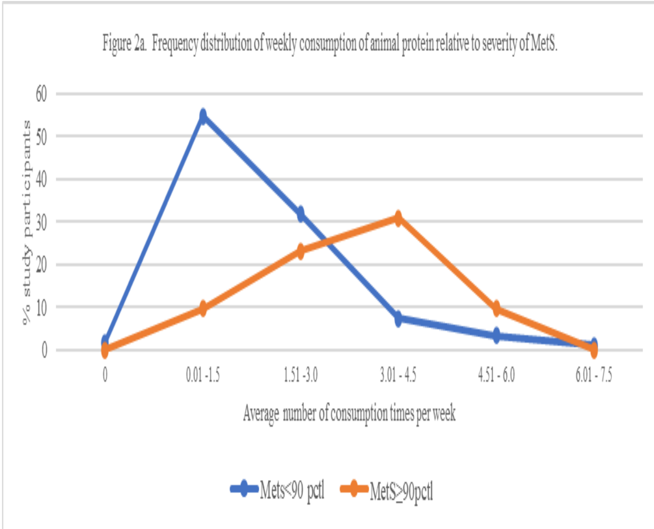
Frequency of weekly consumption of various food items by study subjects. Figure 1.

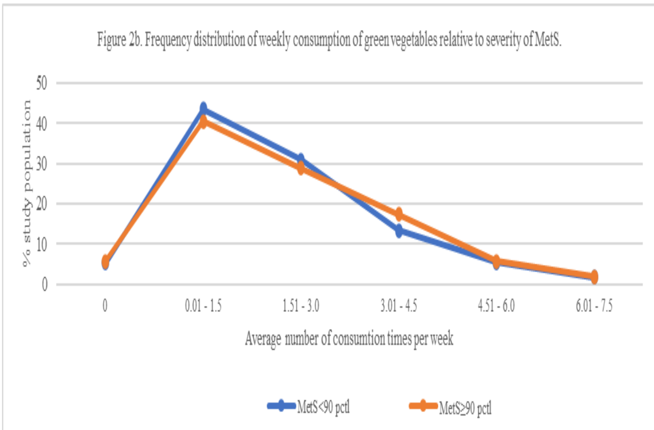
Overall, 1.6%, 5.2%, 0%, 1.8%, 2.9%, 2.1% and 32.0% of the study participants respectively did not consume animal protein, green vegetables, carbohydrates, sweets, dairy products, and fruits weekly. On the other hand, 66.6%, 52.9%, 57.6%, 47.8%, 35.1%, 62.2% and 39.3% respectively consumed these food items less than twice weekly. Dairy products (40.8%, 18.1% respectively) topped the food items that were mostly consumed 2-<4 and 4-<6 times weekly. In all, only 5.2% of study participants consumed nuts >6 times per week.

