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CLINICAL RESEARCH ARTICLE

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Role of obesity and blood pressure in epicardial adipose tissue thickness in children

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BACKGROUND: Elevated body mass index (BMI) has been associated with cardiac changes, such as higher epicardial adipose tissue (EAT) thickness. This fat has been identified as a predictive factor of cardiovascular diseases during adulthood. However, few studies have tested the association of multiple cardiovascular risk factors (high weight or blood pressure) with EAT in adolescents and children. Therefore, the main objective of this current research was to determine the impact of BMI, overweight, obesity, and blood pressure on EAT thickness in children.
METHODS: A descriptive cross-sectional study focused on elementary and high school students aged 6–16 years was carried out by utilizing diverse measurements and instruments, such as echocardiography.
RESULTS: EAT thickness ($N = 228$) was linked to sex (more predominant in boys 2.3 ± 0.6; $p = 0.044$), obesity (2.3 ± 0.6; $p < 0.001$), and hypertension (2.6 ± 0.6; $p = 0.036$). The logistic regression indicated that age, sex, and BMI seemed to be more relevant factors in EAT thickness in children (adjusted R square $= 0.22$; $p < 0.001$).
CONCLUSIONS: This paper examined the associations of sex, age, and cardiovascular risk factors (arthrometric measures and blood pressure) with EAT thickness, indicating that it is necessary to assess whether the findings are associated with future events.

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IMPACT:

- Excessive weight gain and blood pressure in the early stages of life have been associated with adipose tissue. This increase in weight and blood pressure has been attributed to alterations in the epicardial adipose tissue linked to anthropometric markers in adults, but no related study has been implemented in Spanish children.
- This study revealed how higher epicardial adipose tissue is linked to body mass index, other anthropometric parameters, and blood pressure in Spanish children. These measurements are related to high epicardial adipose tissue thickness, which in early stages does not imply pathology but increases the risk of developing cardiovascular diseases.

INTRODUCTION

Excessive body fat is a significant risk factor for metabolic,[1] hormonal,[2] and immunological alterations.[3] The prevalence of elevated body mass index (BMI), which can cause serious diseases,[3] has increased in recent decades. This shift is reflected by the overweight and obesity rates, resulting in a high prevalence of other health diseases, such as hypertension and diabetes.[4,5] In Europe, it is estimated that one out of four individuals is overweight and one out of ten is obese.[6]

Additionally, high BMI has been associated with increased visceral fat deposits and other cardiac and cardiovascular modifications.[7] Additionally, visceral fat deposits have been defined as a marker of cardiovascular risk related to other risk factors, such as metabolic syndrome, diabetes, coronary artery diseases, and arteriosclerosis.[8] Moreover, structural changes in the cardiac geometry translate into increased wall thickness and left ventricle mass and index, which are reflected by diverse markers[9,10] including the left ventricular end-systolic cavity dimension.[11,12] These modifications also seem to be appreciable by analyzing epicardial fat[13,14]; for instance, epicardial adipose tissue (EAT) thickness has been studied as a possible marker of cardiac modifications and metabolic diseases.[14,15] EAT has been highlighted as a potential predictive marker of multiple illnesses, such as hypertension, metabolic syndrome, and cardiovascular disease (CVD).[16,17] As a risk factor, EAT thickness has been partially associated with high blood pressure (HBP), subclinical coronary artery diseases, and metabolic disorders.[9,18–20]

The diagnosis of increased EAT thickness is made through echocardiography. Increased BMI, waist circumference (WC), or

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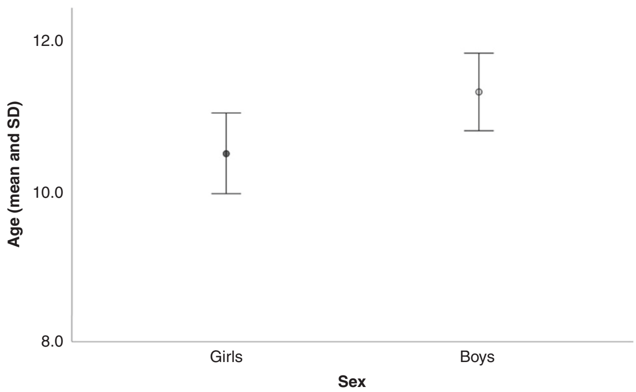

Fig. 1 Boxplot of the mean age and standard deviation for girls and boys. Representation of distribution of mean age (colored circle) and standard deviation (SD) (axis Y) according to sex (axis X).

