

Insulin Resistance, Dyslipidemia and Cardiovascular Changes in a Group of Obese Children

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Abstract

Background: Obesity-related comorbidities are present in young obese children, providing a platform for early adult cardiovascular disorders.

Objectives: To compare and correlate markers of adiposity to metabolic disturbances, vascular and cardiac morphology in a European pediatric obese cohort.

Methods: We carried out an observational and transversal analysis in a cohort consisting of 121 obese children of both sexes, between the ages of 6 and 17 years. The control group consisted of 40 children with normal body mass index within the same age range. Markers of adiposity, plasma lipids and lipoproteins, homeostasis model assessment-insulin resistance, common carotid artery intima-media thickness and left ventricular diameters were analyzed.

Results: There were statistically significant differences between the control and obese groups for the variables analyzed, all higher in the obese group, except for age, high-density lipoprotein cholesterol and adiponectin, higher in the control group. In the obese group, body mass index was directly correlated to left ventricular mass ($r = 0.542$; $p = 0.001$), the homeostasis model assessment-insulin resistance ($r = 0.378$; $p \leq 0.001$) and mean common carotid artery intima-media thickness ($r = 0.378$; $p \leq 0.001$). In that same group, insulin resistance was present in 38.1%, 12.5% had a combined dyslipidemic pattern, and eccentric hypertrophy was the most common left ventricular geometric pattern.

Conclusions: These results suggest that these markers may be used in clinical practice to stratify cardiovascular risk, as well as to assess the impact of weight control programs. (Arq Bras Cardiol. 2015; 104(4):266-273)

Keywords: Pediatric Obesity; Insulin Resistance; Dyslipidemias; Cardiovascular Diseases.

Introduction

The growing prevalence of childhood obesity has led to an increased risk of diabetes and cardiovascular diseases in adulthood^{1,2}.

One of the most concerning complications of childhood obesity is insulin resistance, considered a precursor of type 2 diabetes mellitus³. In clinical practice, the homeostasis model assessment-insulin resistance (HOMA-IR) is used to diagnose insulin resistance and it is an independent predictor of cardiac pathology in adulthood⁴. Clinically *acanthosis nigricans*, a hyperpigmented, brownish velvety lesion, usually found in skin folds, has been related to obesity and insulin resistance⁵.

In adults, common carotid artery intima-media thickness (cIMT) correlates with the incidence of cardiovascular events, and, as such, is considered a useful tool for cardiovascular risk stratification⁶. Several studies have shown that cIMT is increased in children with cardiovascular risk factors, possibly making it a useful tool for assessing cardiovascular risk in children^{7,8}.

Another cardiovascular risk factor is left ventricular mass (LVM)⁹. As shown by the Bogalusa Heart Study, childhood adiposity is related to LVM in adults, and left ventricular hypertrophy is strongly and independently related to cardiovascular morbidity and mortality^{10,11}. Although left ventricular hypertrophy is rare in obese children, cardiac remodeling might be present, which in adults has also been found to predict adverse cardiovascular outcomes, particularly in hypertensive patients¹²⁻¹⁵.

Dyslipidemia is another cardiovascular risk factor related to obesity. It is estimated that about 42% of obese children have lipid abnormalities, particularly those with visceral obesity¹⁶. In these, the most common lipid abnormality pattern consists of elevated triglycerides, decreased high-density lipoprotein cholesterol and normal to mildly elevated low-density lipoprotein cholesterol.

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Plasma lipoproteins also seem to be of particular importance in the assessment of dyslipidemic patients. Apolipoprotein B reflects the entire spectrum of atherogenic particles. In contrast, apolipoprotein A-I is considered to have anti-atherogenic properties¹⁷. Lipoprotein (a) consists of a cholesterol-rich low-density lipoprotein cholesterol particle. In adults, several studies have identified lipoprotein (a) as a risk factor for premature atherosclerotic disease¹⁸. In children, it is a potential marker of cardiovascular risk, and, in this context, some authors have found it to be more sensitive than anthropometric measures¹⁹.