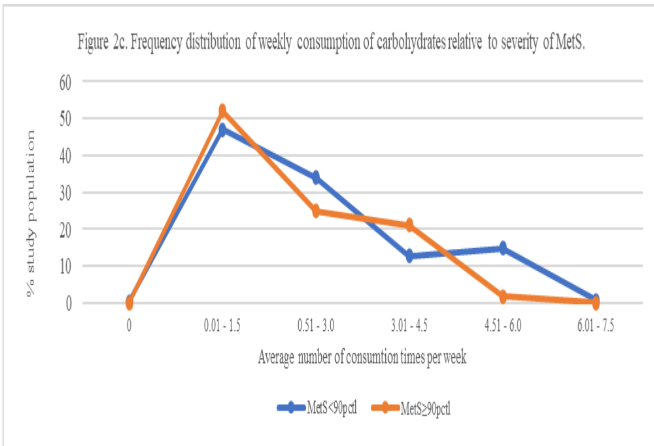


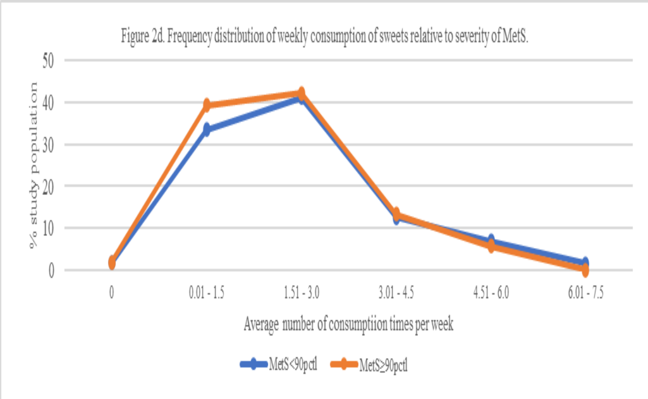
Frequency distribution charts of weekly consumption of (a) Animal protein (b) Green vegetables (c) Carbohydrate (d) Sweets (e) Dairy products (f) Fruits (g) Nuts and (h) physical exercise relative to degree of Metabolic syndrome among study subjects (Figure 2 (a-h)).

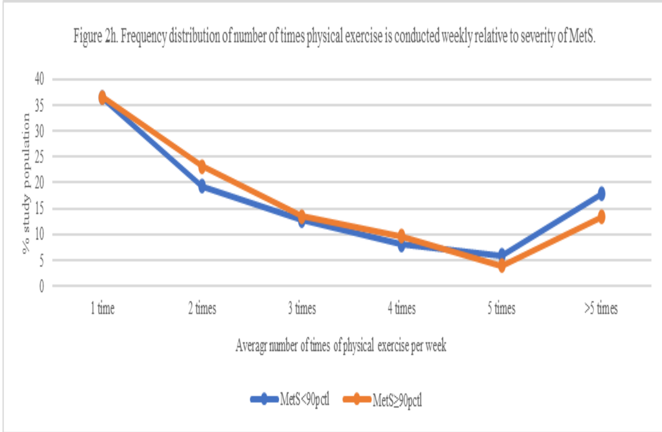
To compare, higher proportions of target group (30.8% and 9.6%), than non-target group (7.3%, 3.4%) consumed animal protein 3.01 to 4.5 times per week and >4.5 times per week respectively. Likewise, higher proportions of target group (17.3%) than non-target group (13.4%) consumed green vegetables >3 times per week. On the contrary, higher proportions of non-target group (43.5%) than target group (40.4%) consumed green vegetables >1.5 weekly. There was no significant difference in the proportion of those who consumed sweets more than 1.51 times weekly regardless of their MetS status. Surprisingly 65.4% of target group and 46.4% of non-target group hardly consumed fruits weekly, 15.3% and 10.9% of the index group and non-target group consumed fruits 3.01-4.5 times weekly while only 1.9% and 5.0% of the respective groups consumed fruits >4.5 times weekly. In all, 23.1% and 19.3% of target and non-target groups engaged in physical activities twice weekly, while just 13.4% and 17.8% respectively engaged in physical activities >5 times weekly.

