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ASSESSMENT OF THE NUTRITIONAL STATUS, FOOD CONSUMPTION PATTERN AND SHORT CHAIN FATTY ACIDS AMONG ADOLESCENT SCHOOL GIRLS IN IGABI LGA, KADUNA STATE

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ABSTRACT

Proper nutrition practice is critical during adolescence since it is the second opportunity to catch up growth, and have a strong effect on lifetime nutritional status and health of the adolescent. This study was to assess the nutritional status, food consumption pattern, and short chain fatty acids among adolescent school girls in Igabi LGA, Kaduna State, Nigeria. A cross-sectional study was conducted among 229 adolescent girls (mean age ≈ 15 years) attending public (n = 126) and private (n = 103) secondary schools in Nigeria. The study revealed that private-school participants were slightly older (15.8 ± 1.7 vs 15.4 ± 1.9 years), more likely to be Hausa (55% vs 63% public), and came from households with higher parental education (49 % vs 24 % tertiary) and lower family-size extremes. Finding of this study using (what method/technique/approach?) showed a higher prevalence of stunting (32% vs 19%) and underweight (28% vs 15%) in public schools, while overweight (12% vs 10%) and obesity (5% vs 8%) were comparable. Short chain fatty acids (SCFAs) demonstrated significantly lower concentrations in public schools (acetate 120.5 ± 20.5 µmol/g, propionate 30.2 ± 5.5 µmol/g, butyrate 20.1 ± 4.2 µmol/g) compared to private schools (150.8 ± 25.1, 40.5 ± 6.8, 28.5 ± 5.1 µmol/g). The relationship linked higher SCFA-producing bacteria to greater dietary diversity, nutritional status and better socio-demographic characteristics ($p < 0.05$). These findings underscore that socioeconomic advantage, nutritional status, food-consumption pattern, and dietary diversity co-vary with a SCFAs profile, suggesting that integrated school-based nutrition and counselling interventions could narrow the health gap between public and private school adolescents in Nigeria.

Keywords: Socio-demographic, dietary diversity, food frequency, Association, Food consumption

INTRODUCTION

Adequate nutrition is critical during adolescence since it is the second opportunity to catch up growth, and have a strong effect on lifetime nutritional status and health of the adolescents (Patridge *et al*., 2022). Nutritional status is the evident state of an individual in relation to their nourishment (consumption and utilization) (Amosu *et al*., 2011). Nutritional status, which is classified as either wasting or stunting or underweight (thinness), if the BMI is less than 18.5kg/m2 and micronutrient deficiency (Caballero *et al*., 2005). The prevalence of adolescent girls' malnutrition in Kaduna State show that thinness is 8.2%, overweight as 13.2%, and obesity as 1.6% (NFCMS, 2021). At the national level, the prevalence of adolescent girls with normal weight was 80.4 %; that is, most healthy adolescent girls in Nigeria had an expected body weight compared to unhealthy adolescent girl of the same age (NFCMS, 2021). Due to increased nutrition demand for growth and development, including sexual development, maturation, and the initiation of menarche, adolescent girls are vulnerable to undernutrition (WHO, 2018). Undernutrition among adolescent girls is a major public health concern (WHO, 2002; Stang and Mt, 2005). In developing countries, undernutrition among late adolescent females is far worse and remains a major public health problem; however, it has received less policy attention (WHO, 2018). A secondary analysis of 11 Asian and South Africa (SA) countries revealed the highest prevalence of under nutrition among adolescent girls in Nigeria (32.9%) (Lob-Corzilius, 2007). Another study in southern Nigeria reported the prevalence rate of overweight and obesity as 11.4% and 2.8% (Ene-Obong *et al*., 2012). In many African countries, the nutritional status of adolescent girls' results from chronic under-nutrition associated with deficiencies in muscular strength and working capacity (Deshmukh *et al*., 2006). Although overweight and obesity are becoming more prevalent among adolescents' girls (Lob-Corzilius, 2007). As a key predictor in adolescent girls, overweight and obesity are associated with severe health problems, such as diabetes mellitus, hypertension, cerebrovascular disease, atherosclerotic coronary heart disease, colorectal cancer, from all causes, and lower educational attainment (Stice *et al*., 2005; Stray-Pedersen *et al*., 2009). Similarly, East African countries have a higher burden of undernutrition in adolescent girls (USAID, 2018). For instance, in South Asia, about two out of five adolescent girls are undernourished (Deshmukh *et al*., 2006). Globally, around 10.0% of the adolescents are overweight, varying from10.0% in Africa and Asia, more than 20.0% in the USA and Europe (Meseret, 2008; Carvalho *et al*., 2009).

Compared to the male counterpart, female adolescents are more vulnerable to nutritional deficiencies due to menarche, growth spurt and other physiological developments (USAID, 2018). Optimal nutrition during the growth period of adolescent girls play a vital role in shaping the health and wellbeing of adolescent girls to the adulthood as well as their unborn children (Norris *et al*., 2021). As a result of the physical, psychological, hormonal, cognitive and social transformation changes that occur during this growth period, the body's nutritional needs, eating habits and food choices fluctuate (Visscher and Seidell, 2001). These changes have implications towards the alarming rate of non-communicable disease including obesity, hypercholesteramia, high glucose levels which are emerging public health problems (WHO, 2000). Studies have demonstrated that malnutrition leads to nutrition-associated diseases and significant public health

issues that result in elevated risk of morbidity and mortality (UNICEF, 2013).

