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The Contribution of Obesity to Alterations in Atherogenic Lipids in Cameroon Children

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Abstract: *Background:* Obesity among children is rising steadily in Cameroon and its association with dyslipidemia and consequently cardiovascular risk has become a concern for medical researchers. This study aims at determining the prevalence of dyslipidemia and also quantifying the effects of obesity assessed using BMI, waist circumference (WC) and waist-to-height ratio (WHtR) on changes in atherogenic lipid levels in children. *Methods:* A hospital-based analysis was carried out in children (270 males, 296 females) of ages 5 to 16 years at the outpatient unit of the Bamenda Regional Hospital in Cameroon. Body weight, height and waist circumference were measured and adjusted for age and gender. BMI and WHtR were calculated. A vacutainer was used to obtain fasting venous blood samples from the children. The total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C) concentrations were determined by enzymatic method using an automated clinical chemistry analyzer - RX Monaco (RANDOX, UK). The relationships between obesity and altered serum lipid concentrations were assessed using multiple quantile regression analysis. *Results:* From this sample, 46.4% and 44.9% of females and males respectively had at least one lipid disorder and the most common lipid disorder was low HDL-C. After adjusting for age and gender, BMI-obesity was significantly associated with a 6.76mg/dl, 4.92mg/dl and 5.09mg/dl increase in TC ($p = 0.016$), TG ($p = 0.021$) and LDL-C ($p = 0.001$) respectively, and a decrease (-3.92mg/dl) in HDL-C ($p = 0.030$). Also, central obesity (WC) significantly increased TC ($p = 0.001$) and LDL-C ($p = 0.020$) by 6.01mg/dl and 4.32mg/dl respectively and decreased HDL-C by -4.01mg/dl ($p = 0.003$). WHtR was also associated with a 6.69mg/dl and 5.18mg/dl increase in TC ($p < 0.001$) and LDL-C ($p < 0.001$) respectively. *Conclusion:* This study reinforces the frequent occurrence of altered serum lipid levels in Cameroon children and the contribution of BMI-obesity to the condition. Future studies are required to evaluate the contribution of other modifiable drivers of dyslipidemia in childhood to aid interventions, as this condition can increase the risk of future cardiovascular disease.

Keywords: Obesity, Dyslipidemia, Children, Quantile Regression, Cameroon

1. Introduction

Evidence is pointing to a rapid rise in the number of overweight/obese children in recent decades and the situation is now considered as a global emergency [1]. A report had indicated that the number of overweight/obese children between the ages of 5 and 17 years might increase to 355 million by 2025 [2]. In Sub-Saharan Africa, the proportion of overweight/obese children is also on the rise [3]. A nationwide survey in Cameroon has revealed that overweight/obesity is

affecting more children in the Grass-field area of the country [4]. Also, a recent report in the North West Region (part of the Grass-field area) of Cameroon revealed that the prevalence of central overweight/obesity has increased by more than 5% in the past decade [5].

This is concerning because childhood obesity has been shown to contribute to abnormal serum lipid levels (low levels of high-density lipoprotein cholesterol – HDL-C and elevated levels of total cholesterol – TC, triglycerides – TG and low-density lipoprotein cholesterol – LDL-C). It has also been shown to contribute to high blood pressure and insulin resistance in children and adolescents, and increasing cardiovascular disease (CVD) risk in adulthood [6]. The alterations in serum lipid levels have also been shown in autopsy studies to be a predisposing factor of atherosclerotic lesions in two year old children and young adults [7], and can be considered to be important mediators in the development of CVD later in life [8]. For instance, increase in TC in childhood has been shown to contribute to the thickening of the carotid intima-media complex, which is a condition that can predispose adults to atherosclerosis [9, 10]. Also, evidence from major epidemiologic studies have shown that obesity, high levels of LDL-C and lower levels of HDL-C in children and youth contribute to an increased risk in physiologic arteria changes in adulthood [6, 11]. Therefore, in order to slow down the development of CVD-related health outcomes, it is important for initiatives to curb obesity and dyslipidemia to begin in childhood.

