



Research Article

Correlation Between Selected Nutritional Biomarkers and Metabolic Syndrome Components Among In-School Adolescents in Gusau Urban Area, Zamfara State, Nigeria

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Abstract

The paucity of data on the dietary and nutrient intakes and the correlation between selected biomarkers and metabolic syndrome among adolescents in Gusau urban, Zamfara state, necessitates a comprehensive dietary assessments. This study investigated the correlation between selected nutritional biomarkers and metabolic syndrome components among adolescents in Gusau urban area, Zamfara State. This study used a cross-sectional design involving 400 participants drawn from 6 private and 5 public secondary schools. Respondents were selected through stratified proportionate sampling combined with random sampling techniques. Biochemical measurements included nutritional biomarkers and components of metabolic syndrome (MetS): blood pressure, fasting blood glucose, total cholesterol, triglycerides, high-density lipoprotein, and low-density lipoprotein. All parameters were assessed using standard laboratory procedures. Data were analyzed using Pearson's bivariate correlation to examine relationships between variables, with statistical significance set at $p \leq 0.05$. Results showed that most participants were aged 15–19 years (58.5%) and male (68.25%). While mean metabolic syndrome components and nutritional biomarkers were generally normal, females aged 10–14 years had an elevated Na: K ratio. Serum uric acid correlated positively with LDL ($r = .548^{**}$) and TCH ($r = .360^{*}$) in males 10–14 years, with a positive relationship with SBP ($r = .391^{**}$) and DBP ($r = .336^{*}$) in females (10–14). In males 15–19 years, SUA had a positive relationship with HDL ($r = .337^{**}$), LDL ($r = .337^{**}$), TRIG ($r = .333^{**}$) and TCH ($r = .484^{**}$). Serum sodium-to-potassium ratio correlated positively with LDL ($r = .268^{*}$). Serum albumin correlated with TRIG ($r = .371^{*}$) and TCH ($r = .358^{*}$). There was a significant ($p \leq 0.05$) relationship between selected nutritional biomarkers and metabolic syndrome components in adolescents, offering evidence supporting the use of serum uric acid and albumin as potential early screening markers for metabolic syndrome in adolescents. This study demonstrates the practical relevance of the selected nutritional biomarkers and metabolic syndrome and further strengthens the case for early nutrition intervention in schools using these selected nutrition biomarkers as potential screening markers for metabolic syndrome screening.

Keywords

Nutrient-Consumption, Metabolic-Syndrome, In-school, Adolescents, Gusau Urban Area, Zamfara State, Nigeria

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1. Introduction

Metabolic syndrome is a multifactorial condition characterized by a group of interrelated metabolic risk factors that increase the likelihood of atherosclerotic cardiovascular disease and type 2 diabetes mellitus, especially among overweight and obese individuals [24]. Key features include insulin resistance, central obesity, hypertension, hyperinsulinemia, dyslipidemia characterized by elevated triglycerides and reduced high-density lipoprotein cholesterol (HDL-C) and a prothrombotic state [17, 36]. This study adopts the International Diabetes Federation [10] criteria to identify MetS in children and adolescents. Based on IDF guidelines, MetS is diagnosed in adolescents who have central obesity plus any two of the following: triglycerides ≥ 150 mg/dL, HDL-C ≤ 40 mg/dL, systolic blood pressure ≥ 130 mmHg or diastolic ≥ 85 mmHg, fasting blood glucose ≥ 100 mg/dL, or previously diagnosed type 2 diabetes [16]. These criteria align with current recommendations from the World Health Organization [40] and the American Academy of Pediatrics [1]. Globally, about 4.5% of children and adolescents are affected by MetS, although prevalence varies widely from 0.5% to 43.8% [26]. Nutritional biomarkers may predict or indicate susceptibility to MetS in adolescents. While several biomarkers have been linked to MetS in adults, limited data exist for adolescents. This study focuses on three potential nutritional biomarkers: serum uric acid, serum sodium-to-potassium ratio, and serum albumin. These may act as early indicators, allowing timely intervention to prevent or reduce MetS progression in adolescents. Serum uric acid (SUA) is the end product of purine metabolism [8]. Elevated SUA is associated with gout and several MetS components [18]. Growing evidence shows a relationship where higher doses produce stronger effects between high SUA levels and MetS risk [22, 48]. Hyperuricemia prevalence is rising worldwide, with a disproportionate burden in developing countries [47]. Although the SUA and MetS link is well studied in adults, its role in adolescent MetS remains unclear. In this study, hyperuricemia was defined as SUA >7.0 mg/dL ($416.4 \mu\text{mol/L}$) for males and >6.0 mg/dL ($356.9 \mu\text{mol/L}$) for females. Dietary habits are recognized as major determinants of MetS development [22]. The serum sodium-to-potassium (Na: K) ratio may be a better predictor of blood pressure and cardiovascular disease (CVD) risk than sodium or potassium alone [30]. Findings on the relationship between sodium, potassium, and MetS risk have been mixed [9]. However, recent evidence links low potassium and high sodium intake to greater risk of hypertension, stroke, and obesity [11]. Reducing sodium and increasing potassium intake are key WHO [41] strategies for preventing non-communicable diseases. Yet most populations consume less potassium and more sodium than recommended, resulting in dietary Na: K ratios of 1–2 [6] and serum levels around 36.4 mmol/L . Serum albumin is important for antioxidant activity, plasma volume regulation, and assessment of nutritional status [2]. Low albumin is associated with cardiovascular disease, malnutrition, inflammation, and liver disease [34]. Conversely, high albumin has been linked to hypertension and