Methods

Subjects

We carried out an observational and transversal analysis, in a cohort of obese children, recruited randomly from the Cardiovascular Risk Clinic of the Department of Pediatric Cardiology of Coimbra's Pediatric Hospital, Portugal. This study complied with the Declaration of Helsinki. All parents gave their informed consent, which had been approved by the local Ethics Committee.

The inclusion criteria for the study group was primary obesity [body mass index (BMI) above the 95th percentile (P95) for sex and age] in children aged 6 to 17 years, without recent or chronic illnesses. The control group included healthy children within the same age range with normal BMI. All children had undergone a 12-hour fast prior to clinical evaluation and blood sampling.

The study group comprised 121 children and the control group, 40 children, of both sexes.

The variables analyzed were age, pubertal age, sex, BMI, waist circumference (WC), percentage fat mass (%FM), *acanthosis nigricans*, cIMT, leptin, adiponectin, insulin, glucose, HOMA-IR, total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, triglycerides, apolipoprotein A-I, apolipoprotein B, lipoprotein (a), left ventricular end-diastolic diameter (LVED), left ventricular end-systolic diameter (LVSD), interventricular septum diameter (IVS), left ventricular posterior wall diameter (LVPW), left ventricular mass index (LVMI) and LVM, left ventricular relative wall thickness (RWT).

Anthropometric and clinical evaluation

Acanthosis nigricans was documented as zero (0) if not present and as one (1) if present. Pubertal stage was based on Tanner's classification and divided into prepubertal (Tanner stage 1) and pubertal (Tanner stage 2-5). Weight (in kilograms to the nearest 100g) was determined using a SECA 220 digital weight scale (Medical Scales and Measuring Systems, Germany) and, for standing height (in centimeters to the nearest 0.1cm), a stadiometer was used, with the children wearing only underwear. BMI was calculated based on the formula: $BMI = (\text{weight}/\text{height}^2)^{20}$. Waist circumference (to the nearest 0.1cm) was measured using a plastic flexible tape placed midway between the last rib and the iliac crest. Its percentile was based on published WC charts²¹. Percentage fat mass was determined

by bioelectric impedance using the BIA 101 Anniversary analyzer (AKERM SRL, Italy), and defined according to %FM charts published by McCarthy²².

Blood collection and biochemical analysis

Serum and plasma were prepared from collected venous blood samples (15 mL) and then frozen (-80°C) for storage until analysis.

Insulin levels were determined by chemiluminescence and processed in the IMMULITE 2000 (Siemens Healthcare Diagnostics Products Ltd) analyzer, and glucose levels were analyzed in the VITROS 5.1 FS system (Ortho Clinical Diagnostics, Johnson & Johnson) with Micro Slide™ technology. HOMA-IR was calculated based on the formula: $HOMA-IR = \text{insulin (mU/L)} \times \text{glucose (mmol/L)} / 22.5$, taking 3 as the cutoff value for the diagnosis of insulin resistance.

Total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol and triglyceride levels were measured using an automated biochemical VITROS 5.1 FS analyzer (Ortho Clinical Diagnostics, Johnson & Johnson).

Apolipoprotein A-I, B and lipoprotein (a) levels were determined by immunonephelometry and processed in the BN ProSpec® System (Siemens Healthcare Diagnostics Inc.) analyzer.

Leptin (eBioscience, San Diego, CA, USA) and adiponectin (BioVendor, Brno, Czech Republic) were evaluated using commercially available enzyme-linked immunosorbent assay kits, and the absorbances were measured at 450 nm (BIO-RAD Microplate Reader Model 680, Hercules, CA, USA).

Ultrasonography

To determine cIMT, we used a General Electric Vivid 7 Dimension (GE, USA) ultrasound system and a linear, high resolution 12-mHz probe and the technique recommended by Mannheim²³.