other anthropometric measurements of adiposity may be useful as indirect predictors of increased EAT.[21] Additionally, the combination of BMI and WC, by which visceral fat alteration diagnoses during childhood can be analyzed,[18] could be used as a predictor of EAT and, therefore, the risk of CVD.[9] Nevertheless, imaging measures have become more important,[17,20] despite the cost of imaging measurements, such as MRI. In addition, in recent years, other imaging detection techniques in adults, such as echocardiography, have increased due to their low cost and accessibility.[16,17] The use of echocardiography for determining EAT thickness in adults has been improved based on its specific capacity to detect fat modification as a possible indirect marker of CVD and metabolic changes.[22]

The relevance of EAT as a possible marker for other diseases and its association with diverse parameters, such as BMI, has been mainly established in adults.[7,15] More recent articles have indicated that EAT in overweight children tends to be similar to that identified in adults, indicating possible diagnostic value.[10,23,24] One study that used echocardiography indicated no significant associations between EAT thickness and diseases in children, specifically metabolic syndrome.[25]

Despite the importance of determining EAT thickness for its possible predictive value for CVDs and the associations of EAT with indirect measures linked to excess adiposity,[16,17,26] little research has combined the indirect (BMI, WC, or BP) and direct (echography) measures in pediatric populations.[16] Nonetheless, determining the associations of diverse anthropometric measurements with EAT thickness through echocardiographic screening in children is highly relevant as a noninvasive approach for the early detection and prevention of cardiac problems, especially in primary healthcare and general practice.[23,27]

Therefore, the main objective of this current research was to determine the impact of BMI, overweight and obesity rates, and BP on EAT thickness in children. The secondary objective was to analyze the associations of indirect measures, such as WC, with EAT thickness.

METHODS

Design, procedure, and sample

This descriptive cross-sectional study focused on elementary and high school students aged 6–16 years (95% Caucasian) from a small size town in southern Spain (approximately 3000 inhabitants with an average household income per capita of 19,416 00 eur).

Before the inclusion of participants, informative talks were held for parents and students in each educational center. In these meetings, the research objectives and methodology were explained, questions that arose were answered, and a contact email and a telephone number where any subsequent consultation could be made were provided. After reading the participant information statement, consent form, and questionnaires, and signed the consented form by the parents or legal guardians and the students themselves, participants were able to take part in this research.

The inclusion criteria were age, parent or legal guardian acceptance at the time of starting the study, and signed informed consent by the parents or legal guardians, the student, and the principal researcher. The exclusion criteria were children under 6 years and adolescents over 16 years of age who were excluded when the study began or had not signed the informed consent form. The anthropometric measurements and cardiography data of each participant were gathered by two general practitioners in the different centers. Such centers did not have a health consultation facility, but they were close to the primary health center. The anthropometric indices, BP, and physical measurements were obtained in each elementary and high educational center during three or four sessions, generally on a Friday, in which groups between eight and ten children were assessed. Additionally, the echocardiography was taken in the town's primary health center by appointment.

The participants were recruited to participate from March 2018 to February 2019. A nonprobability convenience sample of 254 participants was recruited from March 2018 to February 2019. Most participants agreed to undergo the ultrasound (238; 93.7%) and after gathering all data the final sample totaled 228 subjects (120 boys, ages ranging between 11 and 12 years and 108 girls with ages between 10 and 11 years) (Fig. 1). The girls were significantly younger than the boys with a difference of 8 months ($p < 0.05$).

Measures and instruments

Anthropometric measurements. Anthropometric variables were measured following the International Standards for Anthropometric Assessment[28] using a portable model Seca 213® (Seca, Hammer Steindamm, Hamburgo, Germany). Weight, BMI, percentage of fat mass and lean mass, and total body water composition were obtained with a model Omron BF-511 (Omron Healthcare Europe B.V., Hoofddorp, Netherlands) impedance meter, classified according to Melo Salor.[29]

BMI was calculated by the BMI equation, and BMI was categorized according to Melo Salor's tables[29] and the World Health Organization.[30] The selection of these tables and the structure of BMI to determine the normal weight, overweight, and obesity was based on the modeling of z scores. In this sense, BMI groups[29] were grouped using the cut points according to age and sex, for instance, 12-year-old girls have up to 14.4 (underweight), 20.8 (normal weight), 25.0 (overweight), and >31.9 (obesity).