hypercholesterolemia [34]. Recent studies report a positive association between serum albumin and MetS, including its components such as hypertension, dyslipidemia, and insulin resistance [14, 19]. Biomarkers are essential for early detection and risk stratification in MetS and offer potential for nutrigenomic and preventive nutrition strategies in adolescents [47]. Adolescent malnutrition has long-term effects on metabolic and cardiovascular health [45]. The global rise in adolescent MetS over the past three decades is concerning [26]. This growing burden underscores the urgent need for multi-sectoral action targeting underlying factors like childhood overweight and obesity [27, 40]. Early identification is more cost-effective and efficient than late intervention. In several African countries, including Nigeria, there is limited research on the relationship between selected nutritional biomarkers; serum uric acid, serum sodium-to-potassium ratio, and serum albumin and MetS in adolescents. Therefore, this study examines the correlation between these nutritional biomarkers and MetS components among adolescents in Gusau urban area, Zamfara State. The aim is to evaluate these biomarkers as potential risk indicators for early detection of MetS in adolescents, which could help reduce adult MetS prevalence.

2. Methodology

2.1. Study Design

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

2.2. Study Area

The research was undertaken in the urban area of Gusau, the capital city of Zamfara State, Northwest, Nigeria. Many households in Zamfara experience food insecurity, particularly during the lean season [39]. As of the 2006 census, the city had a population of 383,162 people [25]. Gusau local government is made up of eleven (11) political wards; six (6) are rural wards and five (5) urban wards.

2.3. Study Population

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

2.4. Sample Size Determination

The sample size was statistically derived using Cochran's formula

Cochran's sample size formula (1963);

2.5. Sampling Technique and Procedures

Using multi-stage sampling, 6 private schools out of 19 and 5 public schools out of 10 were proportionately and randomly selected from the five urban political wards in Gusau, Zamfara State. One private and one public school were randomly picked from each ward, except Galadima ward where two private schools and one public school were selected based on proportion. Participants were then chosen through proportionate stratified random sampling, with stratification by school, class, and gender, to achieve a total sample size of 400.

2.6. Data Collection

2.6.1. Ethical Considerations

Approval to conduct the study was granted by both the Ethics Committee of Ahmad Sani Yariman Bakura Specialist Hospital, Gusau (Ref: ASYBSH/SUB/205/VOL.1) and the Office of the Director of Administration at the Zamfara State Ministry of Education (Ref: MOE/ADM/034/VOL.1).

2.6.2. Informed Consent/Assent

Prior to data collection, permission was obtained from the heads of schools and parents/guardians of participants. In addition, assent was obtained from all participating students before their involvement in the study.