In the same ultrasound system, left ventricular diameters were assessed by 2D M-mode echocardiography in the parasternal long axis view with the patient in the left lateral decubitus position, using a high-resolution 3.5-mHz transducer.

Left ventricular mass was calculated using Devereux's formula: $0.8\{1.04[LVED+LVPW+IVS]^3 - LVED^3\} + 0.6$. Left ventricular geometry was assessed based on the LVMI (increased if > P95 for sex and age) and the RWT (increased if > 0.41), and classified as follows: normal, if both parameters were within the normal range; concentric remodeling, if RWT was increased and LVMI was normal; concentric hypertrophy, if both parameters were increased; and eccentric hypertrophy, if LVMI was increased and RWT was normal.

Statistical analysis

Data were analyzed using the IBM SPSS 20 software. To calculate the case and control population sample size, we used the G*Power 3.1.5 program. Based on a 0.05 level of significance, a 0.80 power, a 0.52 effect size, and a control to study group ratio of 3, our study group and our control group had to include 118 and 40 individuals, respectively.

Based on the sample size of the variables included in this study, normality was tested using the Kolmogorov-Smirnov or the Shapiro-Wilk analysis.

To compare the quantitative variables in both groups, Student *t* test was used, if the distribution was normal, and Mann-Whitney U test, if not. Chi-square test was used for categorical variables.

To verify the association between quantitative parameters, we used Pearson's correlation if their distribution was normal, and Spearman's correlation, if not.

Quantitative variables are expressed as mean and respective standard error of the mean, and qualitative variables, as N(%).

For multivariate analysis between the two groups, logistic regression was used.

The results were considered statistically significant at $p < 0.05$.

Results

Comparative analysis between the two groups

One hundred and twenty-one obese children, 61 boys and 59 girls, with ages between 6 and 17 years (mean age, 11.65 ± 0.432 years) were included in this study. The control group was made up of 40 healthy, non-obese children, 29 boys and 12 girls, within the same age group (mean age, 12.73 ± 0.270 years).

We firstly compared the two groups regarding anthropometric, clinical, analytical and ultrasonographic parameters, whose results are shown in Table 1.

As age ($p = 0.038$) and sex ($p = 0.027$) showed significant statistical differences between the two groups, with higher age in the control group, the analysis was repeated using logistic regression, but adjusted for these parameters.

Table 1 – Anthropometric, analytical and ultrasonographic parameters of the obese and non-obese groups

Variable	Obese		Non-obese		p-value
	N	Mean \pm SEM	N	Mean \pm SEM	
Age (years)	121	11.65 \pm 0.432	40	12.73 \pm 0.270	0.038**
BMI	121	28.465 \pm 0.438	40	18.933 \pm 0.429	< 0.001*
WC (cm)	121	93.15 \pm 1.197	40	68.16 \pm 0.861	< 0.001**
%FM (%)	121	36.840 \pm 0.647	40	18.544 \pm 0.526	< 0.001*
Leptin (ng/mL)	118	28.973 \pm 1.627	40	4.845 \pm 0.706	< 0.001
Adiponectin (μ g/mL)	95	3.597 \pm 0.140	32	5.173 \pm 0.413	0.001
HOMA-IR	118	2.81 \pm 0.165	33	1.54 \pm 0.151	< 0.001**
LVED (mm)	121	45.92 \pm 0.54	40	44.28 \pm 0.97	NS
LVSD (mm)	121	29.29 \pm 0.43	40	27.34 \pm 0.74	< 0.023*
IVS (mm)	121	7.21 \pm 0.16	40	7.11 \pm 0.22	NS
PWD (mm)	121	7.51 \pm 0.17	40	6.92 \pm 0.24	0.045*
LVM (g)	121	108.27 \pm 3.75	40	95.80 \pm 5.46	NS
LVMI	121	34.30 \pm 0.79	40	28.80 \pm 0.99	< 0.001*
RWT	121	0.33 \pm 0.080	40	0.32 \pm 0.012	NS
cIMT (mm)	119	0.49 \pm 0.005	40	0.44 \pm 0.055	0.001**
TC (mg/dL)	121	166.86 \pm 2.522	40	163.83 \pm 5.394	NS
LDL-C (mg/dL)	121	96.45 \pm 2.44	40	82.71 \pm 3.74	0.003*
HDL-C (mg/dL)	121	47.33 \pm 0.90	40	59.17 \pm 2.04	< 0.001**
TG (mg/dL)	121	92.33 \pm 4.94	40	59.15 \pm 4.28	< 0.001**
Apo A-I (g/L)	114	1.34 \pm 0.018	33	1.47 \pm 0.043	0.001*
Apo B (g/L)	114	0.74 \pm 0.016	33	0.66 \pm 0.032	0.016*
Lp (a) (mg/dL)	114	27.42 \pm 2.56	33	17.6 \pm 2.92	0.014*
Male N(%)	121	61 (50.8%)	40	29 (70.7%)	0.027*