Short chain fatty acids (SCFAs) notably butyrate, propionate and acetate which are byproducts of bacterial fermentation of indigestible carbohydrates (Ryodai *et al*., 2020). Disruption in these SCFAs level have been reported to modify the effects of diets in female adolescent girls (Kumar *et al*., 2018). For increased physical growth, psychosocial development, optimal cognitive performance and prevention of inflammatory bowel diseases, cancer, obesity and diabetes, it is crucial to investigate in-depth the nutritional status, food consumption pattern, and short chain fatty level among adolescent girls in the study area. Despite the enormous burden of adolescent girls' malnutrition in this region and the nation as a whole, there is lack of data on possible association between nutritional status, socio-demographic characteristic, dietary diversity and short chain fatty acids, among adolescent school girls in the study area and also little or nothing have been done in sub-sahara Africa; availability of such data will be of utmost importance in developing strategies for combating nutrition-associated diseases in adolescent girls.

MATERIALS AND METHODS

Chemical and Reagents

The chemical and reagents (nitric acid, hydrochloric acid, acetic acid, propionic acid and butyric acid) that were used for this study are of analytical grade.

Equipment

This study is a cross sectional study design, in which subjects were recruited, interviewed and sample collected at a point in time. The sample include adolescent school girls (10-19years) and caregivers of adolescent school girls in Igabi, Local Government Area of Kaduna State. Adolescent school girls, who are deformed, pregnant, lactating, absent during the period of this study, and caregivers of adolescent school girls who declined the invitation were excluded from this study. About 229 study participants was sampled for this study. A multistage sampling method was used. Igabi LGA, were stratified into four zones; (North, South, East and West). It consisting of 12 wards, those wards with no public and private secondary schools were de-selected. Four wards was selected at random, one ward from each stratum. Proportionate sampling were used to select 2 private schools and one public schools from each selected ward. Study participants were chosen from each selected public and private secondary schools using simple random sampling methods based on the school records. Socio-demographic characteristics and food consumption pattern of the adolescent girls were assessed using validated semi-structured questionnaires which was administered through semi-structured interviews and conducted by a trained interviewer. Anthropometrics indices were assessed using food and nutrition technical guide (FANTA) Cogill, 2010). The feacal samples were collected in a sterile container by health personnel. The chemicals and materials used for this study include electronic digital weighing balance, stadiometer, High Performance liquid Chromatography, plain bottles, micro pipette, conical flask, centrifuge, vortex mixer, thermal cycler, validated semi structure questionnaires, and writing materials were used **f**eacal samples collected was stored at 4°C and the samples were handled in a safety cabinet, wearing gloves and mask (Zhang *et al*., 2023)

Short Chain Fatty Acid (SCFAs) Determination and Quantification

SCFAs were extracted from faecal samples as previously described (Lee *et al*., 2003). Faecal samples (0.2 g) were diluted at a 1:4 to 1:8 ratio (w/v) using sterile distilled water. Samples were vortexed for 1 min and centrifuged at 10,000rpm for 10 min. The supernatant was filtered through a nylon econofilter with a pore size of 0.2 µm and stored at −20 °C for downstream analysis. Further analyses were carried out using high performance liquid chromatography (HPLC). Faecal sample extract (40 µl) was injected directly into an HPLC System (Shimadzu LC-10AD Liquid Chromatography) with a Shimadzu SPD-6A UV–Vis detector (Shimadzu, Kyoto, Japan). SCFAs in faecal samples were separated using a Hi-Plex H ion-exchange resin column 300 × 7.7 mm (Agilent Technologies, Malaysia) at 65°C. The target compounds were detected using a UV detector at a wavelength of 210 nm. A 0.01M solution of Sulphuric acid (H2SO4) was filtered through a 0.45-µm nylon membrane as the mobile phase at a flow rate of 0.6 ml/min. Seven calibration standards were prepared at six levels of concentration from 0.01 M to 0.06 M for acetic acid and 0.02 M to 0.12 M for propionic acid and butyric acid. The calibration curves were constructed by plotting the relative peak area against the molarity of the solution (Takashi *et al*., 2024). Faecal SCFAs concentrations were expressed as mean micromoles per gram wet weight.

Statistical Analysis

Data obtained was analyze using SPSS version 30. Descriptive statistics was used to present data in frequencies and percentage. In other cases, data were presented as mean ± SD. WHO, Anthro. Plus was used to analyze anthropometric indices. Chi-square test were used to determine association between social demographic characteristics and nutritional status. A 5% significance level was used.

RESULTS AND DISCUSSION

The results for the socio-demographic, nutritional status, food consumption pattern and short chain fatty acids among 229 adolescent school girls in Igabi LGA, Kaduna, Nigeria, are presented in Tables and Figures below:

Table 1: Socio-demographic Characteristics of Adolescent School Girls in Igabi LGA, Kaduna State (n=229)

Characteristics		School Type		
		Public	Private	Total
		n(%)	n(%)	n(%)
Age (Years)	(mean ± SD)	(15.4±1.9)	(15.8±1.7)	(15.58±1.81)
Sex	Female	126(100%)	103(100%)	229(100%)
Ethnicity	Hausa	80(63%)	57(55%)	137(59.8%)
	Yoruba	20(16%)	20(19%)	40(17.5)
	Igbo	15(12%)	15(15%)	30(13.1%)
	Others	11(9%)	11(11%)	22(9.6%)
Class	Junior Secondary School	36(29%)	20(19%)	56(24.5%)
	Senior Secondary School	90(71%)	83(81%)	173(75.5%)