2.7. Statistical Analysis

Data are presented as median, mean, and standard deviation values. Pearson's bivariate correlation was used to examine relationships between variables, and statistical significance was defined as $p \leq 0.05$. All statistical analyses were conducted using IBM SPSS Statistics, Version 27.

3. Results

3.1. Nutritional Biomarkers of Respondents Based on Sex

The table below showed the nutritional biomarkers levels of respondents by gender. The mean values were within the normal ranges for males uric acid (3.0 -7.7mg/dl, 4.11 ± 1.14), albumin (34 - 54g/l, 36.58 ± 5.25), sodium (>135 - 145mmol/L, 134.9 ± 3.45), potassium (3.6 - 5.2mmol/L, 3.65 ± 0.39), serum sodium to potassium ratio (36.63mmol/L, 37.44 ± 4.45) while in females uric acid (2.7 -5.7mg/dl, 4.91 ± 1.12), albumin (34 - 54g/l, 40.06 ± 4.92), sodium(>135 - 145mmol/L, 134.8 ± 3.66), potassium (3.6-5.2mmol/L, 3.61 ± 0.36), serum sodium to potassium ratio (36.63mmol/L, 37.78 ± 4.37), there was a slight elevated (37.78mmol/L) mean value for serum sodium to potassium ratio compared to the cut off value (36.63mmol/L) while maximum range value for uric acid (6.9mg/dl) (10.1mg/dl) and serum sodium to potassium (47.33mmol/L) (48.97mmol/L) were high for both genders respectively.

Table 1. Nutritional Biomarkers of respondents by sex.

Nutritional biomarkers	Cut-off Values	Mean $\pm$ SD	Min	Max
Male (n=119)				
URIC ACID (mg/dl)	3.0 -7.7mg/dl	4.11 ± 1.14	2	6.9
ALBUMIN (g/l)	34 - 54g/l	36.58 ± 5.25	23	48
Sodium (mmol/L)	>135 - 145mmol/L	134.9 ± 3.45	126	142
Potassium (mmol/L)	3.6 - 5.2mmol/L	3.65 ± 0.39	3	4.9
Serum Na: K (mmol/L)	36.63mmol/L	37.44 ± 4.45	26.3	47.33
Female (n=83)				
URIC ACID (mg/dl)	2.7 -5.7mg/dl	4.91 ± 1.12	2.9	10.1
ALBUMIN (g/l)	34 - 54g/l	40.06 ± 4.92	29	52
Sodium (mmol/L)	>135 - 145mmol/L	134.8 ± 3.66	126	143
Potassium (mmol/L)	3.6 - 5.2mmol/L	3.61 ± 0.36	2.9	4.8
Serum Na: K (mmol/L)	36.63mmol/L	37.78 ± 4.37	26.7	48.97

Na-Sodium, K-Potassium, SD- standard deviation.

3.2. Nutritional Biomarkers of Respondents by Age

The table below showed the nutritional biomarkers' levels of respondents by age. Age 10-14 years uric acid (4.33 ± 1.06), albumin (38.68 ± 5.68), sodium (135.1 ± 3.24), potassium (3.62 ± 0.34), and serum sodium-to-potassium ratio

(37.73 ± 3.98) while for age 15-19 years uric acid (4.53 ± 1.29), albumin (37.44 ± 5.07), sodium (134.7 ± 3.76), potassium (3.65 ± 0.4), serum sodium to potassium ratio (37.45 ± 4.75). The mean values were within the acceptable range except in serum sodium to potassium ratio within (10-14) years were observed to be elevated (37.73 mmol/L).

Table 2. Nutritional Biomarkers of respondents by age.

Nutritional Biomarkers	Age	Mean $\pm$ SD	Min.	Max.
10-14yrs (n=93)				
URIC ACID (mg/dl)		4.33 ± 1.06	2.6	7.2
ALBUMIN (g/l)		38.68 ± 5.68	24	52
Sodium (mmol/L)		135.1 ± 3.24	129	142
Potassium (mmol/L)		3.62 ± 0.34	3	4.9
Serum Na: K (mmol/L)		37.73 ± 3.98	26.53	45.5
15-19yrs (n=109)				
URIC ACID (mg/dl)		4.53 ± 1.29	2	10.1
ALBUMIN (g/l)		37.44 ± 5.07	23	46
Sodium (mmol/L)		134.7 ± 3.76	126	143
Potassium (mmol/L)		3.65 ± 0.4	2.9	4.8
Serum Na: K (mmol/L)		37.45 ± 4.75	26.25	49

Na-Sodium, K-Potassium, SD- standard deviation.