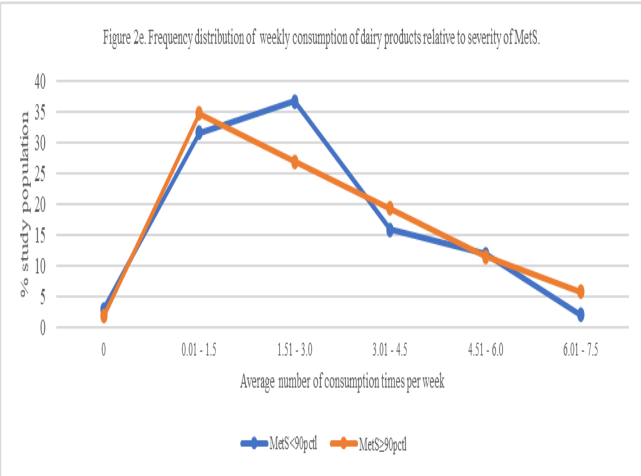


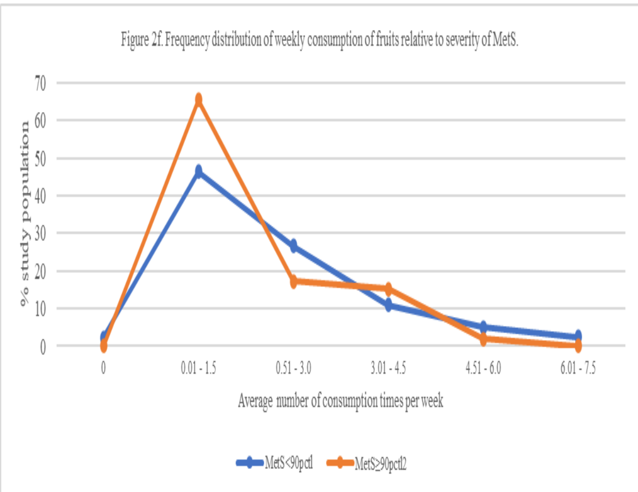












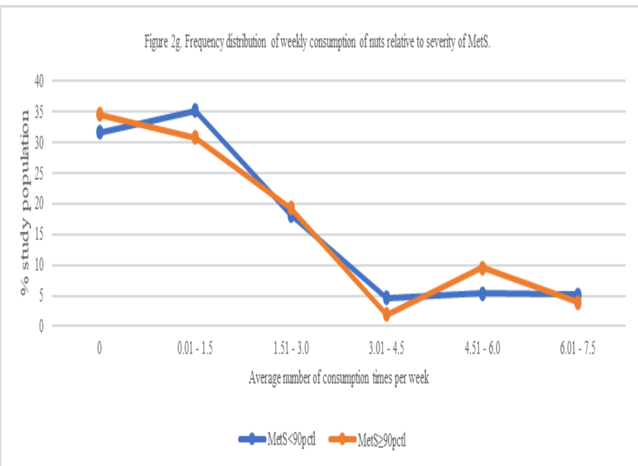


Figure 2(a-h). Frequency distribution charts of weekly consumption of (2a) Animal protein (2b) Green vegetables (2c) Carbohydrate (2d) Sweets (2e) Dairy products (2f) Fruits (2g) Nuts and Physical exercise (2h) relative to degree of Metabolic syndrome among adolescents in Lagos, Nigeria.

Linear logistic regression with MetS as dependent variable and high consumption of various food items as predictor variables (Table 4).

Logistic regression was used to analyze the relationship between weekly consumption of specific foods and the probability of metabolic syndrome. The coefficient estimates for all study participants engaged in high weekly consumption of sweets (-0.26), fruits (-0.93) and physical exercise (-0.26) were negative, indicating a lower probability of having MetS. However, since the respective P-values are greater than 0.05, these predictor variables had no statistically significant effect on whether or not study participants belonged to the target group or not. The coefficient estimates for boys with high weekly consumption of sweets (-0.44) and of fruits (-0.95) were negative, indicating a decreased chance of being in the target group of MetS. However, since the respective P-values are greater than 0.05, these predictor variables had no statistically significant effect on grouping the boys in the target group of MetS. The coefficient estimates for girls with relatively high weekly consumption of animal protein (-0.02), carbohydrate (-0.60), dairy products (-0.49), and fruits (-0.46) were negative, indicating a decreased chance of being in the target MetS group. Again, these predictor variables, each with P-value >0.05, had no statistically significant effect on whether or not the girls belonged to the target MetS group. The coefficient estimates for girls with relatively high weekly physical exercise was also strongly negative (-1.57), indicating a strong probability of being in the non-target group.