Different measures to assess obesity are currently being used in epidemiological studies and include: Body mass index (BMI), waist circumference (WC), percentage body fat (%BF) and waist-to height ratio (WHtR) and others. A recent study has demonstrated that these parameters are useful in identifying dyslipidemia in children and adolescents [12]. A previous report had indicated that BMI and WC are associated with dyslipidemia in children and youths [13]. Also, a recent study that used BMI, WC, WHtR and %BF to assess obesity, revealed that the concentrations of TC and LDL-C were significantly higher in obese children than healthy weight children. The authors also reported that 21% of changes in TC was explained by excess body fat [14]. In addition, a Brazilian study reported that obese adolescents were 3.3 times at risk of having unfavourable triglyceride levels when compared with healthy weight adolescents [15]. However, this study had a low response rate of 40.8%. Furthermore, a recent study indicated that WHtR explained 2.7% of changes in LDL-C [16]. WHtR was the most reliable parameter that identified decreased HDL-C and increased TC, TG and LDL-C in children and adolescents in a recent report [12].

In Cameroon, there is paucity of data on lipid levels in children and relationships between obesity parameters and unfavourable serum lipid levels. In addition, it is not well known which of the obesity parameters contributes the most to dyslipidemia in children and adolescents, which could be useful in screening for cardiovascular risk factors. This study therefore sets out to determine the proportion of children with dyslipidemia and also evaluate the influence of different parameters of obesity on alterations in serum lipids concentrations in children.

2. Materials and Methods

2.1. Study Participants

This study was hospital-based and included children who were consulting at the outpatient unit of the Bamenda Regional Hospital, North West Region of Cameroon. These children visited the hospital either for routine check-up or to consult for non-specific illnesses. In the recruitment process 583 children who had fasted overnight for 12 hours were selected. However, based on medical records, 17 children were excluded from the study. Those excluded had either undergone recent surgery, had a history of chronic diseases like renal diseases or type 1 diabetes or were undergoing clinical nutritional care. This gave a final sample of 566 children (270 males and 296 females) between the ages of 5 and 16 years.

2.2. Ethical Considerations

This study was approved by the Ethical Review Committee/Institutional Review Board of The University of Bamenda (Ref. No. 2021/103H/UBa/IRB). Administrative authorization was obtained from the Regional Delegation of Public Health of the North West Region of Cameroon. Hospital clearance was also obtained from the Bamenda Regional Hospital. In addition, the parents/guardians gave written informed consent before data collection. The children gave verbal assent before any study-related procedure was carried out.

3. Data Collection

3.1. Anthropometry

All anthropometric data were collected in the Bamenda Regional Hospital premises during consultation at the outpatient unit by trained nurses. All measurements were taken in the morning hours between 7.30 and 9.00 am. A portable stadiometer (Seca 213, Germany) was used to measure standing height to the nearest 0.1cm. Body weight was measured to the nearest 0.1kg using a tetrapolar eight electrode bioimpedance digital scale (Omron BF 511, Japan). The study participants were all barefoot and had light clothing during measurement. Body mass index (BMI) was calculated in kg/m^2 by dividing the body weight (kg) by the square of the height (m^2). Height, weight and BMI z-scores were calculated using a growth monitoring software (WHO AnthroPlus), which employs the growth standard of the WHO for children between 5 to 19 years [17]. The WHO BMI cut-off points of > 1 z-score and > 2 z-score were used to classify the study participants as overweight and obese respectively [17]. Waist circumference was measured to the nearest 0.5cm using a non-elastic and flexible tape (Seca 201, Germany) following the protocol of McCarthy *et al* [18]. The waist circumference readings were

also adjusted for age and gender using a growth monitoring software (LMS Growth) that includes the UK growth reference data for waist circumference, and the 91st percentile was the cut-off point to determine if participants are centrally overweight/obese [18]. The WHtR was calculated by dividing the WC (cm) by height (cm) and participants classified as 'low risk' or 'high risk' when WHtR is < 0.5 and ≥ 0.5 respectively as higher upper body fatness poses health risks [19].

3.2. Biochemical Examination

Biochemical examinations were carried out at the laboratory of the Bamenda Regional Hospital. A vacutainer was used to obtain fasting blood samples (5ml) from the antecubital veins of the study participants. After collection, the blood sample was allowed to coagulate, and then centrifuged at 3000 rpm for 3 minutes, which separated the blood into serum and packed cells. A pipette was used to extract sufficient quantity of serum into a sample vial for lipid analysis.