3.3. Correlation Between Nutritional Biomarkers and Metabolic Syndrome Components for Males 10-14 Years

The Pearson correlation showed the association between nutritional biomarkers and metabolic syndrome for male 10-14 years. The result showed that uric acid was strongly, positive and significantly ($p \leq 0.001$) associated with LDL ($r =$

0.548 , $p \leq 0.001$) and TCH ($r = 0.360$, $p \leq 0.005$), and negatively weak association with SBP ($r = -0.384$, $p \leq 0.001$) and DBP ($r = -0.337$, $p \leq 0.005$). SBP had a very strong and positive association with DBP ($r = 0.729$, $p \leq 0.001$) while a negative strong association exist with LDL ($r = -0.533$, $p \leq 0.001$) and TCH ($r = -0.422$, $p \leq 0.001$). DBP was moderately associated negatively with LDL ($r = -0.490$, $p \leq 0.001$) and TCH ($r = -0.497$, $p \leq 0.001$).

Table 3. Correlation between Nutritional biomarkers and metabolic syndrome components for males 10-14 years.

Variables	1	2	3	4	5	6	7	8	9	10
Male	1									
10-14	2.ALB (g/l)	-0.185	1							
	3.Na: K (mmol/L)	0.15	-0.092	1						
	4.SBP(mmHg)	-.384**	0.051	-0.043	1					
	5.DBP(mmHg)	-.337*	0.089	-0.086	.729**	1				

Variables	1	2	3	4	5	6	7	8	9	10
6.FBS (mmol/L)	-0.277	-0.076	-0.054	0.184	0.133	1				
7.HDL (mmol/L)	0.104	0.196	-0.103	-0.146	-0.147	-0.017	1			
8LDL (mmol/L)	.548**	-0.198	0.09	-.533**	-.490**	-0.109	-0.072	1		
9.TRIG(mmol/L)	-0.055	0.161	0.124	0.025	-0.169	-0.038	0.257	-0.102	1	
10.TCH(mmol/L)	.360*	0.074	0.131	-.422**	-.497**	-0.132	.584**	.603**	.488**	1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). UA-Uric acid, ALB-Albumin, Sodium (Na), Potassium (K), SBP-Systolic blood pressure, DBP-Diastolic blood pressure, FBS-Fasting blood sugar, HDL-High density lipoprotein, LDL-Low density lipoprotein, TRIG-Triglycerides, TCH-Total cholesterol.

3.4. Correlation Between Nutritional Biomarkers and Metabolic Syndrome Components for Females 10-14 Years

Female 10-14 years, uric acid showed a positive, moderate and significance level ($p \leq 0.001$) association with SBP ($r = 0.391$, $p \leq 0.001$) and DBP($r = 0.336$, $p \leq 0.005$) while albumin

showed a weak but positive association with TCH($r = 0.299$, $p \leq 0.005$) and a moderate negative but significant ($p \leq 0.001$) with SBP ($r = -0.408$, $p \leq 0.001$) and DBP($r = -0.417$, $p \leq 0.001$). There was a very strong relationship with SBP and DBP($r = 0.739$, $p \leq 0.001$), FBS($r = 0.613$, $p \leq 0.001$) with a moderately positive relationship with HDL($r = 0.413$, $p \leq 0.001$) while DBP was strongly correlated with FBS($r = 0.673$, $p \leq 0.001$) and HDL($r = 0.330$, $p \leq 0.005$)

Table 4. Correlation between Nutritional biomarkers and metabolic syndrome components for females 10-14 years.