To determine the WC, an inextensible measuring tape was used, and the waist–height ratio (WHtR) was calculated by dividing the WC by the height (cm). The body fat percentage (BF%) and fat-free (FF%) mass were calculated using the Faulkner equation.[31]

Blood pressure. BP measurements were performed with an automatic sphygmomanometer: the Omron M6 comfort® model. BP was measured following the European Society for Arterial Hypertension recommendations for children and adolescents.[32] HBP was defined as at least three successive SBP or DBP measures greater than or equal to the 95th percentile (P95) for a given age, sex, and height percentile.

Regulated echocardiogram. Each subject underwent a two-dimensional (2D) transthoracic echocardiogram. The measurement was carried out via a standard technique with the patients in the left lateral decubitus position, following the method validated by Iacobellis et al.[7] An echocardiographer cardiologist performed the technique. The measurement identified the hypoechoic space anterior to the right ventricular wall, with the EAT thickness determined according to the epicardial surface and the parietal pericardium. This assessment was made following recommendations and previous work,[33] so EAT was not confused with pericardial fluid. Two cardiologists evaluated the results and assessed EAT thickness appropriately.

All patients underwent a complete ultrasound study with M-mode, 2D transthoracic echocardiography, and Doppler. Images were taken in the long- and short-axis parasternal projection, at the apical point of four cameras, three cameras, and two cameras, as well as in the subxiphoid plane. A Philips iE33 with probe S5-1 (Koninklijke Philips. Electronics N.V., Eindhoven, Netherlands) was used for the measurement.

EAT was identified as the echolucent space between the outer wall of the myocardium and the visceral layer of the pericardium. This was measured perpendicularly over the free wall of the right ventricle at the

Table 1. Characteristics of the sample according to study variables and sex.

Variable	Total $N = 228$	Boys $N = 120$	Girls $N = 108$	p
Underweight	1 (0.4%)	0 (0.0%)	1 (0.4%)	0.55
Normal weight	118 (49.6%)	59 (49.2%)	54 (50.5%)	0.99
Overweight	62 (27.2%)	31 (25.8%)	31 (28.7%)	0.57
Obesity	51 (22.3%)	30 (25%)	21 (19.5%)	0.35
Anthropometric indices				
BMI (Kg/m^2)	20.3 ± 4.5	20.7 ± 4.6	19.9 ± 4.5	0.2
WC (cm)	66.1 ± 11.2	68.5 ± 11.9	63.2 ± 9.6	<0.001
WHtR	0.45 ± 0.06	0.46 ± 0.07	0.44 ± 0.05	<0.05
BF%	24.8 ± 8.6	23.8 ± 8.8	26 ± 8.2	0.054
FF%	31.8 ± 4.3	33.3 ± 4.7	30.1 ± 3	<0.001
Blood pressure				
SBP (mmHg)	110.5 ± 10.8	112.3 ± 11.1	108.5 ± 10.1	<0.05
DBP (mmHg)	68.3 ± 6.5	68.5 ± 6.5	68.1 ± 6.6	0.59
Hypertension	15 (6.3%)	7 (5.5%)	8 (7.3%)	0.83
Physical activity				
Course Navette (min)	4.4 ± 2.4	4.6 ± 2.3	4.2 ± 2.1	0.13
Jump (cm)	131.9 ± 33	140.8 ± 35.6	121.5 ± 26.1	<0.001
Sit-ups	19.7 ± 5.6	20.7 ± 6.2	18.6 ± 4.4	<0.01

BMI body mass index, *WC* waist circumference, *WHtR* waist-to-height ratio, *BF%* body fat percentage, *FF%* free-fat mass percentage, *SBP* systolic blood pressure, *DBP* diastolic blood pressure.
To carry out the analysis, chi^2, Kruskal–Walls, and Student's *t* test were used.

end of systole in three cardiac cycles using a long parasternal or short parasternal view. The measurement was performed on the free wall of the right ventricle for two reasons: (1) this point is anatomically recognized as the one with the most significant epicardial fat and (2) the long parasternal and short parasternal axes allow the most accurate measurements of epicardial fat on the right ventricle, with optimal cursor orientation in each view.

Assessment of fitness level. The assessment of fitness level was conducted through the Eurofit battery tests: Endurance, through the Course Navette test,[34] and Muscular Strength through three tests: (a) extended jump test without impulse and with feet together to evaluate the explosive strength of the lower body; (b) hand strength test, and (c) abdominal strength test by performing the maximum number of complete sit-ups over 30 min. A physical condition level was obtained for each child and adolescent from the results of the different tests.

