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Electrocardiographic and Echocardiographic Findings in Adolescent Overweight and Obese Secondary School Children in Benin City, Nigeria

Wilson E. Sadoh[1*], Nosakhare J. Iduoriyekemwen[1] and Barbara E. Otaigbe[2]

[1]Department of Child Health, University of Benin / University of Benin Teaching Hospital, P.M.B. 1111, Benin City, Nigeria.
[2]Department of Paediatrics, University of Port Harcourt / University of Port Harcourt Teaching Hospital, Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author WES designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author NJI co-wrote the protocol, managed the analysis of the study and author BEO managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To determine the electrocardiography (ECG) and echocardiography findings in adolescent school children.
Study Design: A cross sectional descriptive study.
Place and Duration of Study: Selected secondary school in Benin City, Nigeria. The study was conducted between May and June 2016.
Methods: Subjects were overweight and obese school children from a private secondary school while controls were school children with normal weight. Overweigh and obesity were defined as BMI percentiles between 85th and 95th and >95th percentile respectively. Subjects and controls both had ECG and echocardiography evaluations. Analysis was done with SPSS version 20.0.
Results: Forty nine subjects and 49 controls were recruited. Of the subjects, 21(42.9%) and 28(57.1%) were obese and overweight respectively. Six (12.24%) subjects had chamber

**Corresponding author: E-mail: sadohehi@yahoo.com, ehidiamen.sadoh@uniben.edu;*

enlargement compared to one (2.04%) control, OR = 6.0, p = 0.12). The difference in mean left ventricular mass indexed to height (LVM/ht) of obese subjects 99.81 ± 32.80 g/m, overweight subjects 85.96 ± 20.52 and controls 81.63 ± 15.66 24.25 g/m, was significant, p = 0.0091. The LVM/ht was positively correlated with WC, r = 0.34, p = 0.024 and BMI, r = 0.37, p = 0.013.
Conclusion: Overweight and obesity is associated with increase in LVM and other chamber enlargement. Efforts should be stepped up to prevent overweight and obesity amongst school children for better cardiovascular health.

Keywords: Overweight; obesity; echocardiography; electrocardiography; left ventricular mass.

1. INTRODUCTION

The burden of adolescent obesity and overweight has been on the rise globally in both developed and developing countries with 23.8% of boys and 22.6% of girls being overweight or obese in 2013 [1]. Rising prevalence have also been noted in developing countries as well. In a study conducted in Lagos, Nigeria, amongst adolescent school children, the prevalence of obesity and overweight was 13.8% and 9.4% respectively [2]. This is a huge increase compared to a previous study [3].

Obesity and overweight can predispose to cardio-metabolic problems in later life [4]. Cardiovascular abnormalities occur early in adolescence, and these can be elicited on echocardiography and electrocardiography. Echocardiography can reveal left ventricular hypertrophy as demonstrated by an increase in left ventricular mass (LVM) [5]. Some studies have shown that obese children have a significantly larger LVM compared to non-obese children and have also demonstrated ventricular systolic dysfunction [5-7]. Left ventricular hypertrophy has been identified as an independent risk factor for cardiovascular related morbidity and mortality [8].

A variety of ECG changes have been reported in obese children including increase in heart rate and PR and QRS intervals, T wave changes, ST segment deviations, chamber hypertrophy and QTc prolongation [7]. These changes in echocardiography and ECG have been reported to be worse with worsening degree of obesity, and to reverse on weight reduction by exercise and diet [9].

Another important cardiovascular related morbidity associated with overweight and obesity is elevated blood pressure. It has been demonstrated that obese individuals have a six fold increased risk of developing hypertension compared to non-obese people [10]. The elevated blood pressure can also be reversed following reduction in weight. There is paucity of studies on the echocardiographic and electrocardiographic findings in African over-weight and obese children.

In the present study, the echocardiographic parameters especially the LVM and the ECG findings in obese and overweight adolescent school children in Benin City, Nigeria were compared with school children with normal weight. The relationship between some ECG variables and the LVM were also evaluated.