Variable	1	2	3	4	5	6	7	8	9	10
Female 10-14										
1. UA (mg/dl)	1									
2. ALB (g/l)	-0.151	1								
3. Na: K (mmol/L)	0.285	0.096	1							
4.SBP(mmHg)	.391**	-.408**	0.092	1						
5.DBP(mmHg)	.336*	-.417**	0.067	.739**	1					
6. FBS (mmol/L)	0.173	-0.213	0.119	.613**	.673**	1				
7. HDL (mmol/L)	-0.019	0.063	-0.118	.413**	.330*	0.277	1			
8. LDL (mmol/L)	-0.159	0.248	-0.177	-0.292	-0.176	-0.137	-0.281	1		
9. TRIG (mmol/L)	0.04	0.141	0.052	0.021	-0.033	0.164	.305*	0.009	1	
10.TCH (mmol/L)	-0.179	.299*	-0.16	-0.066	-0.106	0.034	0.273	.644**	.604**	1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). Sodium (Na), Potassium (K), Dietary. BMI-Body mass index, WC-Waist circumference, WHR-Waist-hip ratio, MUAC-Mid upper arm circumference, SBP-Systolic blood pressure, DBP-Diastolic blood pressure, FBS-Fasting blood sugar, HDL-High density lipoprotein, LDL-Low density lipoprotein, TRIG-Triglycerides, TCH-Total cholesterol, CHO-Carbohydrate.

3.5. Correlation Between Nutritional Biomarkers and Metabolic Syndrome Components for Males 15-19 Years

The association between the nutritional biomarkers and metabolic syndrome components among adolescents of 15-19

years males showed a weak but significant ($p \leq 0.001$) relationship between uric acid as a nutritional biomarker with HDL($r = 0.337$, $p \leq 0.001$), LDL($r = 0.337$, $p \leq 0.001$), TRIG($r = 0.333$, $p \leq 0.001$) and strongly significant ($p \leq 0.001$) relationship with TCH($r = 0.484$, $p \leq 0.001$). There was also a positive but weak relationship between serum sodium to potassium ratio and LDL($r = 0.268$, $p \leq 0.005$). FBS with LDL($r = -0.325$, $p \leq 0.001$).

Table 5. Correlation between Nutritional biomarkers and metabolic syndrome components for males 15-19 years.

	Variable	1	2	3	4	5	6	7	8	9	10
Male	1. UA (mg/dl)	1									
15-19	2. ALB(g/l)	0.007	1								
	3. SNa: K (mmol/L)	0.053	-0.142	1							
	4. SBP(mmHg)	0.053	0.1	0.03	1						
	5. DBP(mmHg)	-0.092	-0.051	0.063	.658**	1					
	6. FBS (mmol/L)	-0.146	0.101	-0.024	0.016	0.089	1				
	7. HDL (mmol/L)	.337**	0.028	0.033	-0.157	-0.21	0.028	1			
	8. LDL (mmol/L)	.337**	-0.034	.268*	0.082	-0.121	-.325**	0.104	1		
	9. TRIG (mmol/L)	.333**	0.131	-0.093	-0.088	-0.221	-0.057	.345**	0.096	1	
	10.TCH (mmol/L)	.484**	0.041	0.162	-0.012	-0.226	-0.221	.599**	.790**	.537**	1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). Sodium (Na), Potassium (K), D-dietary. BMI-Body mass index, WC-Waist circumference, WHR-Waist-hip ratio, MUAC-Mid upper arm circumference, SBP-Systolic blood pressure, DBP-Diastolic blood pressure, FBS-Fasting blood sugar, HDL-High density lipoprotein, LDL-Low density lipoprotein, TRIG-Tri-glycerides, TCH-Total cholesterol, CHO-Carbohydrate

3.6. Correlation Between Nutritional Biomarkers and Metabolic Syndrome Components for Females 15-19 Years

In adolescents females 15-19years, a moderate significant ($p \leq 0.005$) relationship was shown between Albumin with TRIG($r = 0.371$, $p \leq 0.005$) and TCH ($r = 0.358$, $p \leq 0.005$) while serum sodium to potassium ratio had a moderately weak and a negative correlation with SBP($r = -0.377$, $p \leq 0.005$ and DBP($r = -0.327$, $p \leq 0.005$). SBP strongly and positively correlated with DBP ($r = 0.676$, $p \leq 0.001$) and weak negative LDL($r = -0.332$, $p \leq 0.001$)

Table 6. Correlation between Nutritional biomarkers and metabolic syndrome components for females 15-19 years.