Statistical analysis

After obtaining all the data, SPSS (IBM, Armonk, NY) version 28 was used to analyze each measurement. The absolute and relative frequencies were used for categorical variables, such as normal weight or overweight incidence. Additionally, the median was used for such variables. The mean and standard deviation, along with the 95% confidence interval (CI), were used for the quantitative analysis. To test for normality, the Kolmogorov–Smirnov test with Lilliefors correction and Q-Q graphs were used, showing differences between subgroups (BMI groups) ($p < 0.05$) and normally distributed data in the whole sample ($p > 0.05$).

Based on the results from the Kolmogorov–Smirnov test, the comparison of two or three independent means was carried out using the Mann–Whitney *U*, Student's *t* test, and analysis of variance (ANOVA), and the Kruskal–Wallis test according to the variable being analyzed. When indicated, the chi^2 test with the Yates correction or Fisher's test was used. Additionally, the two- and three-way ANOVA test for three factors was applied for EAT values and sex, BMI, and hypertension, transforming the variables according to the cut-off points for diagnosing obesity or hypertension.[32] Quantitative bivariate correlations were assessed, and Pearson's correlation coefficient was used. Finally, logistic regression was used to determine associations between the EAT and obesity and hypertension. The stepwise method was applied in logistic regression according to mean EAT thickness. The elimination of the variables of the model was dependent on their *p* value, and the receiver operating characteristic (ROC) curve was implemented to determine the impact of BMI and other anthropometric measures, as well as personal factors, such as age or sex, on the EAT thickness.

RESULTS

The prevalence of obesity and overweight in the sample ($N = 228$) was 49.5%. There were significant differences between the obesity or overweight and normal weight children regarding BMI (22.7 ± 3.6 vs. 18.4 ± 4.2; $p < 0.001$), WC (71.2 ± 10.1 vs. 62.1 ± 10.2; $p < 0.001$), WHtR (0.5 ± 0.04 vs. 0.4 ± 0.06; $p < 0.001$), FF% (30.1 ± 5.6 vs. 20.7 ± 8.3; $p < 0.001$), SPB (113.2 ± 10.2 vs. 108.4 ± 10.7; $p = 0.007$), hypertension (13.1 vs. 1.6; $p < 0.001$), jumps (126.2 ± 27.4 vs. 135.8 ± 36.5; $p < 0.001$), and sit-ups (19.4 ± 4.9 vs. 20.0 ± 6.0; $p < 0.001$).

Sex differences were assessed for anthropometric indices, BP, and physical activity, showing significant differences between girls and boys (Table 1). Table 1 shows that there were no significant differences in the rate of overweight regarding sex (28.7%, 95% CI 20.7–37.9 vs. 25.8%, 95% CI 16.5–33.4; $p = 0.57$). The BMI showed a mean of 20.3 with a standard deviation of 4.5 (95% CI 19.7–20.9), and the participants were close to the 85th percentile. The WHtR was 0.45 ± 0.06 with a 95% CI of 0.45–0.46, which was significantly higher in boys than in girls (0.46 ± 0.07 vs. 0.44 ± 0.05; $p < 0.05$). The BF% was 24.8 ± 8.6 with a 95% CI from 23.7 to 25.9, and the mean FF% was 31.8 ± 4.3, with a 95% CI 31.2–32.3 (33.3 ± 4.7 in boys vs. 30.1 ± 3 in girls; $p < 0.001$), with no significant differences between sexes for BF%. Finally, these parameters showed significant differences between girls and boys (Table 1).

The BP results showed no differences between boys and girls, except for systolic BP (SBP) (Table 1). Boys had slightly higher levels of diastolic BP (DBP) than girls (68.5 ± 6.5 vs. 68.1 ± 6.6; $p = 0.59$), hypertension being slightly more prevalent in girls (5.5 vs. 7.3%; $p = 0.83$). SBP was significantly higher in boys than in girls (112.3 ± 11.1 vs. 108.5 ± 10.1; $p < 0.05$), with a difference of 3.8 ± 1. Finally, the physical activity test showed a mean value of 4.4 ± 2.4 min with a 95% CI of 4.1–4.7, with no significant difference between boys and girls (4.6 ± 2.3 vs. 4.2 ± 2.1; $p = 0.13$). In addition, there was a considerable difference regarding the mean number of jumps (140.8 ± 35.6 vs. 121.5 ± 26.1; $p < 0.001$) and sit-ups (20.7 ± 6.2 vs. 118.6 ± 4.4; $p < 0.01$) between boys and girls.