N: sample number; SEM: standard error of the mean; p-value: level of significance; BMI: body mass index; WC: waist circumference; %FM: percent fat mass; HOMA-IR: homeostasis model assessment for insulin resistance; LVED: left ventricular end-diastolic diameter; LVSD: left ventricular end-systolic diameter; IVS: interventricular septum diastolic diameter; PWD: left ventricular diastolic posterior wall diameter; LVM: left ventricular mass; LVMI: left ventricular mass index; RWT: relative wall thickness; cIMT: common carotid artery intima-media thickness; TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol; TG: triglycerides; Apo A-I: apolipoprotein A-I; Apo B: apolipoprotein B; Lp (a): lipoprotein (a); *Student *t* test; **Mann-Whitney U test.

On adjusting, the statistical differences remained, but LVED ($p < 0.001$) and LVM, both higher in the obese group, ($p < 0.001$) became significant.

Analysis of the obese group

In the obese group, we firstly analyzed the influence of sex and age group (pre- and adolescence) on these variables. Regarding sex, leptin ($p = 0.001$) and adiponectin ($p = 0.04$) were significantly higher in girls, and LVED ($p = 0.023$), LVM ($p = 0.011$) and LVMI ($p = 0.044$) were significantly higher in boys. Analysis by age group showed statistically significant differences for LVED ($p < 0.001$), LVSD ($p < 0.001$), IVS ($p = 0.008$) and LVPW ($p < 0.001$), higher in the pre-adolescent group, and BMI ($p < 0.001$), WC ($p < 0.001$), triglycerides ($p = 0.014$) and adiponectin ($p = 0.010$), higher in the adolescent group.

Acanthosis nigricans was found in 62% of the obese population (0% in the non-obese group). In the pre-adolescent group, males were more affected (53.7% vs 48.5% in females) and, in the adolescent group, females predominated (51.5% vs 46.3% in males).

We then used Pearson's correlation to establish the association between the indices of adiposity and insulin resistance, dyslipidemia, cIMT and LVMI.

Regarding the echocardiographic data, as demonstrated in Table 2, BMI was directly and moderately correlated to LVED ($r = 0.54$; $p < 0.001$) and LVSD ($r = 0.46$; $p < 0.001$), as well as to LVM ($r = 0.54$; $p < 0.001$), and less so to LVPW ($r = 0.34$; $p < 0.001$), IVS ($r = 0.19$; $p = 0.034$) and LVMI ($r = 0.26$; $p < 0.001$). Waist circumference showed a similar pattern, whereas %FM was not correlated to any of these parameters. The RWT was not correlated to these indices.