	Variable	1	2	3	4	5	6	7	8	9	10
Female	1. UA(mg/dl)	1									
15-19	2. ALB (g/l)	0	1								
	3. Serum Na: K (mmol/L)	0.01	0.029	1							
	4. SBP (mmHg)	-0.019	0.04	-.377*	1						
	5. DBP (mmHg)	0.036	0.022	-.327*	.676**	1					
	6. FBS (mmol/L)	-0.019	0.2	0.18	0.313	0.274	1				
	7. HDL (mmol/L)	-0.011	0.236	-0.161	0.093	0.137	0.163	1			
	8. LDL (mmol/L)	0.096	0.007	0.045	-.332*	-0.204	-0.311	-0.183	1		
	9. TRIG (mmol/L)	0.2	.371*	0.038	-0.088	-0.042	-0.157	-0.017	0.151	1	
	10.TCH (mmol/L)	0.095	.358*	0.005	-0.252	-0.197	-0.288	0.153	.623**	.634**	1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). Sodium (Na), Potassium (K), SBP-Systolic blood pressure, DBP-Diastolic blood pressure, FBS-Fasting blood sugar, HDL-High density lipoprotein, LDL-Low density lipoprotein, TRIG-Triglycerides, TCH-Total cholesterol

4. Discussion

For males, the mean values of nutritional biomarkers fell within the normal ranges for uric acid, albumin, and serum sodium-to-potassium ratio, while for females, the uric acid and albumin were within the normal range while serum sodium-to-potassium ratio was slightly elevated above the normal range. In contrary to a study [46], which claimed that males specifically have a heightened serum uric acid levels than females of the same age, which is related to the urination effect of estrogen, in this study females showed higher mean values for uric acid than males, though within the normal cut-off value. According to [23] on a prolonged rise in serum uric acid and its predictors during a 25-year follow-up, the mean serum uric acid readings here were identical to those throughout follow-up, which climbed from 4.7 ± 1.1 to 5.0 ± 1.2 mg/dl.

The mean and standard deviation, compared to cut-off values of metabolic syndrome components of the respondents by gender, were within the normal cut-off ranges for metabolic syndrome components considered in this research for both males and females, respectively. Waist circumference (WC) was elevated at +1SD in female respondents; high waist circumference is linked with type 2 diabetes mellitus and related metabolic disorder and its components. This present finding might be attributed to genetics, typical hormonal fluctuations, or the low physical activity like participation in sports that is culturally instilled in females in northern Nigeria. The average results here were lower than the average values for obesity and metabolic syndrome among marginalized school-going teenagers in Karachi, Pakistan. The technique used to gather the data, as well as the lifestyle and behavioral habits of men and women, might be the cause of this discrepancy in the mean values of the metabolic syndrome indicators.

The mean and standard deviation of the metabolic syndrome components among the respondents according to age fell within the cut-off limits considered in this study. Age demonstrates a key role in the metabolic syndrome components observed in this study since the components of the metabolic syndrome tend to rise with age, as higher values for SBP, DBP, FBS, and HDL were observed in respondents aged 15-19, while LDL, TRIG, and TCH increased in respondents aged 10-14 years. This study is comparable to one by [35] on dietary intake, obesity, and metabolic risk factors among children and adolescents in the SEACO-CH20 cross-sectional study. The authors of that study noted that metabolic syndrome is a newly-emerging field of study among adolescents, characterized by the confluence of risk factors such as abdominal obesity, elevated blood pressure (BP), fasting blood sugar (FBS), triglyceride (TG), and low high-density lipoprotein cholesterol (HDL-C). These factors increase the likelihood of developing type 2 diabetes (T2D) and cardiovascular diseases (CVD) in future. Approximately 5% of adolescents worldwide, with some regional and national variations, are

considered to have metabolic syndrome, according to available data [27]. More than 35 million teenagers between the ages of 13 and 18 are forecasted to have metabolic syndrome. Age, ethnicity, and geography all have a substantial effect on metabolic syndrome prevalence [5].