Characteristics		School Type		
		Public	**Private**	**Total**
		n(%)	**n(%)**	**n(%)**
Family Income	Low-middle Income	80(63%)	34(33%)	114(49.8%)
	Higher Income	46(37%)	69(67%)	115(50.2%)
Religion	Islam	85(68%)	63(61%)	149(65.1%)
	Christianity	40(32%)	40(39%)	80(34.9)
Living With	Parents	100(79%)	90(87%)	190(83%)
	Guardian	26(21%)	13(13%)	39(17%)
Occupation	Students	126(100%)	103(100%)	229(100%)
Parent Education level	Primary	30(24%)	3(3%)	33(14.4%)
	Secondary	50(40%)	50(49%)	100(43.6%)
	Tertiary	30(24%)	50(49%)	80(34.9%)
	No formal Education	16(13%)	0(0%)	16(7.1%)
Family Size category	1 - 3 members	20(16%)	25(25%)	45(19.65)
	4 - 6 members	65(52%)	49(47%)	114(49.78)
	7 - 10 members	25(20%)	20(19)	45(19.65)
	11-15 members	10(8%)	5(5%)	15(6.55)
	16-20 members	3(2%)	2(2%)	5(2.18%)
	>20 members	3(2%)	2(2%)	5(2.18%)

Table 2: Anthropometric Characteristics of Adolescent School Girls in Igabi, LGA, Kaduna State (n=229)

Variables	Public Schools	Private Schools	Total	T-Test	P-Value
Age (years)	15.4 ± 1.8^a	15.8 ± 1.7^a	15.58 ± 1.8	-1.72	0.087
Weight (kg)	48.5 ± 8.5^a	50.2 ± 8.83^b	52.2 ± 9.1	-2.15	0.032
Height (cm)	155.2 ± 6.5^a	156.04 ± 6.39^b	157.1 ± 6.2	-1.98	0.048
BMI (kg/m²)	20.1 ± 3.2^a	20.54 ± 3.37^b	21.1 ± 3.5	-2.51	0.012

Results are presented as mean ±SD; Across the rows, results with different superscripts are significantly different at $p \leq 0.05$

Table 3: Nutritional Status Distribution of Adolescent School Girls in Igabi LGA, Kaduna State (n=229)

Nutritional Status	School Type		
	Public	**Private**	**Total**
	n(%)	n(%)	n(%)
Stunting (<-3SD)	40(32%)	20(19%)	60(26%)
Normal Height (<-2SD)	80(63%)	75(73%)	155(68%)
Underweight (<-3SD)	35(28%)	15(15%)	50(22%)
Normal Weight (>-2SD)	70(56%)	70(68%)	140(61%)
Overweight (>+1SD)	15(12%)	10(10%)	25(11%)
Obese (>+2SD)	6(5%)	8(8%)	14(6%)

Table 4: Food Consumption Pattern (24hours Dietary Recall) of Adolescent School Girls in Igabi LGA, Kaduna State, (n=229)

Variables		Public n(%)	Private n(%)	Total n(%)
Breakfast Consumption		90(71%)	90(87%)	180(78%)
	Cereals	60(48%)	70(68%)	130(56.7%)
	Bread	40(32%)	50(49%)	90(39.3%)
	Fruits	20(16%)	30(29%)	50(21.8%)
Lunch Consumption		120(95%)	100(97%)	220(96%)
	Rice	80(63%)	60(58%)	140(61.1%)
	Beans	40(32%)	30(29%)	40(17.5%)
	Vegetables	50(40%)	60(58%)	30(13.1%)
Dinner Consumption		110(87%)	90(87%)	200(87.3%)
	Rice	70(56%)	50(49%)	120(52.4%)
	Meat/fish	40(32%)	50(49%)	90(39.3%)
	Vegetables	40(32%)	50(49%)	90(39.3%)
Snacking		80(63%)	70(68%)	150(65.5%)
	Fruits	20(16%)	30(29%)	50(21.8%)
	Chips/Cookies	50(40%)	40(39%)	80(34.9%)

Variables		Public n(%)	Private n(%)	Total n(%)
Beverages		70(68%)	90(87%)	160(69.8%)
	Water	100(79%)	90(87%)	190(82.9%)
	Sugary drinks	40(32%)	20(19%)	60(26.2%)

Table 5: Frequency of Food Consumption of Adolescent School Girls in Igabi LGA, Kaduna State, (n=229)

Variables		SchoolType		
		Public n(%)	Private n(%)	Total n(%)
GrainsandCereals				
	Daily	80(63%)	70(68%)	150(65.5%)
	3-4times/week	30(24%)	20(19%)	50(21.8%)
	Rarely	16(13%)	13(13%)	29(12.7%)
Fruits				
	Daily	40(32%)	60(58%)	100(45.6%)
	3-4times/week	50(40%)	30(29%)	80(33.1%)
	Rarely	36(28%)	13(13%)	49(21.3%)
Vegetables				
	Daily	50(40%)	70(68%)	120(52.4%)
	3-4times/week	40(32%)	20(19%)	60(26.2%)
	Rarely	36(28%)	13(13%)	49(21.4%)
ProteinSources				130(56.8%)
	Daily	60(48%)	70(68%)	60(26.2%)
	3-4times/week	40(32%)	20(32%)	39(17%)
	Rarely	26(20%)	13(13%)	
Dairy				
	Daily	70(56%)	80(78%)	150(65.5%)
	3-4times/week	30(24%)	15(15%)	45(19.6%)
	Rarely	26(20%)	8(8%)	34(14.8%)
Snacks	Daily	80(63%)	60(58%)	140(61.1%)
	3-4times/week	30(24%)	30(29%)	60(26.2%)
	Rarely	16(13%)	13(13%)	29(12.7%)
SugaryDrinks	Daily	50(40%)	20(19%)	70(30.5%)
	3-4times/week	40(32%)	30(29%)	70(30.5%)
	Rarely	36(28%)	53(51%)	89(39%)