Left ventricular mass index above the P95 and RWT > 0.41 were seen in 31.7% and 18.3 % of the sample, respectively. Based on these findings we then subdivided left ventricular geometry into three patterns: eccentric hypertrophy (21.7%); concentric hypertrophy (10%); and concentric remodeling (8.3%).

Concerning the plasma lipids and lipoproteins profile, high-density lipoprotein cholesterol was the only variable that was inversely, but weakly correlated to BMI ($r = -0.30$; $p < 0.01$) and WC ($r = -0.26$; $p < 0.01$). Percentage fat mass did not show any significant correlation to plasma lipid and lipoprotein levels.

Body mass index was directly, but weakly correlated to leptin ($r = 0.39$; $p < 0.001$), cIMT ($r = 0.21$; $p = 0.026$) and HOMA-IR ($r = 0.38$; $p < 0.001$). Waist circumference was directly, but weakly correlated to leptin ($r = 0.34$; $p < 0.001$), cIMT ($r = 0.19$; $p = 0.047$) and HOMA-IR ($r = 0.36$; $p < 0.001$). Percent fat mass was directly, but weakly correlated to leptin ($r = 0.29$; $p = 0.002$) and HOMA-IR ($r = 0.36$; $p < 0.001$).

The HOMA-IR was inversely correlated to high-density lipoprotein cholesterol ($r = -0.2999$; $p = 0.002$) and directly, but weakly, correlated to triglyceride levels ($r = 0.25$; $p = 0.006$).

In this study, 38.1% of our population was considered insulin resistant, 68.9% had *acanthosis nigricans*, higher than the non-insulin resistant group (31.1%), although this difference was not statistically significant ($p = 0.515$). Girls and adolescents represented 60% and 62.2% of the insulin resistant group, the statistical differences being non-significant ($p = 0.088$ and $p = 0.221$, respectively).

The cIMT was directly correlated to LVM ($r = 0.21$; $p = 0.019$), LVED ($r = 0.30$; $p = 0.001$) and LVSD ($r = 0.30$; $p = 0.001$).

Table 2 – Correlations between body mass index, waist circumference and percentage fat mass with the echocardiographic parameters, leptin, common carotid artery intima-media thickness and insulin resistance in the obese group

Variable	BMI (Kg/m ²)		WC (cm)		%FM (%)	
	Pearson correlation	p-value	Pearson correlation	p-value	Pearson correlation	p-value
LVED (mm)	0.54**	< 0.001	0.53**	< 0.001	-0.05	0.593
LVSD (mm)	0.46**	< 0.001	0.47**	< 0.001	-0.06	0.497
IVS (mm)	0.20*	0.034	0.16	0.103	0.16	0.082
PWD (mm)	0.34**	< 0.001	0.32**	0.001	0.14	0.124
LVM (g)	0.54**	< 0.001	0.52**	< 0.001	0.09	0.324
LVMI	0.26**	< 0.001	0.10	0.298	0.09	0.311
RWT	0.06	0.508	0.05	0.578	0.17	0.064
cIMT (mm)	0.21*	0.025	0.19*	0.047	0.03	0.725
Leptin (ng/mL)	0.34**	< 0.001	0.34**	< 0.001	0.29**	0.002
Adiponectin (µg/mL)	0.18*	0.046	0.27**	0.004	0.22**	0.016
HOMA-IR	0.38**	< 0.001	0.36**	< 0.001	0.35**	< 0.001

BMI: body mass index; WC: waist circumference; %FM: percent fat mass LVED: left ventricular end-diastolic diameter; LVSD: left ventricular end-systolic diameter; IVS: interventricular septum diameter; PWD: left ventricular posterior wall diameter; LVM: left ventricular mass; LVMI:left ventricular mass index; RWT: relative wall thickness; cIMT: common carotid artery intima-media thickness; HOMA-IR: homeostasis model assessment for insulin resistance; correlation is significant at the *0.05 level and at the **0.01 level (2-tailed).