TC, TG, and HDL-C levels in serum were estimated in mg/dl by enzymatic method using RX Monaco, a fully automated clinical chemistry analyzer (RANDOX, UK). Daily quality controls were run with the Randox Assayed Mutisera level 2 and level 3 following the manufacturer's instructions. The Friedewald equation was used to calculate the levels of LDL-C [20]. During the collection of blood samples, the study participants were asked if they had eaten in the morning in order to know their fasting state.

The study participants were classified as having acceptable, borderline and high levels of lipids following the recommendations of the Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents [21]. The cut-off points (in mg/dl) for the classification were as follows: TC: acceptable < 170, borderline 170 - 199, high ≥ 200; TG: acceptable < 90, borderline 90 - 129, high ≥ 130; LDL-C: acceptable < 110, borderline 110 - 129, high ≥ 130: HDL-C: acceptable > 45, borderline 40 - 45, low < 40 [21].

The presence of one or more of the following was also used to define dyslipidemia: TC ≥ 200mg/dl, TG ≥ 130mg/dl, LDL-C ≥ 130mg/dl and HDL-C < 40mg/dl [22].

3.3. Statistical Analysis

The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to check for the normal distribution of continuous variables. The comparisons of continuous variables by gender were assessed using Mann-Whitney *U*-test and results have been presented as median (interquartile range). Proportions were compared using the Chi-squared test and we have reported the proportions and their corresponding confidence intervals. The Kruskal-Wallis test was used to compare the median of serum lipids across categories of measures of obesity (unadjusted analysis). Multiple quantile regression analysis was used to assess the influence of the measures of obesity on serum lipids. In this analysis, the measures of obesity were the independent variables and the association tested between the independent variables and each serum lipid (modelled as the dependent variable). Also, in the regression analysis, the model was adjusted for all variables in the unadjusted analysis, age and gender. The regression coefficient estimates of the median of the serum lipids were calculated using the Powel Kernel method [23]. The cut-off point for statistical significance was $p < 0.05$. All statistical tests were carried out using R version 3.4.1, which has the 'quantreg' package included [23].

4. Results

Table 1 shows a description of the sample. The females were significantly ($p < 0.05$) taller and heavier than the males. However, these differences were no longer statistically significant after adjusting for age. Also, waist circumference, wait-to-height ratio and total cholesterol were significantly ($p < 0.05$) higher in females than males.

Table 1. *Descriptive characteristics of the study population.*

Variables	Whole sample (n=566)	Males (n=270)	Females (n=296)	*p*-value
	Median (IQR)	Median (IQR)	Median (IQR)	
Age (years)	12.5 (4.4)	11.4 (4.7)	13.2 (3.5)	< 0.001
Height (cm)	150.0 (20.0)	144.5 (25.8)	155.0 (13.0)	0.013
Height z-score	-0.28 (1.28)	-2.00 (1.68)	-3.00 (1.15)	0.936
Weight (kg)	44.0 (27.0)	35.0 (28.0)	49.0 (23.0)	0.002
Weight z-score	0.10 (1.30)	-0.05 (1.40)	0.18 (1.32)	0.237
BMI (kg/m^2)	19.2 (6.1)	18.4 (7.2)	20.7 (6.0)	0.001
BMI z-score	0.59 (1.79)	0.50 (2.07)	0.60 (1.58)	0.712
Waist circumference (cm)	68.0 (12.0)	64.0 (13.0)	70.0 (11.0)	< 0.001
Waist circumference z-score	1.09 (1.11)	0.70 (1.13)	1.42 (0.83)	< 0.001
WHtR	0.46 (0.05)	0.45 (0.06)	0.46 (0.04)	0.019
Total cholesterol (mg/dl)	159.1 (38.7)	152.7 (39.0)	163.2 (40.5)	< 0.001
Triglycerides (mg/dl)	92.1 (59.2)	91.9 (70.7)	93.0 (54.9)	0.096
HDL (mg/dl)	57.1 (44.0)	56.2 (44.2)	61.1 (42.4)	0.158
LDL (mg/dl)	74.8 (51.3)	73.7 (49.5)	80.0 (55.9)	0.404

*Mann-Whitney U test; IQR, interquartile range.