Table 4. Linear logistic regression analysis of the association between Metabolic syndrome as dependent variable and high consumption of various food items as predictor variables.

Categories		All		Boys		Girls
Number of observations		613		236		377
LR χ^2		6.77		7.86		8.72
Prob > χ^2		0.56		0.45		0.37
Pseudo R^2		0.02		0.04		0.06
Log Likelihood		-177.00		-95.13		-67.96
Predictor variables	Category	Coefficient	Std Err	Z	P-value	95% CI
Animal protein	All	0.38	0.37	1.02	0.31	-0.35, 1.12
	Boys	0.47	0.51	0.94	0.35	-0.52, 1.46
	Girls	-0.02	0.67	-0.03	0.98	-1.32, 1.29
Green vegetables	All	0.56	0.37	1.52	0.13	-0.16, 1.29
	Boys	0.77	0.48	1.58	0.11	-0.18, 1.71
	Girls	0.001	0.67	0.00	1.00	-1.32, 1.32
Carbohydrate	All	0.15	0.45	0.33	0.74	-0.73, 1.03
	Boys	0.39	0.58	0.66	0.51	-0.75, 1.52
	Girls	-0.60	0.85	-0.71	0.48	-2.26, 1.06
Sweets	All	-0.26	0.40	-0.66	0.51	-1.04, 0.52
	Boys	-0.44	0.54	-0.81	0.42	-1.50, 0.62
	Girls	0.09	0.67	0.13	0.90	-1.23, 1.41
Dairy products	All	0.10	0.36	0.28	0.78	-0.60, 0.81
	Boys	0.22	0.47	0.47	0.64	-0.70, 1.14
	Girls	-0.49	0.69	-0.71	0.48	-1.84, 0.86
Fruits	All	-0.93	0.53	-1.75	0.08	-1.97, 0.11
	Boys	-0.95	0.65	-1.46	0.14	-2.23, 0.33
	Girls	-0.46	0.93	-0.50	0.62	-2.28, 1.35
Nuts	All	0.28	0.41	0.67	0.50	-0.53, 1.08
	Boys	0.03	0.52	0.06	0.96	-0.99, 1.05
	Girls	0.82	0.70	1.18	0.24	-0.55, 2.19
Physical exercise	All	-0.26	0.33	-0.80	0.43	-0.91, 0.38
	Boys	0.38	0.41	0.94	0.35	-0.41, 1.18
	Girls	-1.57	0.77	-2.04	0.04	-3.07, -0.06
_Cons	All	-2.43	0.72	-3.35	0.001	-3.85, -1.01
	Boys	-2.95	0.89	-3.30	0.001	-4.70, -1.20
	Girls	-0.33	1.43	-0.23	0.82	-3.13, 2.48