Discussion

We have demonstrated that there are statistically significant differences between the obese and control groups for the variables analyzed and that adiposity has a clear impact on insulin resistance, dyslipidemia, cIMT and LVM in obese children.

Insulin resistance in childhood is predictive of insulin resistance in adult life. It is the most common metabolic abnormality related to obesity and is strongly linked to type 2 diabetes and cardiovascular disorders^{24,25}. Based on the HOMA-IR results, 38% of the obese group individuals were considered insulin resistant. None had type 2 diabetes. In our study the prevalence of insulin resistance is lower than that published (50%-70%)²⁶. This discrepancy may be due to the different HOMA-IR cutoff values used in the various reports to diagnose insulin resistance, as standardized cutoff value has not been put forward²⁷.

The association between obesity and *acanthosis nigricans* has been well documented. The overall prevalence is 62%, similar to that found in our group of obese children (65%), mainly in boys (70.5%). As insulin is related to *acanthosis nigricans*, some authors have proposed it as a reliable marker of hyperinsulinemia, and hence, insulin resistance²⁸. As expected, we found insulin to be significantly correlated to *acanthosis nigricans*; however, we failed to establish an association between *acanthosis nigricans* and insulin resistance, as one third of our obese children with insulin resistance had no evidence of *acanthosis nigricans*. This observation is consistent with some results published²⁹. Clearly, in our experience, *acanthosis nigricans* was not a reliable marker of insulin resistance, and, thus, should not be used as a screening marker for type 2 diabetes in obese children, as proposed by some authors⁵. Nevertheless, as a clinical sign in the context of obesity, it ought to alert clinicians to the underlying pathophysiological mechanisms of insulin resistance and act accordingly. In fact, our observations led to the conclusion that insulin resistance was mostly related to %FM, BMI, WC and leptin, and inversely related to high-density lipoprotein cholesterol. These findings mirror the most important factors related to insulin resistance, namely the interplay between adiposity, adipokines and dyslipidemia.

Dyslipidemia was also a prominent cardiovascular risk factor found in our study population, particularly when compared to our control group. Considering the values proposed by the National Cholesterol Education Program Expert Panel on Cholesterol Levels in Children³⁰, 45% had intermediate-high to high levels of triglycerides, 42.5% had intermediate-low to low levels of high-density lipoprotein cholesterol and 31% had intermediate-low to low levels of low-density lipoprotein cholesterol. As a combined dyslipidemia, it represented 12.5% of our sample. This pattern is different from that found in non-obese children, namely high total and low-density lipoprotein cholesterol levels, and is considered particularly atherogenic as small dense low-density lipoprotein particles are inefficiently cleared by low-density lipoprotein receptors, elevated total low-density lipoprotein levels increase the risk of entrapment in the subendothelial matrix, and decreased levels of high-density lipoprotein particles limit

reverse cholesterol transport. As observed in our study, insulin resistance was inversely correlated to high-density lipoprotein cholesterol but not to low-density lipoprotein cholesterol, potentially contributing to the mechanisms that trigger early onset atherosclerosis and, hence, cardiovascular disease in young adults. Research shows that this combined dyslipidemia pattern is increasing in prevalence and predicts vascular dysfunction in young adults and early clinical events in adult life.

We also compared apolipoprotein A-I, B and lipoprotein (a) between the two groups. Although the obese group undoubtedly had a more atherogenic profile [higher apolipoprotein B and lipoprotein (a) and lower apolipoprotein A-I], none of these variables correlated to insulin resistance. Individually, apolipoprotein B was weakly correlated to leptin ($r = 0.33$; $p < 0.001$), apolipoprotein A-I was inversely, but weakly, correlated to BMI ($r = -0.19$; $p = 0.042$), and lipoprotein (a) to BMI ($r = 0.22$; $p = 0.019$) and leptin ($r = 0.21$; $p = 0.029$). Unlike Cunningham et al¹⁹, which found lipoprotein (a) to be a useful cardiovascular risk marker in children, we did not come to the same conclusion, possibly due to differences in population ethnicity. In fact, based on these findings, it appears that plasma lipoproteins do not offer an advantage over lipoprotein cholesterol measures in the management of dyslipidemias and risk stratification during childhood, at least in our population. Along the same lines, studies in obese adults with insulin resistance have concluded that plasma lipoproteins do not provide further prognostic information when compared to the standard lipoprotein cholesterol profile.