The sample was formed by 73 children (32.0%) whose age was between 6 and 9 years, 71 (31.1%) who were between 9 and 12 years, and 84 (36.8%) who were >12 years. The differences between the age groups (children, prepuberal, and adolescents) in sex, anthropometric indices, BP, and physical activity were analyzed, showing no differences between the groups, except for WC (59.8 ± 9.6 vs. 66.1 ± 9.6 vs. 71.6 ± 10.4; $p = 0.01$), presence of hypertension (1.3 vs. 0.8% vs. 4.2%; $p = 0.046$), the number of jumps (103.2 ± 16.2 vs. 130.6 ± 20.8 vs. 156.8 ± 32.3; $p = 0.001$), and sit-ups (16.2 ± 8.8 vs. 19.9 ± 4.3 vs. 21.7 ± 6.5; $p = 0.03$) (Table 2).

EAT thickness was analyzed according to the ultrasound measurement planes (long and short sternal) as well as overall (mean of the total measurements) and according to sex (Fig. 2), obesity, and arterial hypertension. EAT thickness was higher among boys for the long and global planes than among girls (Table 3). EAT was higher in obese children than in normal weight children (2.2 ± 0.7 vs. 1.8 ± 0.5; $p < 0.001$ for the long parasternal axis (LPA); 2.4 ± 0.7 vs. 1.8 ± 0.6; $p < 0.001$ for the short parasternal axis (SPA); 2.3 ± 0.6 vs. 1.8 ± 0.5; $p < 0.001$ for the global), and the difference was more significant in boys (2.3 ± 0.8 vs. 1.8 ± 0.5; $p < 0.001$ for the LPA; 2.4 ± 0.8 vs. 1.9 ± 0.6; $p < 0.001$ for the SPA; 2.4 ± 0.7 vs. 1.8 ± 0.5; $p = 0.006$

Table 2. Characteristics of the sample according to age group, separated according to age.

Variable	Between 6 and 9 years	Between 9 and 12 years	Over 12 years	p
Boys	33 (14.5%)	37 (16.2%)	50 (21.9%)	0.2
Girls	40 (17.5%)	34 (14.9%)	34 (14.9%)	
Groups according to BMI				
Underweight	1 (0.4%)	0 (0.0%)	0 (0.0%)	0.27
Normal weight	37 (15.5%)	31 (13.0%)	45 (18.9%)	
Overweight	19 (8.0%)	20 (8.4%)	23 (9.7%)	
Obesity	16 (6.7%)	19 (8.0%)	16 (6.7%)	
Anthropometric indices				
BMI (Kg/m^2)	18.1 ± 3.3	20.1 ± 4.7	22.3 ± 4.4	0.15
WC (cm)	59.8 ± 9.6	66.1 ± 9.6	71.6 ± 10.4	0.01
WHtR	0.47 ± 0.04	0.45 ± 0.05	0.43 ± 0.3	0.21
BF%	23.7 ± 8.2	25.5 ± 8.7	25.4 ± 8.9	0.5
FF%	28.1 ± 2.7	31.8 ± 2.7	34.7 ± 4.4	0.056
Blood pressure				
SBP (mmHg)	103.9 ± 8.1	109.6 ± 10.1	117.0 ± 9.4	0.064
DBP (mmHg)	65.7 ± 5.4	68.2 ± 6.3	70.8 ± 6.6	0.59
Hypertension	3 (1.3%)	2 (0.8%)	10 (4.2%)	0.046
Physical activity				
Course Navette (min)	7.8 ± 1.2	7.9 ± 0.9	7.2 ± 1.6	0.087
Jump (cm)	103.2 ± 16.2	130.6 ± 20.8	156.8 ± 32.3	0.001
Sit-ups	16.2 ± 8.8	19.9 ± 4.3	21.7 ± 6.5	0.03

BMI body mass index, *WC* waist circumference, *WHtR* waist-to-height ratio, *BF%* body fat percentage, *FF%* free-fat mass percentage, *SBP* systolic blood pressure, *DBP* diastolic blood pressure.
For the analysis of the results, chi^2 and ANOVA were applied.