The overall prevalence of dyslipidemia in this study is 45.6%. Dyslipidemia affected more females (46.4%) than males (44.9%). However, this gender difference was not significant (X^2-value = 0.091, $p = 0.833$). The most

common dyslipidemia among the study participants was low HDL-C (39.1%) followed by elevated TG (23.8%), TC (13.4%) and LDL-C (13.1%). Also, the prevalence of combined dyslipidemia (two or more lipid disorders) was 26.5%.

Figure 1 shows the distribution of the study participants according to the different serum lipid levels in males and females. When the proportions were compared, there was also no significant difference in the levels of TC (X^2-value = 2.903, p = 0.234), TG (X^2-value = 0.493, p = 0.782), LDL-C (X^2-value = 2.009, p = 0.366) and HDL-C (X^2-value = 0.916, p = 0.632) between males and females.

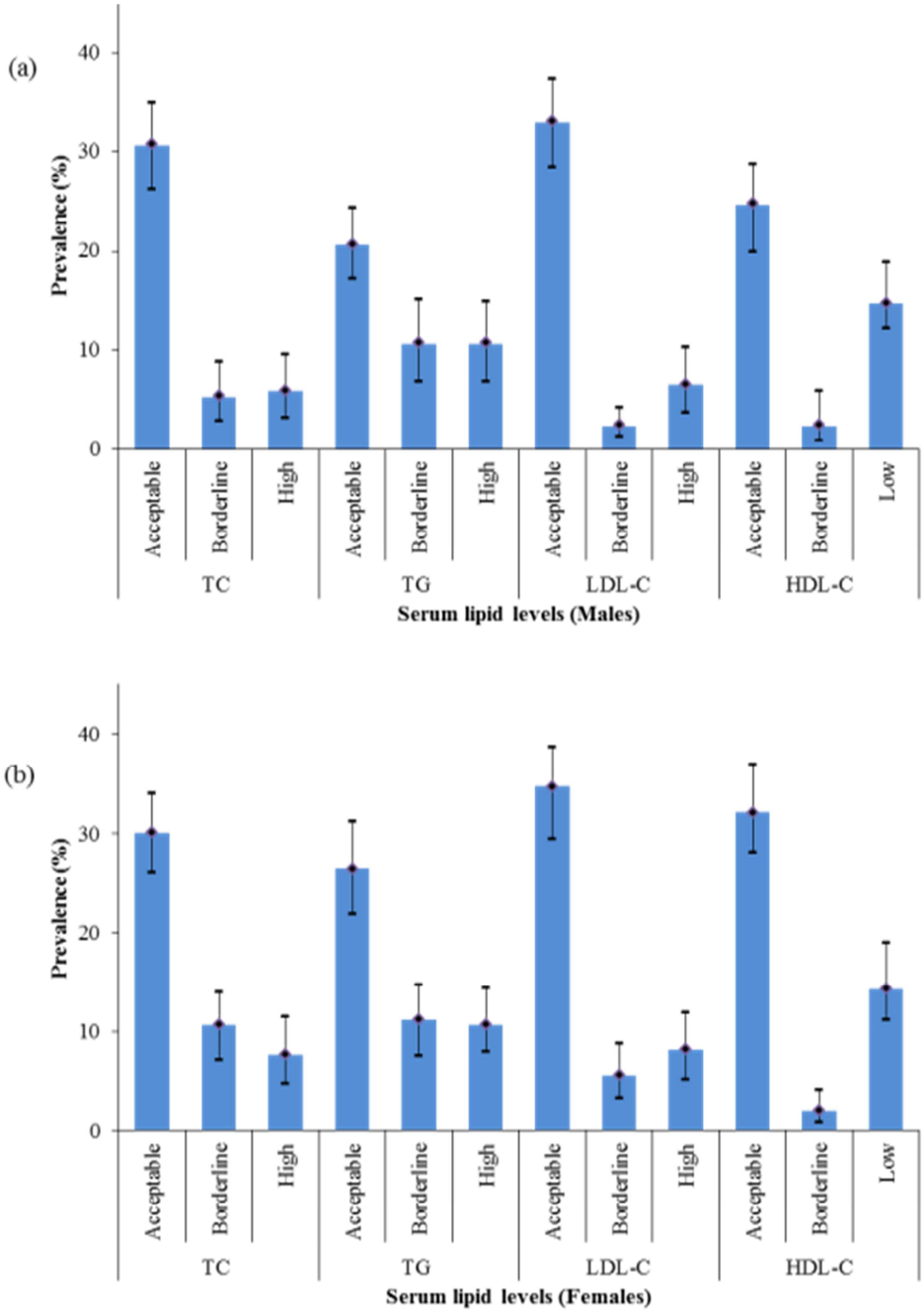

Figure 1. *Serum lipid levels in males (a) and females (b).*

Table 2 shows a comparison of median of the serum lipids across categories of measures of obesity. When the whole sample was considered, the BMI-obese children had significantly higher median TC (p = 0.021), TG (p = 0.024) and LDL-C (p = 0.011) when compared with underweight participants. Children who were centrally obese (WC) had significantly higher median TC (p = 0.002) and LDL-C (p = 0.019) compared to normal weight children. Also, children who are at 'high risk' (WHtR) had significantly higher median TC (p = 0.001) and LDL-C (p = 0.019) compared to 'low risk' children. Also, BMI-obese participants had significantly (p = 0.043) lower median HDL-C than underweight children.

On a gender basis, BMI-obese male children had significantly higher median TG (p < 0.001) and LDL-C (p =

0.038) than underweight children. Male children at 'high risk' (WHtR) also had significantly higher median LDL ($p = 0.009$) than those at 'low risk'. However, no significant differences were recorded in median lipid levels across waist circumference categories in males.

In females, there were significantly higher levels of TC ($p = 0.015$), TG ($p < 0.001$) and LDL-C ($p = 0.003$) among those who are BMI-obese than those who are underweight. Median HDL-C was also significantly ($p = 0.012$) lower in BMI-obese than underweight females. In addition, the centrally obese (WC) females had significantly higher and lower median LDL-C ($p = 0.003$) and HDL-C ($p = 0.005$) respectively when compared with those who had a normal weight. Females at 'high risk' (WHtR) had significantly higher median TC and LDL-C than those at 'low risk'.