For males, the mean values of nutritional biomarkers fell within the normal ranges for uric acid, albumin, and serum sodium-to-potassium ratio, while for females, the uric acid and albumin were within the normal range while serum sodium-to-potassium ratio was slightly elevated above the normal range. Poor physical activity may be the cause of high albumin levels in females, as evidenced by the lack of play areas and adequate room for athletics in certain private and public female schools. Researches have demonstrated that moderate physical activity induces an apparent abnormality in glomerular permeability, manifesting in high urinary excretion of albumin and other high molecular weight proteins; an inversely inactive lifestyle will accumulate albumin in serum.

The nutritional biomarkers' levels of respondents by age show that for ages 10-14, serum uric acid, serum albumin, and serum sodium-to-potassium ratio were within the normal range, and for ages 15-19 years, uric acid, albumin, and serum sodium-to-potassium ratio had mean values that were within the normal range too, though lower than 41.32 ± 6.17 , as reported by [31], in hypertensive patients in Nigeria. Serum uric acid was high in adolescents aged 15-19 years, showing that age remains one of the contributing factors to an elevated rate of serum uric acid.

The Pearson's correlation showed the correlation between nutritional biomarkers and metabolic syndrome for males 10-14 years old. In this finding, serum uric acid was strongly, positively, and significantly ($p \leq 0.001$) correlated with LDL and TCH, which may be due to obesity and visceral fat accumulation [29], and negatively weakly correlated with SBP and DBP, which might be because of the vasodilatory impact of uric acid and elevated nitric oxide production [42], while in females, uric acid showed a positive, moderate, and significant level ($p \leq 0.001$) of association with LDL and TCH which may be due to obesity and visceral fat accumulation [29], and negatively weak correlation with SBP and DBP while in females, uric acid showed a positive, moderate and significant level ($p \leq 0.001$) association with SBP and DBP which may be due to hormones like estrogen which can stimulate RAAS. High serum uric acid increases oxidative stress and causes inflammation. In older adolescents, males (15-19 years), the result showed a weak but significant ($p \leq 0.001$) association between uric acid as a nutritional biomarker with HDL, LDL, and TRIG and a strongly significant ($p \leq 0.001$) association with TCH. These findings were partially similar to a study by [28], that serum uric acid levels were found to be positively associated with serum triglycerides, total cholesterol, low-density lipoprotein cholesterol, and the triglyceride-to-high-density lipoprotein cholesterol ratio in Bangladeshi adults.

A significant inverse correlation was observed between serum uric acid and high-density lipoprotein (HDL) cholesterol levels, independent of gender and potential confounding variables, highlighting uric acid's crucial role in regulating dyslipidemia. This research supports the notion that hyperuricemia and dyslipidemia share common underlying mechanisms, highlighting the need for further investigation into the intricate relationships between uric acid and lipid profiles. Serum high-density lipoprotein (HDL) a known beneficial effect of cholesterol is its protective properties for cardiovascular disease risk. In our study, for adolescent males 15–19 years, A significant inverse correlation was observed between serum HDL cholesterol and serum uric acid (SUA) levels, consistent with previous research findings [33]. Elevated serum uric acid levels have been identified as a significant predictor of smaller, denser low-density lipoprotein (LDL) and high-density lipoprotein (HDL) particles, which are associated with increased atherogenic potential [38]. A diminished amount of high-density lipoprotein (HDL) cholesterol helps the build-up of atherosclerosis and by chance may predispose adolescents to cardiovascular disease, despite the limited direct evidence supporting the positive effects of high-density lipoprotein in reducing cardiovascular disease has not clearly been understood yet [33]. Previous research [4] has identified a linear correlation between triglyceride and serum uric acid (SUA) levels, a finding consistent with the results of the current study. It is assumed that the synthesis of triglycerides requires nicotinamide adenine dinucleotide phosphate hydrogen (NADPH), which resulted in increased serum uric acid (SUA) production [33]. Several studies have observed a concurrent relationship between dyslipidaemia and hyperuricemia, including a significant association between serum uric acid (SUA) and lipid profiles in the Indian adult population., Italy [21], and the USA [33]. Hyperuricemia has become more prevalent in recent years, largely due to the growing frequency of obesity, hypertension, and metabolic syndrome [48]. The complex interplay between these factors necessitates the development of comprehensive treatment guidelines, incorporating dietary interventions, lifestyle modifications, and pharmacological measures to mitigate hyperuricemia and its deleterious health consequences [46]. The mechanisms underlying hyperuricemia-induced endothelial dysfunction and inflammation involve the suppression of nitric oxide (NO) production and the increased formation of ROS, leading to oxidative stress and vascular damage [44].