Discussion

This cross-sectional investigation is one of the very few that observed the association of protein, green vegetables, fruits and other food items as well as physical exercise with metabolic syndrome among adolescents in a sub-Saharan African country. One of the major findings in this study is that weekly consumption of animal protein was low among a large proportion of the study subjects and of these, it was low among girls more than boys, among early more than late adolescents and among overweight/obese more than lean subjects. This finding is corroborated by the report of a study [27] which shows that individuals in sub-Saharan Africa are not eating sufficient quantities of protein. Other possible reasons why weekly consumption of animal protein is low among study subjects may be related to (i) food insecurity (ii) climate change and (iii) education. Food insecurity in sub-Saharan Africa is due to lack of financial aid, and subsidies to support subsistence animal husbandry on one hand and lack of modern technology on the other hand [28]. Drought and water shortage negatively alter food supply, exacerbating food insecurity, poverty, and hunger [29]. Lack of information on the appropriate and adequate nutrition may also be a contributing factor to protein energy malnutrition [30]. On the contrary high weekly consumption of animal protein was observed in higher proportions of boys, those in late adolescence and lean subjects. These results are supported by various studies on the effect of high consumption of animal protein on health of adolescents. For example, Segovia-Siapco et al [31] reported that high protein intake from animal protein possibly poses a risk to adolescent health, contributing to general adiposity, and Joslowski et al [32] suggested that among girls, a habitually higher animal protein intake during puberty may precipitate an upregulation of the GH-IGF-1 axis, which is still discernible in young adulthood while among boys, it may exert a long-term programming of the GH-IGF-1 axis. Boys whose weekly consumption of animal protein was high were approximately twice as likely to have MetS than those with low weekly intake of animal protein. However, girls with high weekly consumption of animal protein were not likely to develop MetS. This novel finding was in contrast to the report from another study on older adults which states that a higher intake of total protein was associated with lower odds of having metabolic syndrome in both genders [33]. Animal proteins, made up of amino acids, of which nine – histidine (His), isoleucine (Ileu), leucine (Leu), lysine (Lys), methionine (Met), phenylalanine (Phe), threonine (Thr), tryptophan (Tryp) and valine (Val) are classified as amino acids and which cannot be synthesized by the body and should, therefore, be obtained from the diet – are essential elements in a diet. An in-vivo study has shown that methionine, primarily from animal protein, displays atherogenic effects by inducing vitamin B deficiency, hyperhomocysteinemia and atherosclerosis and is thereby associated with a higher risk of acute coronary syndrome [34]. Animal protein intake higher than the normal has thus been associated with an increased risk of abdominal obesity, general obesity, and elevated cholesterol levels [35-38] in males. Possibly, female hormones such as estrogen may play a role in converting excess amino acids from animal protein to body fat. However, a previous study observed no association between protein intake and hormones such as estradiol, progesterone, luteinizing hormone, or follicle stimulating hormone levels, nor was there an association between protein intake and ovulation [39]. The study also suggested that a diet high in animal protein is substantially linked with reduced testosterone levels among healthy women [39] while a meta-analysis study indicates that high protein diets decrease total testosterone in males, but low protein diets do not [40]. Further, there may be a disparity in the digestibility of amino acids from high intake of animal protein by boys and girls. This, however, needs more investigation. Another key finding in this paper is that, overall, sweets reduced the risk of MetS. This is contrary to what was earlier reported that sweet dietary pattern increases the risk of MetS and some of its components in Iranian children and adolescents [41]. Results from this study also shows that, overall, adolescents with high level of physical activities were less likely to have MetS compared to those with low level of physical activities (χ^2=0.51, P-value=0.47, OR=0.79, 95% CI=0.42, 1.50). DeBoer [42] suggested that high level of physical activity serves to preserve or elevate total energy expenditure in the face of reduced caloric intake. The US Center for Disease Control and Prevention (CDC/P) and the World Health Organization (WHO) recommend at least 60 minutes of moderate to vigorous physical activity among school-age children and adolescents [43]. In this study, only 26.9% of adolescents with MetS were engaged in moderate/vigorous physical activities, similar to what Nader et al [44] observed that <30% of adolescents engage in this much activity. Not surprising then that, in all the study subjects, higher levels of physical activity were associated with a lesser odd for MetS, a finding similar to what Ekelund et al [45] and Stabelini et al [46] had reported. Guinhouya et al [47] also suggested that moderate to physical exercise, as opposed to sedentary life, is helpful at increasing insulin sensitivity thus preventing diabetes and or metabolic syndrome. Participants in the target group of MetS (17, 32.7%) were about 1.34 more likely to be high consumers of green vegetables, especially boys (12, 35.3%; OR=1.66, 95% CI=0.77, 3.59), lean subjects (13, 33.3%; OR=1.5, 95% CI=0.75, 3.00), and those in early adolescence (9, 37.5%; OR=2.2, 95% CI=0.91, 5.22). This result aligns with what was reported by Hosseinpour-Niazi et al [48] that higher vegetable consumption (≥ 30 g/d) was significantly and inversely associated with risk of MetS, compared with lower vegetable consumption and by what Li et al [49] that at a lower or moderate rate, green vegetable consumption was negatively associated with MetS risk and what Zhang and Zhang [50] noted in a meta-analysis that vegetable intake was negatively related to MetS. This study reports that consumption of fruits has protective effect on MetS, a finding that is consonant with the report of other studies. For example, Mirmiran et al [51] observed no significant association between intake of fruit and combined total fruit and the risk of MetS and an older study by Esmaillzadeh et al [52] contended that higher intakes of fruit and vegetables are associated with a lower risk of the metabolic syndrome which may be the result of lower C -reactive protein concentrations. Data from our study shows that high weekly consumption of nuts is associated with MetS. This is contrary to the findings in other studies that nut consumption may be beneficial in the prevention on MetS [53] and that daily tree nut consumption lowers the risk of MetS by improving waist circumference, lipid biomarkers, and/or insulin sensitivity—without requiring caloric restriction [54].