2. METHODOLOGY

In this cross-sectional descriptive study, school children aged between 10 and 16 years from a private secondary school in Benin City were recruited for this study between May and June 2016. The children who met the criteria for overweight (BMI percentile ≥85th – 95th) and obesity (BMI percentile >95th) were recruited as subjects [11]. The controls were children from the same school with normal BMI of 5th - 85th percentile. Children with known congenital or acquired cardiac heart disease or were discovered to have such on investigation during the study were excluded.

A convenience sample size of 49 subjects and 49 controls were recruited for the study. The subjects were screened from a pool of students drawn from the arms in class one to class six. The subjects were recruited consecutively until the required number of subjects were met.

The bio-data of the study population was taken with the aid of a proforma that included age, gender, socio-economic class using the method described by Olusanya et al. [12].

2.1 Anthropometric Measurement

The anthropometric parameters of the children that were measured included the weight, height,

the BMI, the waist circumference (WC) and hip circumference (HC). The weight was measured using a digital scale without shoes and heavy clothing such as school cardigan. The height was taken with the aid of a stadiometer, without shoes and the occiput, heel of both feet resting against the stadiometer and the student looking straight ahead. The BMI was the ratio of the weight (kg) and the square of the height in meter. The WC was measured with a non-distensible tape midway between the lowest rib and the superior iliac crest while the HC was measured at the level of the greater trochanter.

The blood pressure was measured with a mercury sphygmomanometer on the right arm with the patient sited, using an appropriate cuff as prescribed by the Fourth report of blood pressure in children and adolescents [13].

2.2 Electrocardiography

A 12 lead electrocardiogram (ECG) was performed on the subjects and controls. The ECG was recorded on an ECG paper using a portable electronic ECG machine (Schiller AT-1 Model, Switzerland). The tracings were analyzed in the standard fashion [14]. QTc values >0.44 seconds, were considered prolonged. ST segment changes (elevation or depression) occurred when the ST segment was ≥ 2 mm above or below the isoelectric line [14].

2.3 Echocardiography

The subjects and controls had transthoracic echocardiographic evaluation using a portable SonoSite Micromaxx echocardiography machine. SonoSite Inc. Bothel, WA 98021 USA. The LV dimensions and functions were interrogated using 2D, M mode and Doppler facilities. Two sets of LV dimensions were obtained and the mean was taken as the value. The LVM was calculated based on the formula by Devereux et al. [15] and indexed to the height of the subjects in meter. The analysis of the reports was done according to the recommendations of the American Society of echocardiography [16].

2.4 Statistical Analysis

The data was entered into and analyzed with IBM-SPSS version 20.0 (Chicago IL). In estimating the sample size, a minimum number with 80% power to detect a difference of 20% in the LVM between obese and non-obese groups was sought. Using the values obtained from a previous study [7], a value of 49 was obtained and thus a sample size of 49 was recruited in each arm. The proportion of participants with certain variables such as those with prolonged QTc were expressed in percentages. The overweight and obese subjects were combined in analysis of ECG parameter because of absence of significant findings while they were separate in the analysis of the echocardiography parameters. Differences in proportions were tested with χ^2 test. The means of continuous variables were compared with t test or ANOVA where >2 means were compared. The relationship between LVM and the WC and HC were tested with Pearson correlation test. Level of significance was set at P = <0.05 at 95% of confidence level.

3. RESULTS

3.1 Socio-demographic Characteristics of Subjects and Controls

Forty nine subjects and 49 age and sex matched controls were recruited for this study. The mean age of the subjects 12.31 ± 1.42 (range; 10 – 16) years was not statistically significantly different from that of the controls 12.31 ± 1.42 (range; 10 – 16) years, p = 1.00. There was also no significant gender difference between the subjects and controls, p = 1.00 while the difference in the socio-economic classes between subjects and controls was statistically significant, p = 0.0083 (Table 1).