The atherogenicity induced by insulin resistance and lipid abnormalities during childhood result in structural vascular changes that can be assessed non-invasively by ultrasonography of the cIMT. This variable has been validated as a cardiovascular risk marker in children and adults, although in obese children, observations have not always been consensual³¹. We sought to correlate cIMT with other cardiovascular risk markers and its usefulness as a surrogate of preclinical atherosclerosis. Contrary to the findings by Tounian et al³², in our analysis, cIMT was significantly higher ($p < 0.001$) in the obese group. In this group, multivariate analysis demonstrated that the most significant correlations were with age ($r = 0.26$; $p = 0.004$), BMI ($r = 0.21$; $p = 0.025$) and WC ($r = 0.19$; $p = 0.047$), suggesting a direct link between adiposity and cIMT, whereas lipids and lipoproteins were not related. The latter finding does not concur with the observations published by Magnussen et al³³, a far larger study, where childhood dyslipidemia was related to an increase in cIMT in adulthood. Most likely our smaller sample size accounts for these differences.

We also investigated whether LVM and LVMI were linked to adiposity. Left ventricular mass index was above the P95 in 32% of our obese group. Through multivariate analysis, we were able to show a direct correlation to age, BMI and WC, but, when indexed to height^{2,7}, only BMI remained significantly correlated. This confirms previous observations, and highlights the impact of adiposity on left ventricular dimensions, whose adverse effects are already present in our young obese population, and which are known to

track into adulthood. In adults, a LVMI $> 51\text{g}/\text{m}^{2.7}$ carries prognostic significance as these individuals are known to be more susceptible to cardiovascular events^{34,35}. We also aimed at addressing the relationship between adiposity and abnormal ventricular geometric patterns. Overall, 40% of our population presented abnormal geometric patterns, the most common being eccentric left ventricular hypertrophy (21.7%). Considering that obesity is characterized by chronic volume overload, this would be the expected pattern; however, several adult studies have shown that, in fact, concentric hypertrophy is the most common ventricular geometric abnormality, even in the absence of arterial hypertension, implying that mechanisms other than volume overload play a role. Based on these results we postulate that volume overload is an important contributing factor, as we found no other relevant associations. Nevertheless, 10% of our population had left ventricular concentric hypertrophy, followed by 8% with concentric left ventricular remodeling. The latter condition, although not related to increased LVMI, has also been shown to be associated with adverse cardiac events and provides another marker for assessing cardiovascular risk in children³⁶.

This study has a few limitations, our sample size, particularly the control group, being one. Due to our local population characteristics, our sample included Caucasian children only. Implicitly, these factors may represent a bias.

Conclusions

In conclusion, we have highlighted indices of adiposity as a common link to adverse metabolic and structural changes

in obese children. As these track into adulthood, efforts should continue to be made to reverse these changes, aiming at lifestyle modifications, and potentially decreasing the socioeconomic burden of cardiovascular disease in adulthood.

Author contributions

Conception and design of the research: Pires A, Matins P. Acquisition of data: Pires A, Pereira AM, Silva PV, Marinho J. Analysis and interpretation of the data: Pires A, Sena C, Seça R. Statistical analysis: Pires A, Marques M, Sena C. Writing of the manuscript: Pires A, Matins P. Critical revision of the manuscript for intellectual content: Pires A, Matins P, Silva PV, Marinho J, Castela E, Sena C, Seça R. Analysis Procedure: Pereira AM.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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