BMI was the measure of obesity that significantly contributed to the highest median TC, TG and LDL-C and the lowest HDL-C when the whole sample was taken into consideration. Among males, BMI also significantly contributed to the highest median TG and LDL-C. In females, the measures of obesity that significantly contributed to the highest TC level were BMI and WHtR. In addition, BMI-obesity significantly contributed to the highest median TG and LDL-C and lowest HDL-C in females.

Table 2. *Lipid profile of children according to weight status.*

Weight status	TC		TG		LDL-C		HDL-C	
	Median	*p*-value	Median	*p*-value	Median	*p*-value	Median	*p*-value
Whole sample								
Body mass index (BMI)		0.021		0.024		0.011		0.043
Underweight	151.7		81.3		70.6		62.9	
Healthy weight	154.7		84.8		72.9		59.3	
Overweight	162.7		89.5		74.8		57.1	
Obesity	185.6		110.7		113.5		42.0	
Waist circumference (WC)		0.002		0.186		0.019		
Normal	154.7		86.1		67.8		62.7	0.099
Central overweight	165.5		95.5		82.7		56.7	
Central obesity	168.2		99.2		107.2		54.8	
Waist-to-height ratio (WHtR)		0.001		0.236		0.001		0.966
Low risk	158.7		91.4		72.8		57.1	
High risk	174.4		94.5		100.7		56.3	
Males								
Body mass index (BMI)		0.803		< 0.001		0.038		0.455
Underweight	141.2		67.9		70.1		62.7	
Healthy weight	152.3		85.5		72.5		53.0	
Overweight	155.2		90.0		74.1		44.2	
Obesity	158.6		104.8		108.1		36.7	
Waist circumference (WC)		0.824		0.940		0.059		0.296
Normal	141.2		85.5		65.1		56.7	
Central overweight	152.3		98.7		74.5		56.2	
Central obesity	154.1		101.7		102.3		55.2	
Waist-to-height ratio (WHtR)		0.265		0.099		0.009		0.054
Low risk	152.3		91.9		73.1		56.7	
High risk	158.6		90.0		98.7		36.7	
Females								
Body mass index (BMI)		0.015		< 0.001		0.003		0.012
Underweight	155.8		81.3		70.8		63.4	
Healthy weight	164.8		85.5		73.6		63.8	
Overweight	168.9		88.8		95.8		63.2	
Obesity	187.6		140.6		116.7		42.4	
Waist circumference (WC)		0.141		0.190		0.003		0.005
Normal	155.8		88.1		69.2		66.0	
Central overweight	167.5		94.5		85.7		57.0	
Central obesity	169.6		98.2		109.2		54.3	
Waist-to-height ratio (WHtR)		0.003		0.867		0.040		0.160
Low risk	161.7		90.5		72.5		62.8	
High risk	187.6		99.4		101.1		61.1	