Table 1. Socio-demographics of study population

Characteristic	Subjects	Controls	P value
Gender			
Male	20(40.82)	20(40.82)	1.00
Female	29(59.18)	29(59.18)	
Socio-economic class			
High	32(65.30)	18(36.73)	0.0083
Middle & Low	17(34.70)	31(63.27)	

Of the 49 subjects, 21(42.9%) were obese while 28(57.1%) were overweight. The mean ages of the obese and overweight subjects were 12.14 ± 1.42 years and 12.43 ± 1.43 years respectively, p = 1.00. Table 2 shows that the mean BMI, WC, HC, systolic and diastolic blood pressure values in the subjects were significantly higher than in controls, p = <0.05.

3.2 Electrocardiographic Findings in Subjects and Controls

Forty six subjects and controls completed their ECG examination. The subjects had a higher mean resting heart rate 88 ± 14 beat per minute (bpm) compared to the controls 84 ± 13 bpm, p = 0.25. The mean values of the other ECG parameters; PR interval, QRS interval, QTc and QRS axis (degree) between subjects and controls were not statistically significantly different (see Table 3).

Six (12.24%) subjects had evidence of chamber enlargement while only one (2.04%) of the controls had chamber enlargement, OR = 6.0, p = 0.12 (CI = 0.7 to 51.9). Of the seven subjects and control with chamber enlargement, four had left ventricular hypertrophy and three showed evidence of right/left atrial hypertrophy. Of the subjects with chamber enlargement, three each were obese and overweight.

Nine subjects and seven controls had prolonged QTc, the difference was not statistically significant, p = 0.79. Of the nine subjects, three (33.3%) were males and six (66.7%) were females. Of the seven controls, 2(28.57%) were males and five (71.43%) were females.

One (2.2%) each of the subjects had premature atrial contraction (PAC) and right bundle branch block. While four (8.7%) controls had PAC.

3.3 Echocardiographic Parameters of Subjects and Controls

The difference in the mean left ventricular mass indexed for height (LVM/ht) of the obese subjects 99.81 ± 32.80 g/m, the overweight subjects 85.96 20.57 g/m and the controls 81.63 ± 15.66 g/m, was statistically significant, p = 0.0091. The mean values of other left ventricular echocardiographic dimensions of the subjects were significantly higher than in the controls except the LVIDS.

The differences in the mean fractional shortening and ejection fraction in the obese or overweight subjects were not statistically significantly different from that in the controls, p = 0.17 and 0.29 respectively (see Table 4).

There was a positive correlation between the LVM/ht and the WC (r = 0.34, p = 0.024) and the HC (r = 0.24, p = 0.084). The LVM/ht was also positively correlated with BMI (r = 0.37, p = 0.013) but not age (r = 0.10, p = 0.51).

3.4 Comparison of Mean LVM/ht of Subjects According to QTc and Chamber Enlargement

The mean LVM/ht of subjects with prolonged QTc was 105.05 ± 27.98 g/m and in subjects with normal QTc was 92.78 ± 23.51 g/m, p = 0.21. The mean LVM/ht of controls with prolonged QTc was 93.43 ± 18.06 g/m and 79.16 ± 14.22 g/m in controls with normal QTc, p = 0.032.

Table 2. Mean anthropometric and blood pressure parameters of subjects and controls

Characteristics	Subjects	Controls	p value
Mean BMI			
Mean waist circumference (cm)	87.05 ± 8.50	70.90 ± 5.50	<0.0001
Mean hip circumference (cm)	100.60 ± 9.10	82.66 ± 6.75	<0.0001
Mean systolic blood pressure	110.00 ± 12.50	100.00 ± 9.20	<0.0001
Mean diastolic blood pressure	64.71 ± 13.05	58.51 ± 11.89	0.017