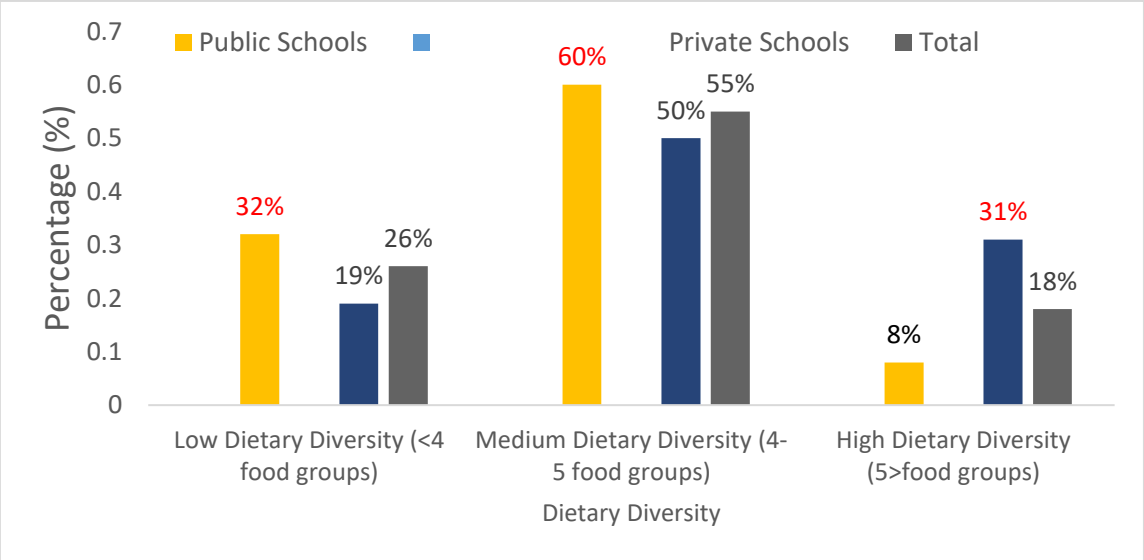

Figure 1: Dietary Diversity of School Girls in Igabi Local Government Area of Kaduna State (n=229)

Table 6: Dietary Diversity Distribution of Adolescent School Girls in Igabi LGA, Kaduna State According to the Age (n=229)

Age group	Dietary Diversity	School Type	
		Public n(%)	Private n(%)
10-11 years (n=40)			
	Low(<4fgroups)	20(50%)	10(25%)
	Medium(4-5fgroups)	15(38%)	20(50%)
	High (>5fgroups)	5(13%)	10(25%)
12-14 years (n=80)			
	Low(<4fgroups)	35(44%)	15(38%)
	Medium(4-5fgroups)	30(38%)	40(50%)
	high(>5fgroups)	15(19%)	25(31%)
15-17 years (n=70)			
	Low(<4fgroups)	25(36%)	10(14%)
	Medium(4-5fgroups)	30(43%)	35(50%)
	high(>5fgroups)	15(21%)	25(36%)
18-19 years (n=39)			
	Low(<4fgroups)	15(38%)	5(13%)
	Medium(4-5fgroups)	15(38%)	20(51%)
	high(>5fgroups)	9(23%)	14(36%)

Table 7: Short Chain Fatty Acids (SCFAs) distribution of Adolescent School Girls in Igabi LGA, Kaduna State (n=229)

SCFAs	School Type	
	Private Type	Public
	n(%)	n(%)
Acetate (µmol/g)	(120.5±20.5)	(150.8±25.1)
Propionate (µmol/g)	(30.2±5.5)	(40.5±6.8)
Butyrate (µmol/g)	(20.1±4.2)	(28.5±5.1)
Total SCFAs (µmol/g)	(170.8±30.2)	(219.8±36.9)

Table 8: Short Chain Fatty Acids (SCFAs) Distribution of Adolescent School Girls in Igabi LGA, Kaduna State According to the Age (n=229)

Age group	SCFAs	Public n(%)	Private n(%)
10-11 years (n=40)	Acetate (µmol/g)	(40.5±9.2)	(45.8±10.5)
	Propionate (µmol/g)	(10.2±2.5)	(12.5±3.2)
	Butyrate (µmol/g)	(6.5±1.8)	(8.2±2.3)
12-14 years (n=80)	Acetate (µmol/g)	(42.1±10.1)	(50.2±12.1)
	Propionate (µmol/g)	(11.5±2.8)	(14.5±3.5)
	Butyrate (µmol/g)	(7.2±2.1)	(9.5±2.5)
15-17 years (n=70)	Acetate (µmol/g)	(45.8±11.2)	(55.1±3.2)
	Propionate (µmol/g)	(13.2±3.2)	(16.8±4.1)
	Butyrate (µmol/g)	(8.5±2.3)	(11.2±2.9)
18-19 years (n=39)	Acetate (µmol/g)	(50.2±12.5)	(60.5±4.5)
	Propionate (µmol/g)	(15.1±3.8)	(18.2±4.5)
	Butyrate (µmol/g)	(9.8±2.5)	(12.8±3.2)

Table 9: Association between Sociodemographic Characteristic and Nutritional Status of Adolescent School Girls in Igabi LGA, Kaduna State (n=229)