Serum albumin showed a weak but positive association with total cholesterol (TCH), which may be due to consumption of a diet of high protein, fat, and cholesterol, as albumin helps in lipid transportation, and a moderate negative but significant ($p \leq 0.001$) association with systolic blood pressure (SBP) and diastolic blood pressure (DBP) due to the antioxidant effect of albumin and fluid balance effect to avoid fluid overload [2], and [20]. In this study, serum albumin had a positive association with TCH and TRIG, which may be due to lipid transportation, hormonal changes, and dietary intake,

while SNa: K had a negative association with SBP and DBP in adolescent females, which may be because of genetic disparity in this gender, poor physical activity levels due to lack of sport facilities in female schools, and probably high prevalence of low high-density lipoprotein (HDL), high triglycerides (TRIG), and high total cholesterol (TCH) noticed among females in this study. [3] hypothesized that the positive correlation between serum albumin concentrations and insulin resistance might be a consequence of hepatic albumin production upregulation in response to insulin-resistant conditions. Insulin resistance is characterized by elevated insulin levels, which can stimulate albumin production in hepatocytes, leading to increased albumin synthesis [32]. Nutritional status has a significant impact on serum albumin levels, making it a valuable marker for assessing nutritional health [14]. Research has shown that elevated serum albumin levels are associated with parameters of over-nutrition, such as obesity and metabolic syndrome [12]. Nevertheless, serum albumin concentrations can be affected by inflammation, and it is known to decrease in response to acute inflammation [7].

In females, a moderately significant ($p \leq 0.005$) association was shown between serum albumin with TRIG and TCH; this may be hormonal or dietary impact due to the lipid transportation activity of albumin [37].

In this study, serum sodium-to-potassium ratio (SNa: K) within 15-19 years was associated with LDL in males and negatively but significantly associated with SBP and DBP in females, which was in contrast with a study [13], whose serum sodium-to-potassium ratio was positively correlated with systolic blood pressure in older patients, while serum sodium-to-potassium ratio had a moderately weak and negative association with SBP and DBP; this may be due to the role of potassium in lipid regulation. However, there was also a positive but weak association between serum sodium-to-potassium ratio and LDL as a result of high fat accumulation in the liver [15]. Hypertension is a significant public health concern, affecting approximately 25% of the global population, with a predicted rise in prevalence to 60% by 2025 [43]. The pathogenesis of hypertension is influenced by serum electrolytes, with sodium and potassium being key players.

5. Conclusion

The nutritional biomarkers and metabolic syndrome components were biochemical markers that gave better understanding of respondents' health status in their respective age and gender that can be targeted to mitigate the risk of metabolic syndrome among adolescents.

6. Recommendation

Based on the result of this study, serum uric acid and serum albumin may be used as independent risk factors of early stage metabolic syndrome, while waist circumference alone may

not have metabolic syndrome causal effect in apparently healthy adolescents.

Abbreviations

BP	Blood Pressure
CVD	Cardiovascular Disease
DBP	Diastolic Blood Pressure
Na: K	Sodium-to-potassium Ratio
FBS	Fasting Blood Sugar
HDL	High Density Lipoprotein
LDL	Low Density Lipoprotein
SPSS	Statistical Package for Social Science
SBP	Systolic Blood Pressure
SUA	Serum Uric Acid
SALB	Serum Albumin
SNa: K	Serum Sodium-To-Potassium Ratio
TCH	Total Cholesterol
TRIG	Triglyceride
WC	Waist Circumference
NCDs	Non communicable Diseases
WHO	World Health Organisation

Author Contributions

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Conflicts of Interest

The authors declare no conflicts of interest.

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