Table 3 shows the multiple quantile regression coefficients for the association between measures of obesity and serum lipid levels.

When the full sample is considered, BMI, waist circumference and WHtR were significantly and positively associated with TC and LDL-C. BMI and waist circumference were significantly and negatively associated with HDL-C. Also, BMI-obese children had a 6.76mg/dl, 4.92mg/dl and 5.09mg/dl increase in TC ($p = 0.016$), TG ($p = 0.021$) and LDL-C ($p = 0.001$) respectively compared with their underweight peers. Those who were centrally obese (WC) had a 6.01mg/dl and 4.32mg/dl increase in TC ($p = 0.001$) and LDL-C ($p = 0.020$) respectively compared to normal children. In addition, those who are 'at risk' (WHtR) had a 6.76mg/dl and 5.18mg/dl increase in TC ($p < 0.001$) and LDL-C ($p < 0.001$) respectively when compared with those at 'low risk'.

Furthermore, BMI-obesity (p = 0.030) and central obesity (WC) (p = 0.003) in the children significantly decreased HDL-C by 3.92mg/dl and 4.01mg/dl respectively, compared to underweight and normal children.

On a gender basis, BMI-obesity was significantly and positively associated with TC, TG and LDL, and negatively associated with HDL-C in both males and females. Waist circumference was significantly and positively associated with LDL-C (p = 0.013) in males. In females, central obesity (WC) was significantly and positively associated with TG (p = 0.041) and LDL-C (p = 0.002). Central obesity had a significant and negative association with HDL-C (p = 0.001) in females. In males, WHtR was significantly and positively associated with LDL-C (p < 0.001) and negatively associated with HDL-C (p = 0.037). In females, WHtR was significantly and positively associated with TC (p = 0.002) and LDL-C (p < 0.001). In both males and females, BMI-obesity was the major contributor to the highest increase in concentrations of TC, TG and LDL-C and the lowest HDL-C concentration.

Table 3. *Associations between measures of obesity and serum lipid concentrations.*