Sociodemographic Characteristic	Nutritional Status Index	Public Schools (n=126)	Private Schools (n=103)	χ^2	p-value
Family Income	Stunting	40 (32%)	20 (19%)	4.71	0.03*
Family Income	Underweight	35 (28%)	15 (15%)	5.41	0.02*
Parents' Education Level	Normal Weight	70 (56%)	70 (68%)	4.08	0.04*
Family Size	Overweight	15 (12%)	10 (10%)	3.84	0.05*
Ethnicity	Obesity	6 (5%)	8 (8%)	5.12	0.02*

*Results are significant at $p<0.05$

Table 10: Association between Socio-demographic Characteristics, Gut Microbiota and Short Chain Fatty Acid of Adolescent School Girls in Igabi LGA, Kaduna State (n=229)

Sociodemographic Characteristic	SCFAs	Public Schools	Private Schools	p-value
Ethnicity	Acetate	10(8%)	5(5%)	0.05*
Family Income	Acetate	24(40%)	27(45%)	0.04*

Parents' Education Level	Propionate	18(30%)	21(35%)	0.02*
Family Size	Butyrate	3(5%)	5(8%)	0.01*

*Results are significant at p<0.05

Table 11: Association between Gut Microbiota, Short Chain Fatty Acid, Dietary Diversity and Eating Behavior of Adolescent School Girls in Igabi LGA, Kaduna State (n=229)

SCFAs	Dietary Diversity	Nutritional Status	Public School	Private School	p-Value
Acetate	High Dietary Diversity	Normal weight	24(40%)	27(45%)	0.04*
Propionate	Medium DietaryDiversity	Normal weight	18(30%)	21(35%)	0.02*
Butyrate	Low Dietary Diversity	Underweight	3(5%)	5(8%)	0.01*
Acetate	High Dietary Diversity	Normal weight	6(10%)	9(15%)	0.02*
Propionate	Medium Dietary Diversity	Normal weight	5(8%)	7(12%)	0.01*
Butyrate	High Dietary Diversity	Normal weight	12(20%)	15(25%)	0.04*
Acetate	Low Dietary Diversity	Stunting	10(8%)	5(5%)	0.05*
Propionate	Low Dietary Diversity	Underweight	9(15%)	6(10%)	0.02*

*Results are significant at p<0.05

Discussion

The findings of this study provide valuable insights into the sociodemographic characteristics, nutritional status, food consumption patterns, dietary diversity, eating behavior, food security, food handling, gut microbiota composition, and short-chain fatty acids (SCFAs) of adolescent school girls in public and private schools in Igabi Local Government Area of Kaduna State, Nigeria. The results show significant differences between public and private schools in terms of all parameters assessed in this study. The mean age of the study population are (15.4±1.9) and (15.8±1.7) for public and private adolescent school girls respectively. This is in contrast with a study conducted in Chikun Local Government Area of Kaduna State (Malaki and Salisu, 2023) and a study reported by Danjuma *et al*., 2020. Among the respondents from public schools, 85(68%) are Muslims while 40(32%) are Christians which is also differed with a study conducted by Malaki and Salisu, 2023. This is due to the fact that, Chikun Local Government Area of Kaduna State is dominated by Christians when compare to Igabi Local Government Area of Kaduna State that is likely dominated by Muslims. This result is not in line with the study of Berry *et al*., 2015. This is also in similarity with a study reported by Paul *et al*., 2023. This is not similar with the study carried out by Malaki and Salisu, 2023 and also differed with our present study. Private schools had higher family income 69(67), parents' education level 50(49%), and smaller family size for 1 - 3 members, 4 - 6 members, 7 - 10 members, 11-15 members, 16-20 members and >20 members; 25(25%), 49(47%), 49(47%), 20(19), 2(2%) and 2(2%) respectively. These findings are consistent with previous research that suggests that private schools tend to have more affluent students with better-educated parents (Kaplan and Owings, 2013). This is vary with a study conducted by Paul *et al*., (2023) and in contrast with a study reported by Obeyera *et al*. (2023).

Our study revealed the nutritional status of adolescent school girls, where stunting is 60(26%), underweight 50(22%), normal weight 140(61%), overweight 25(11%), and obesity 14(6%).Which is different with the prevalence of wasting (thinness) among adolescent girls, (26%) and (49.7%) in two Bangladeshi studies, (Danjuma *et al*., 2020, Berhe and Gebremariam, 2020), and (53.8%) in India (Wassie *et al*., 2015) respectively. Another study carried out in India showed that prevalence of underweight, stunting, and thinness among adolescent girls was found to be (32.8%), (19.5%), and (26.7%), respectively (Arage *et al*., 2019). In Turkey, the rates of being stunted, underweight, and overweight and /or obese were (4.4%), (5.0%), and (16.8%), respectively (Demilew and Emiru, 2018). Ethiopia has one of the highest rates of malnutrition in Sub-Saharan Africa and faces acute and chronic malnutrition and micronutrient deficiencies (Berhe and Gebremariam, 2020). Nutrition deficiencies at different childhood growth and developmental stages including adolescences are common in Sub-Saharan Africa (Gagebo *et al*., 2020). Girls are vulnerable to stunting and wasting during adolescence because this period is characterized by a growth spurt including sexual development, maturation, and the onset of menarche. All of these factors cause an increased demand for nutrients and make girls vulnerable to malnutrition and are compounded by socio-demographic and economic factors (Ayranci *et al*., 2010). In Ethiopia, adolescent girls' aged 15–19 years (29%) are most likely to be thin (body mass index (BMI) below 18.5 kg/m^2). Rural areas have a higher percentage of thin girls (25%) than in urban areas (15%). However, the percentage of overweight or obese women is higher in urban areas (21%) than in rural areas (4%) (Al-Muammar *et al*., 2014). Studies conducted in different regions of Ethiopia reveal that the overall prevalence of stunting among the adolescent girls is (15.5%), (Omobuwa *et al*., 2014), 20.2%, (Adesina *et al*., 2012), (12.2%), (Mahmoud and Taha, 2017) and (15%) (Waweru and Marete, 2016), in Tehuledere, Arsi, Adwa, and Babli districts, respectively. Likewise, the prevalence of thinness varies across different regions of Ethiopia. The prevalence of thinness among adolescent girls was (21.6%), (28%), (21.4%), and (14.8%) in studies conducted in Babille district, (Mahmoud and Taha, 2017), Adwa, (Omobuwa *et al*., 2014) and Arsi zone (Ayranci *et al*., 2010). The findings from this study show that (16.3%) (95% CI: 12.5%, 20.1%) of adolescent girls were stunted. The finding reported by another studies conducted in Bible district, Eastern Ethiopia revealed (15%), (Waweru and Marete. 2016). Tehuledere district