Table 3. The mean electrocardiographic parameters in subjects and controls

Parameters	Subjects Mean SD	Controls Mean SD	P values	Confidence interval
Resting heart rate (bpm)	88 ± 13	85 ± 13	0.25	-8.7 to 2.3
PR interval (sec)	0.145 ± 0.015	0.150 ± 0.02	0.11	-0.001 to 0.01
QRS interval (sec)	0.084 ± 0.008	0.081 ± 0.008	0.07	-0.006 to 0.0003
QTc (sec)	0.425 ± 0.021	0.422 ± 0.021	0.82	-0.008 to 0.01
QRS axis (sec)	49.26 ± 16.77	49.96 ± 21.11	0.80	-8.9 to 6.9

Table 4. Mean echocardiographic parameters of the subjects and controls

Parameters	Controls	Overweight	Obese	P value	95% CI
AOD (mm)	24.00 ± 2.90	25.48 ± 2.57	25.70 ± 3.54	0.042	-2.80 to -0.36
LAD (mm)	24.32 ± 2.94	26.88 ± 2.96	26.55 ± 2.82	0.0007	-3.61 to -0.36
IVSD (mm)	10.62 ± 1.55	10.96 ± 1.27	11.65 ± 1.60	0.040	-1.27 to -0.03
LVIDD (mm)	39.89 ± 3.96	41.80 ± 4.04	42.40 ± 4.98	0.047	-3.92 to -0.44
LVPWDD (mm)	9.68 ± 1.11	10.24 ± 1.17	10.80 ± 1.28	0.0017	-1.30 to -0.32
IVSS (mm)	13.38 ± 1.53	14.48 ± 1.50	15.00 ± 1.34	<0.0001	-.1.95 to -0.71
LVIDS (mm)	23.68 ± 3.01	23.64 ± 3.25	24.70 ± 5.69	0.56	-2.00 to 1.14
LVPWDS (mm)	13.21 ± 0.95	15.25 ± 1.37	14.4 ± 1.16	<0.0001	-2.04 to -1.10
FS (%)	40.45 ± 6.72	43.16 ± 7.05	43.50 ± 8.76	0.17	-5.86 to 0.14
EF (%)	7.87 ± 8.20	80.88 ± 7.59	79.85 ± 8.24	0.29	-5.87 to 0.77
LVM (g)	128.00 ± 24.21	141.36 ± 35.92	156.75 ± 53.70	0.011	-35.03 to -5.37
LVM/ht (g/m)	81.63 ± 15.66	85.96 ± 20.52	99.81 ± 32.80	0.0091	4.8 to 21.8

AOD = Aortic diameter, LAD = Left atrial diameter, IVSD = Interventricular septal diameter in diastole, LVIDD = Left ventricular internal diameter in diastole, LVPWDD = Left ventricular posterior wall diameter in diastole, IVSS = Interventricular septal diameter in systole, LVIDS = Left ventricular internal diameter in systole, LVPWDS = Left ventricular posterior wall diameter in systole, FS = Fractional shortening, EF = Ejection fraction, LVM = Left ventricular mass.

The significant difference on multiple comparison showed the following; LAD: Controls < overweight p = 0.01, IVSD: Controls < obese, p = 0.05, LVPWDD: Controls < obese, p = 0.01. IVSS: Controls < overweight and obese, p = 0.05 and 0.001 respectively. LVPWDS: Control < overweight and obese, p = <0.001 while overweight < obese, p = 0.001. For LVM and LVM/ht, control < obese, p = 0.01

4. DISCUSSION AND CONCLUSION

The mean LVM/ht was significantly larger in subjects than in controls, this finding is consistent with previous reports that showed that LVM increases with increasing body mass [5-7,9]. This relationship between LVM and body mass is also borne out in this study by the positive correlation between LVM and BMI. The increase in LVM was already evident in the overweight children, suggesting the need to begin to aggressively address body weight in overweight children before it progresses to worse degrees of obesity as increase in LVM is worst in morbidly obese children [7]. However, none of the subjects in this study was morbidly obese, for that assertion to be tested.