Weight status	TC			TG			LDL-C			HDL-C		
	Estimate	**SE**	***p*-value**	**Estimate**	**SE**	***p*-value**	**Estimate**	**SE**	***p*-value**	**Estimate**	**SE**	***p*-value**
Whole sample												
Intercept	12.61	4.27	0.001	9.23	2.84	0.027	11.08	2.20	0.010	11.93	3.17	0.006
Body mass index (BMI)												
Underweight	0			0			0			0		
Healthy weight	5.48	0.77	0.123	3.00	0.81	0.091	2.79	0.58	0.106	- 1.08	0.87	0.248
Overweight	5.57	0.79	0.042	3.11	0.87	0.107	2.88	0.70	0.098	- 2.72	0.81	0.054
Obesity	6.76	0.73	0.016	4.92	0.82	0.021	5.09	0.69	0.001	- 3.92	0.79	0.030
Waist circumference (WC)												
Normal	0			0			0			0		
Central overweight	5.69	0.69	0.038	2.47	0.59	0.215	3.09	0.68	0.012	- 2.56	0.69	0.044
Central obesity	6.01	0.74	0.001	3.16	0.63	0.164	4.32	0.76	0.020	- 4.01	0.74	0.003
WHtR												
Low risk	0			0			0			0		
High risk	6.69	0.70	< 0.001	2.99	0.74	0.184	5.18	0.79	< 0.001	- 2.03	0.81	0.249
Boys												
Intercept	14.26	2.65	0.026	10.02	3.79	0.037	11.97	4.21	0.025	13.08	4.11	0.012
Body mass index (BMI)												
Underweight	0			0			0			0		
Healthy weight	5.23	0.99	0.254	2.98	0.94	0.047	3.26	1.19	0.107	- 2.16	1.20	0.169
Overweight	5.48	1.14	0.241	3.68	1.09	0.009	3.27	1.35	0.099	- 2.31	1.11	0.187
Obesity	6.23	1.30	0.047	5.70	1.07	< 0.001	5.96	1.41	0.013	- 4.54	1.16	0.006
Waist circumference (WC)												
Normal	0			0			0			0		
Central overweight	5.11	0.98	0.210	3.01	1.03	0.192	3.97	1.12	0.053	- 0.43	1.28	0.339
Central obesity	5.21	1.20	0.197	3.62	1.29	0.170	5.01	1.23	0.007	- 0.60	1.17	0.472
WHtR												
Low risk	0			0			0			0		
High risk	4.89	0.87	0.219	3.71	1.16	0.113	6.01	1.15	< 0.001	- 3.49	1.07	0.037
Girls												
Intercept	18.06	4.33	< 0.001	14.93	3.87	0.007	15.67	4.21	0.002	15.20	4.64	0.004
Body mass index (BMI)												
Underweight	0			0			0			0		
Healthy weight	5.71	1.26	0.082	3.01	1.01	0.070	3.46	1.25	0.081	- 0.37	1.34	0.256
Overweight	6.02	1.34	0.041	3.07	1.23	0.052	3.50	1.45	0.071	- 0.39	1.52	0.301
Obesity	7.70	1.30	0.011	5.34	1.19	< 0.001	6.38	1.37	0.004	- 4.08	1.44	0.041
Waist circumference (WC)												
Normal	0			0			0			0		
Central overweight	5.37	1.11	0.138	3.07	1.28	0.123	4.01	1.33	0.047	- 2.79	1.52	0.050
Central obesity	6.03	1.29	0.052	4.55	1.40	0.041	5.91	1.54	0.002	- 4.01	1.39	0.001
WHtR												
Low risk	0			0			0			0		
High risk	6.95	0.96	0.002	3.82	1.14	0.099	7.32	1.46	< 0.001	-2.61	1.28	0.211

5. Discussion

The influence of obesity on alterations in lipid levels and the contribution of altered lipid levels to the development of comorbidities like hypertension and cardiovascular disease have attracted a lot of attention from researchers [24]. The main aim of this study is to determine the prevalence of dyslipidemia and quantify the effect of obesity (assessed using different measures) on unfavorable levels of serum lipids (TC, TG, LDL-C and HDL-C) in children. As far as we can tell, this study describes the contribution of obesity to undesirable levels of serum lipids in children of the current age group for the first time in Cameroon.

In this study, majority (54.4%) of children had serum lipid concentrations at acceptable levels. However, 45.6% of the children had at least a type of lipid concentration that is not desirable and this prevalence is higher when compared with those of some European countries like Poland [25] and Denmark [26], where prevalence estimates of dyslipidemia were 39% and 28% respectively. The prevalence estimate in this study was closer to that obtained in a study in Brazil where 48.5% of the children presented with at least one lipid disorder [27]. On a gender basis, no significant difference in the prevalence of dyslipidemia between males and females was observed. Recent studies in Poland [25] and Ghana [28] also had similar observations. However, previous reports have shown higher prevalence among females [26, 29] and most recently, in males [14]. The most prevalent dyslipidemia in both males and females in this study was low HDL-C. This was followed by elevated TG, TC and LDL-C levels. Similar findings were observed in studies carried out in Brazil [15], Mexico [22] and Ghana [28]. However, in some countries, the most prevalent dyslipidemias were high TG followed by HDL-C [30, 31].

The prevalence of low HDL-C observed in this study is worrying. Even though its effect on cardiovascular health is not fully understood, evidence suggests that HDL-C works to protect against atherosclerosis in reverse cholesterol transport, where it takes cholesterol out of peripheral tissues [32]. In fact, a report from Spain revealed that the low rates of coronary heart disease were attributed to high levels of HDL-C in children [33]. This means the children with low HDL-C levels in this study may have a higher risk of cardiovascular events later in life. Also, the prevalence of combined dyslipidemia was 26.5% and evidence indicates that combined pediatric dyslipidemia significantly increased the thickness of the carotid intima-media when compared to children with acceptable lipid levels [34]. This suggests that abnormal levels of each lipid may not independently contribute to cardiovascular disease risk.