(15.5%), (Omobuwa *et al*., 2014) and the Bangladeshi study (15.5%) (Danjuma *et al*., 2020) of stunting. But it is higher than the findings from Turkey (4.4%) (Demilew and Emiru, 2018).Addis Ababa (7.2%), (Tegegne *et al*., 2016). and Mozambique (2.3%) (Yemaneh *et al*., 2012). This is probably due to the difference in the socio-economic and socio-demographic characteristics since people in Turkey and Addis Ababa are higher than those in our study area in terms of socio-economic status. Nevertheless, it was lower than studies conducted in India (19.5%) and Bangladesh (32%), (Berhe and Gebremariam. 2020), two northern Ethiopia studies (28.5%) (Talaie-Zanjani *et al*., 2014), and (31.5%), (Adamu *et al*., 2012). and in Tigray (26.5%). Gebremariam *et al*., 2015). This might be due to the variation in sample size, which increases the proportion of stunting. Correspondingly, the findings from the previous study show that (29%) (95% CI: 24.4%, 33.6%) of adolescent girls were thin. This finding is consistent with a study conducted in Bangladesh (26%), India (26.7%), and Northern Ethiopia (26.1%) (Berhe and Gebremariam, 2020). However, the study is higher than studies conducted in Bible district, Eastern Ethiopia (21.6%), Benue State, Nigeria (11.5%), (Kahssay *et al*., 2020). Adwa town (21.4%) (Mahmoud and Taha, 2017). Northwest Ethiopian study (13.6%), and low-income countries (6.3%) (Mahmoud and Taha, 2017). This might be due to the fact that there is a difference in barriers to undernutrition such as cultural differences and other socio-demographic characteristics. Still, it was lower than studies conducted in Tigray (37.8%), (Gebremariam *et al*., 2015). Kano, Northwestern Nigeria (60.6%), (Danjuma *et al*., 2020) and Kashmir Valley (35%) (Birru *et al*., 2017). This is not consistent with our present study.This is possibly due to the difference in the study area and sample size. The study of Kano, Northern Ethiopia, and Kashmir Valley used a small sample size, which may have led to an increased estimation of the proportion of thinness. On the contrary, the Indian study was hospital-based which may have increased the prevalence of thinness (wasting) due to illness (Birru *et al*., 2017). Again, the study in Tigray was conducted in a rural area, which is predisposed to a high prevalence of thinness among adolescents. Consequently, the nutrient requirements are significantly increased as compared to that of children. So, if the requirements and supply are not balanced, the adolescent girls may be exposed to stunting (Talaie-Zanjani *et al*., 2014). A study conducted in the southern part of Nigeria reported a (13.0%) prevalence rate of underweight and was found to be influenced by residence and income levels (Gebregyorgis *et al*., 2016). Another similar study was conducted in rural and urban areas in Enugu, and the prevalence rate of thinness was (13.9%) (Hossain *et al.,* 2013*).* Globally, around (10.0%) of the adolescents are overweight, varying from 10.0% in Africa and Asia to more than (20.0%) in the USA and Europe (Getachew *et al*., 2019). Another study in southern Nigeria reported the prevalence rate of overweight and obesity as (11.4%) and (2.8%) (Mulugeta *et al*., 2009). Also a study conducted in the southern part of Nigeria found (22.0%) and (49.3%) overweight and obesity, respectively (Demilew and Emiru, 2018). This is also differed with our current study. The BMI was calculated as weight in kg divided by height in metre squared. The BMI categories used are as follows: Underweight (BMI < 18.5 kg/m2); Normal weight (BMI ≥ 18.5 to 24.9 kg/m2); Overweight (BMI≥ 25 to 29.9 kg/m2); Obese (BMI ≥ 30 kg/m2) (Gagebo *et al*., 2020). Another study found that among adolescent girls, the prevalence of stunting was (12.3%) (95% CI: 9.7–14.8). This higher than the findings in our present study. It also exceeded the (6.8%) observed in the Addis Ababa, Ethiopia research (Gebregyorgis *et al*., 2016).Also in contrast, it was lower (34.0%) compared with the research conducted in Bangladesh (Adesina *et al*., 2012), Indonesia (25.0%), (Mahmoud et al., 2017) rural India (19.2%), (Waweru and Marete, 2016).West Bengal in India (20.7%) and (31.4%), (Molarius *et al*., 2000) and various regions of Ethiopia (Erinosho *et al*., 2012). Which is in different with the work reported that, Stunting and thinness are prevalent in Ethiopian adolescent girls, with prevalence rates ranging from (6.8% to 33.2%) and (8.82% to 58.3%) respectively (Mulugeta *et al*., 2009). These disparities could have a long-term nutritional influence on school-aged adolescent girls due to economic condition, and educational attainment of the families. In the study above, half of the adolescent girls had normal body weight, while a one-third of them were underweight, and below one-tenths were overweight (Mulugeta *et al*., 2009). Another studies reported that about half of the students were within normal weight, while more than one fourth were underweight (Ayranci *et al*., 2010). This is not similar with findings of our present study while it was consistent with a study conducted in the north-western part of Nigeria, which found that (63.4%) of the adolescents had healthy-weight, (29.0%) were undernourished, while (5.4%) were overweight and (2.2%) were obese (Omobuwa *et al*., 2014). However, another study documented among the selected schools in the south-south region of Nigeria found a higher proportion of normal weight (85.0%) and a lower proportion of underweight (Adesina *et al*., 2012). A study conducted among nursing students reported that most of them were in the normal weight category; however, about one-fourths were overweight, and the rest were underweight and obese (Mahmoud and Taha, 2017). This finding is inconsistent with our study, which may be due to the willingness of nursing students to keep their weight within the normal range. The findings of this study are consistent with another study conducted among the university students in Rwanda, where almost all students had normal weight, but there was a reasonably high occurrence of overweight among the students (Waweru and Marete. 2016). Our study revealed that private schools had better nutritional status compared to public schools. Private schools had lower rates of stunting 20(19%), underweight 15(15%), overweight 10(10%) and obesity 8(8%). These findings are similar with previous research that suggests that private schools tend to have better nutritional outcomes due to better access to nutritious food and healthcare (Glewwe and Kremer, 2006).