The clinical implications for finding significantly higher LVM in the subjects compared to controls are that left ventricular hypertrophy is an independent risk factor for increased cardiovascular related morbidity and mortality. Overweight and obesity thus impacts on the adolescents a significant risk factor for morbidity and mortality. Another implication is the proneness to hypertension in overweight and obese adolescents. The association between overweight/obesity and elevation of BP has been established by several workers [3,13,17]. The significantly higher BP in subjects compared to controls in this study further buttresses this relationship. The influence of increase in weight on BP can be explained thus: increase in adipose tissue raises the oxygen demand and subsequently an increase in cardiac output and thus increase in the BP. Another contribution to elevated BP is the increase in peripheral vascular resistance [18], in addition to the increased LVM in obesity. Untreated elevated BP in obese children also causes increase in the LVM thus setting up a vicious circle of increasing LVM. It is important to note that other parameters of left ventricular dimension were significantly higher in subjects than in controls as has been demonstrated by previous workers [6,9.18]. The LV functions as depicted by fractional shortening and ejection fractions between subjects and controls were within normal limits and the differences were not significantly different. This finding is in consonance with a previous study that also revealed a non-significant difference in ejection fraction and fractional shortening [19]. This finding suggests that although there are changes in the LVM and dimensions because of increasing body mass, the functions of the LV are largely preserved although the parameters are better in obese and overweight children

perhaps because of the greater force of contraction by the bigger cardiac muscle mass.

The differences in most of the ECG parameters between subjects and controls were not significant. This is different from the findings in the study by Sun et al. [20] that showed significant differences in PR interval, QRS duration and QRS axis between normotensive Chinese children with normal weight, overweight and obesity. This difference could have been due to the larger sample size in the Chinese study. It is also possible that early changes are not picked up by electrocardiography unlike echocardiography and could also explain the absence of some ECG changes such as ST segment changes and flattening of the T wave in the present study. Previous workers have similarly reported these changes.

The resting heart rate of subjects was higher in subjects compared to controls. High resting heart rate have been associated with higher risk of cardiovascular related mortality [21]. The higher heart rate in obese/overweight children may suggest a proneness to cardiovascular related mortality compared to children with normal weight. The frequency of chamber enlargement especially left ventricular enlargement on ECG was much smaller than would be suggested by the significantly higher LVM in the subjects compared to controls in this study. This disparity has been previously reported and points to the superiority of echocardiography over ECG in detecting chamber enlargement. However, this study has demonstrated that the odds of an adolescent with overweight and obesity developing chamber enlargement on ECG was six fold higher compared to the non-overweight/obese adolescent.

This study revealed that adolescents with prolonged QTc had higher LVM/ht compared to those without prolonged QTc irrespective of BMI status. This finding may be due to the larger mass the wave of depolarization will go through in both the ventricular depolarization and repolarization phases that make up the QT interval and does suggest that individuals with increased LVM may be at risk of sudden death. Sudden death have been reported to occur in obese patients without any other risk factor [22].

The strength of this study is the use of both electrocardiography and echocardiography to evaluate the cardiac dimensions and functions of adolescent secondary school children. The weakness is the relatively small sample size of subjects and controls. The clinical implications of some of the findings include; in the evaluation of overweight and obese children, aggressive counselling should be commenced for overweight children to prevent transition into obesity status or reverse the excess weight accumulated as cardiomegaly is already evident in overweight adolescents. Similarly, tachycardia on clinical evaluation should be interpreted with caution since overweight and obese children have a higher heart rate compared to those with normal weight. The new finding in this study as compared to other studies is the association of larger left ventricular mass in adolescents with prolonged QTc compared to those with normal QTc.

In conclusion, obese and overweight adolescents have a higher LVM compared to children with normal weight and more evidence of chamber enlargement on ECG compared to the non-overweight/obese children. The children with prolonged QTc had significant bigger LVM compared to those with normal QTc duration irrespective of the BMI status.

ETHICAL APPROVAL AND CONSENT

Ethical approval (CMS/REC/2016/001) was obtained from the Research and Ethics Committee of the College of Medical Sciences, University of Benin, Benin City. While approval was obtained from the Ministry of Education and the head of the private school. Only the children of parents who gave consent for the study and the children who assented to the study were recruited.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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