Study limitations.

This study has some limitations which require mentioning. First the sample size could have been smaller or bigger than necessary. Secondly, students aged 10 years old were included as adolescents though some school of thought would not regard this group as such. However, this study strictly applies the WHO definition of adolescent to gather data on those aged 10-19 years. The results may not apply to other ecological zones and demographic aspects of the country nor to out-of-school adolescents. Logistic regression analysis was not run for early and late adolescence and for overweight/obese. It was assumed that the comparison between boys and girls may suffice. Further, we did not associate any of these food items with dyslipidemia or fasting blood glucose level of the study subjects. This could be the subject of a future investigation. Quantitative analysis of each of the food items that was consumed was not done nor was the division of each food item into its subgroups assessed. These would have added to the robustness of the findings in this study. Further, linear logistic regression was run for all the participants without categorizing them by sex, BMI-for-age percentile, or stage of adolescence. Had this been done, it would have clearly elucidated the association between MetS and high consumption of studied food items.

Conclusion and Recommendations

This study evaluated food consumption pattern of adolescents of both sexes who were identified as having MetS in Lagos State of Nigeria. High intake of dairy, animal protein and sweets increased the risk of developing MetS, whereas fruits, vegetables, nuts, and regular exercise were protective against MetS. Study subjects with MetS were approximately 1.36, 1.34, 1.06, 1.15 and 1.17 times more likely to be high consumers of animal protein, green vegetables, carbohydrates, dairy products compared to those without MetS. However, subjects without MetS were 0.90, 0.78 and 0.79 times to be high weekly consumers of sweets, fruit, and high level of physical exercise. In other words, subjects with MetS were low consumers of sweets, fruits and with low level of physical exercise. The role of high consumption of dietary animal protein in the management of the MetS is still controversial, thus preventing the development of clear guidelines on high-protein diets and the type of proteins to be recommended. Adolescents' dietary patterns are characterized by continuous alteration with prolonged effects into adulthood, necessitating further research on their dietary patterns including their health effects.

Conflict of interest: The authors declare no competing interest.

Acknowledgement: This project was supported by the Nigerian Institute of Medical Research (NIMR). We thank the parents of the students and the participating students for making this study possible.

Dr. Bamgboye M. Afolabi is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. The data used to substantiate and validate the findings of this study are available from the corresponding author upon request.

Funding: None

Abbreviation:

ANOVA – Analysis of Variance; BMI – Body Mass Index; CDC – Center for Disease Control and Prevention; CI – Confidence Interval; CVD – Cardiovascular Diseases; FBG – Fasting Blood Glucose; HDL – High-density lipoprotein; ; IRB – Institute Review Board; LDL – Low-density lipoprotein; LGA – Local Government Area; MetS = Metabolic syndrome; OR – Odds Ratio; T2DM –

Type 2 Diabetes mellitus; WHO – World Health Organization.

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