Our study shown that, almost have of adolescent school girls participated in the study have Breakfast Consumption of 180(78%), almost all had lunch Consumption 220(96%), and dinner Consumption 200(87.3%), whereby most of the participants also have snacks 150(65.5%) and beverages Consumption 160(69.8%), 190(82.9%) respectively. Study reported by Worku *et al*., (2024) presented similar food consumption frequencies. This may be because adolescents, in general, present a common dietary pattern with low consumption of fruits and vegetables and higher consumption of high-calorie, high-sugar, and preservative-rich foods (Bawadi *et al*., 2012). This is in different with present study. The previous study revealed that, the proportion of individuals classified by the food freguence questionnaire (FFQ) and the average of two 24-hours dietary recalls into the same quartile ranged from (2%) for beverages to (61.3%) for legumes. This is in proportion with our current study and higher than the findings of a similar validation study from Butajira (Murugesan *et al*., 2015). This might be due to the use of the triple 24-hours dietary recall method, which improved the categorization through approaching the values from the food frequency questionnaire which is not in

agreement with our study. However, the proportion classified into opposite quartiles varied from (2%) for cereal and cereal products to (24%) for beverages. This finding contradicts the findings from validation studies conducted in older adults in Iranian people, Mexico Egypt and the Lebanese (Teixeira *et al*., 2013). While in the present study more than half of adolescent school girls consumed Grains and Cereals daily 150(65.5%) while only 29(12.7%) rarely consumed. Almost half of the study participants consumed fruits daily 100(45.6%), more than half consumed vegetables, Protein Sources, Dairy , Snacks daily 120(52.4%),130(56.8%), 150(65.5%), 140(61.1%) and 70(30.5%) consumed Sugary Drinksdaily. 50(21.8%),80(33.1%), 60(26.2%), 60(26.2%), 45(19.6%), 60(26.2%) and 70(30.5%) were consumed for the all food groups 3-4times per week which in different with a research work reported by Worku *et al*., (2024), which stated that, majority of the participants consumed milk/milk products twice or less in a week, and it was significantly associated with their BMI (Worku *et al*., 2024). Similarly, a study reported that milk and dairy products were the best sources of calcium *(*Musa *et al*., 2012). Most participants took red meat at least twice or less in a week. This is, however, in contrast with the findings of another study reporting daily consumption of body building and protective foods by an adolescent was practically non-existent in the study area (Lee, 2003).Vegetables and fruits are an essential part of a healthy diet. This is similar to our present findings. Perhaps' the finding was in agreement with a study stating that vitamins and minerals such as calcium, iron, and iodine must be included in adolescents' diets, and the best sources of vitamins are fruits and vegetables (*Musa et al.,2012).* Another study conducted in America reported that the consumption of fruits and vegetables daily could significantly help to sustain the adolescent girls with expected BMI (Holzer *et al*., 2012). Our findings revealed that more than (90.0%) of the adolescent girls in this study took breakfast regularly, and a significant association was reported with their BMI. A similar study conducted in Georgia reported that about (62.0%) of the adolescent girls with normal BMI had breakfast regularly (Ringel-Kulka *et al*., 2013). This study found significant differences in food consumption patterns between public and private schools. Private schools had higher consumption of fruits, 30(29%), vegetables 50(49%), and protein sources 50(49%), 30(29%) respectively. These findings are consistent with previous research that suggests that private schools tend to have better dietary habits due to greater access to healthy food options (Story *et al*., 2008).