In addition, the median HDL-C obtained in this study was higher than that reported in other studies [15, 27]. Among females, the median HDL-C was also higher than the cut-off point of ≥ 60mg/dl, which indicates increased risk of cardiovascular diseases [35]. The differences in the prevalence and type of most common dyslipidemia in the above studies could be as a result of genetic background and lifestyle differences amongst the participants [36] and also differences in sampling procedures and sample sizes across the different studies. High TG was the second main dyslipidemia in this study. Evidence suggests that excess TG is linked to the production of dense LDL-C particles, which contribute more to cardiovascular disease [37].

BMI-obesity was associated with higher serum TC, TG and LDL-C levels and lower HDL-C. Similar findings were reported in a study by San *et al* [38]. Another report indicated that BMI was positively and negatively correlated with high TG and low HDL-C levels respectively [39]. In another study in Ghana, TG and LDL-C were significantly higher among BMI-overweight/obese children when compared with healthy weight children [28]. However, in another report, BMI was reported to be negatively associated with TC and LDL-C in children [40]. Also, in a report by Lee *et al* [41] BMI-obesity was not associated with TC and LDL-C. In this study, BMI-obesity contributed to the highest TC, TG and LDL-C levels in females and the lowest HDL-C level in males.

Central obesity (WC) was associated with elevated levels of TC and LDL-C, and reduced levels of HDL-C. In a recent report, waist circumference was positively correlated with TG, LDL-C and negatively correlated with HDL-C [16]. However, the authors indicated that the explained variance of the serum lipid levels by the different anthropometric parameters was low. A previous study had contradictory findings in which waist circumference was not associated with TC, TG, LDL-C and HDL-C [27]. With the exception of LDL-C, central obesity (WC) was a weak predictor of dyslipidemia in males in this study.

Being at 'high risk' (WHtR) was associated with higher levels of TC and LDL-C. This is similar to findings of a study carried out by Oliosa *et al* [14], in which WHtR was positively associated with a high TC and negatively associated with lower HDL-C levels. In the current study, higher WHtR was associated with lower HDL-C levels in females only. It was concluded in a Brazilian study that WHtR was a good predictor of elevated levels of TC, TG and LDL-C, and reduced levels of HDL-C in children and adolescents [12].

This current study has shown that obesity is positively associated with elevated fasting TC, TG and LDL-C, and negatively associated with HDL-C. A report had suggested that elevated TG may be a major contributor to abnormal levels of the other lipids [42]. This is because high TG contributes to the development of dense LDL-C particles [37, 43]. Hepatic lipase hydrolyses the elevated TG levels within LDL, and this leads to the creation of small densely packed LDL particles, which enhance atherogenicity because they are slowly metabolized [44]. Also, the elevated levels of TG have been found to delay the clearance of TG-rich lipoproteins [43], which increase cardiovascular risk.

In addition, an increased TG level increases the activity of cholesterylester-transfer-protein, which enhances the exchange of cholesterol esters and TG between LDL and HDL. This results in HDL particles rich in TG, which are hydrolyzed by liver lipase into small HDL, ultimately leading to lower levels of HDL in the circulation [45]. The low levels of HDL impair the removal of cholesterol from peripheral tissues [32].

This study has limitations worth mentioning. It was a hospital-based and we cannot ascertain causality. Also, this study focused only on obesity as a contributing factor to dyslipidemia. The study has not provided information on other factors which could influence serum lipid levels like diet and physical activity [28, 42]. In addition, our sample consisted of 5- to 16-year old children, with differences in maturation, and maturation has been documented to affect lipid levels in the bloodstream [46], an aspect which we did not include in our analysis.

6. Conclusion

This current study has demonstrated excess accumulation of body fat is associated with dyslipidemia in children. BMI was a major contributor to the highest alterations in all the lipids studied, and the most prevalent form of dyslipidemia in this study was low HDL-C. Further research is required to better understand the influence of other determinants of dyslipidemia in children in order to reduce the risk of cardiovascular disease later in life.

Conflict of Interest

The authors declare that there was no conflict of interest regarding this paper.

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