However, a previous study revealed that, adolescent girls were 2.21 times (AOR: 2.21, 95% CI: 1.06–4.60) more likely to experience malnutrotion than those with adequate dietary diversification (Getachew *et al*., 2019). It agreed with the research conducted in various parts of Ethiopia (De-Philippi and Leme, 2015).This might be the case because dietary diversity is a proxy indicator of dietary habits and has the capacity to record consumption of both macronutrients and micronutrients (De-Philippi and Leme, 2015). Studies conducted in other regions of Ethiopia, however, revealed no connection between dietary diversification and stunting in adolescent girls (Wu *et al*., 2011).In our present study, we found out that, not upto half of adolescent school girls have low dietary diversity of 60(26%) and high dietary diversity 60 (26%), while almost half have moderate dietary diversity 110(48%) which is in contrary with the studies reported above (Wu *et al*., 2011). The study also found that private schools had higher dietary diversity 33(32%) compared to public schools 26(20%). These findings are consistent with previous research that suggests that dietary diversity is an important indicator of nutritional quality and health outcomes (Ruel, 2003).

However**,** SCFAs primarily acetate, propionate, and butyrate are produced by enteric microbes as end products of anaerobic fermentation of undigested fiber, and serve as a variety of imperative roles in the gut. Butyrate, which serves as the primary nutrient source for colonocytes (Priyadarshini *et al*., 2014) and functions as a histone deacetylase inhibitor (Szczuko *et al*., 2020 Łoniewska *et al*., 2023). Throughout its inhibition of NF-κB signaling in colonocytes, butyrate contributes to barrier integrity maintenance and reduces levels of intestinal inflammation markers (Malinowska *et al*., 2023). Acetate, propionate, and butyrate also each activate G-protein-coupled receptors (GPRs) that modulate the key metabolic hormones, including peptide YY (PYY) and GLP-1 (Goffredo *et al*., 2016). Consistent with these mechanistic findings, A studies have shown that that, abundance of acetate, propionate, butyrate can protect against weight gain, improve insulin sensitivity, and reduce obesity-associated inflammation (Ostrowska *et al*., 2024). Our study show the quantitative measures of short chain fatty acids from the feacal sample collected from the adolescent school girls. The total mean of short chain fatty acids of both public and private school girls were (170.8±30.2) and (219.8±36.9) respectively. The results revealed that private school girls have higher level of short chain fatty acids level; Acetate (150.8 vs 120.5 µmol/g), Propionate (40.5 vs 30.2µmol/g), and Butyrate (28.5 vs 20.1µmol/g) respectively. The findings suggest that private school girls have higher level of short chain fatty acids, which can have beneficial effects on gut health and overall well-being. This may be due to richness of diversity of bacterial strains obtained from the feacal sample of the adolescent private school girls while the reverse is the case when compare to that of adolescent public school girls and this may be also link to improper nutrition practices recorded from adolescent public school girls. Therefore, the type, amount, and proportion of SCFAs produced by microbiota mainly depend on the type of the diets consumed, food security and knowledge, attitudes and practices by the caregivers of adolescent school girls. This is not similar with a research work reported by Narcisse *et al*., 2019, as their study revealed the molar ratio of the baseline faecal SCFAs to be 9:6:5 for propionic acid, acetic acid, butyric acid. Which is not in accordance with a previous study that reported acetate as the major SCFA, followed by propionate and butyrate (Schwiertz *et al*., 2010). While study by Schwiertz *et al*., 2010 is similar with our study. It has been suggested that such discrepancies occur due to a complex interaction between different dietary factors in different regions and countries, leading to differences in microbiome diversity and gut transit time (Bervoets *et al*., 2013). SCFAs can be used by colon cells as a local energy source and participate in many metabolic processes, such as lipid metabolism and glucose homeostasis (Bervoets *et al*., 2013). They contribute to the regulation of insulin sensitivity and glucose metabolism, potentially influencing the occurrence of some metabolic disorders such as type 2 diabetes or obesity (Den Besten *et al*., 2013). SCFAs are transported from the intestinal lumen into the host's blood and are taken up by organs, where they act as substrates or signaling molecules. SCFAs are metabolized at three main sites in the body (epithelial cells of the cecum and colon, liver cells, and muscle cells) (Den Besten *et al*., 2013). The study found significant differences in SCFAs between public and private schools. Private schools had higher levels of acetate, propionate, and butyrate. These findings are consistent with previous research that suggests SCFAs are important

indicators of gut health and are influenced by dietary habits (den Besten *et al*., 2013).

In our study, there was a significant associations between sociodemographic characteristics and nutritional status among adolescent school girls. Family income, parents' education level, and family size are significantly associated with nutritional status at p=<0.05. The chi-square values indicate the strength of the associations, with higher values indicating stronger associations. This is in line with a recent study reported that, socio-demographic factors and socio-economic factors are associated with the nutritional status of adolescents (Wu *et al*., 2011). This may be mainly due to nutrition, epidemiologic, and socio-demographic transition across the world (Scott *et al*., 2013).Also a study in United State (US), shows that, Socio-economic status was found to be associated with nutritional status of US adolescents (Chan *et al*., 2013). These studies are in line with our present study. The study association between sociodemographic characteristics, and short chain fatty acids in public and private schools at p=<0.05.

CONCLUSION

The integrated study reveals a coherent pattern: private-school adolescent girls benefit from higher socioeconomic status, greater dietary diversity, better nutritional status, and food consumption pattern, all of which correlate with a SCFAs profiles and reduced levels of good nutritional practices in Public-school girls, facing opposite conditions, show higher rates of stunting, and underweight. Targeted interventions improving school meals, nutrition education, and good nutritional practices could narrow these gaps and promote healthier gut ecosystems across both settings.

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