for the global) than in girls (2 ± 0.6 vs. 1.7 ± 0.4; $p < 0.05$ for the LPA; 2.2 ± 0.7 vs. 1.7 ± 0.5; $p < 0.001$ for the SPA; 2.1 ± 0.4 vs. 1.7 ± 0.4; $p < 0.001$ for the global). Additionally, the EAT thickness was higher in hypertensive children (2.2 ± 0.7 vs. 1.8 ± 0.5; $p = 0.031$ for LPA and 2.2 ± 0.7 vs. 1.8 ± 0.5; $p = 0.031$ for the global). Moreover, the two-way ANOVA for the three factors (sex, hypertension, and obesity) (Table 3) indicated that sex, obesity, and hypertension were related to EAT thickness. The global EAT thickness was significantly different according to obesity and hypertension (2.7 ± 0.6 vs. 1.7 ± 0.5; $p = 0.05$), with no differences between girls and boys in regard to hypertension and obesity. The results among the boys indicated that EAT thickness was mediated by the presence of obesity (2.4 ± 0.7 vs. 1.8 ± 0.5; $p = 0.006$ for the global), which was the same for the girls (2.1 ± 0.4 vs. 1.7 ± 0.4; $p < 0.001$ for the global). Additionally, the girls with obesity and HBP had more diverse EAT thickness values than girls who did not have both indicators (2.6 ± 0.6 vs. 1.6 ± 0.4; $p = 0.036$).

A deeper analysis was carried out using logistic regression based on the significant association between EAT thickness and BMI (Fig. 3a) and EAT and BP (Fig. 3b). Figure 3a shows the area under the curve (AUC) of the ROC curve, showing significant values for LPA (0.76 with a 95% CI from 0.682 to 0.833), SPA (0.76; 95% CI of 0.682–0.833), and global (0.746; 95% of 0.67–0.813) ($p < 0.001$). The analysis focused on hypertension and EAT thickness measured in the SPA, which obtained the highest discriminant capacity (0.723, 95% CI of 0.59–0.852; $p < 0.001$), followed by the global parasternal axis (0.677 with a 95% CI of 0.531–0.824; $p < 0.05$) (Fig. 3b).

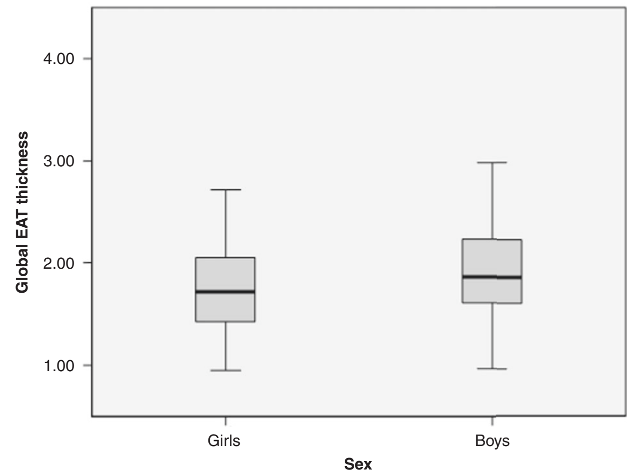

Fig. 2 Boxplot of the mean and standard deviation of global EAT thickness according to sex. Distribution of mean global epicardial adipose tissue thickness and its confidence interval at 95% (axis Y) according to sex (axis X).

In addition, correlation analysis was performed using the coefficient correlation between the quantitative variables and EAT thickness. The results showed that there were associations between global EAT thickness and age ($r = 0.13$; $p < 0.05$), height ($r = 0.21$; $p < 0.01$), weight ($r = 0.39$; $p < 0.001$), BMI ($r = 0.43$; $p < 0.001$), SBP ($r = 0.23$; $p < 0.001$), DBP ($r = 0.16$; $p < 0.01$), WC ($r = 0.42$; $p < 0.001$), WHtR ($r = 0.34$; $p < 0.001$), and BF% ($r = 0.35$; $p < 0.001$). Based on the significance of the results, linear regression was implemented for the previous anthropometric measures and the global thickness. The analysis showed that age and anthropometric indices were significantly associated with the global thickness (Table 4). The analysis indicated high significance for the variables (R square = 0.23; Adjusted R square = 0.22; $p < 0.001$). Table 4 shows strong associations with global EAT thickness, except for FF%, which had a lower significance value. Therefore, these findings aroused interest in developing a predictive model based on multiple linear regression. BMI was the anthropometric index that obtained the best predictive capacity (goodness of fit, r^2). It was found that the combination of more than one anthropometric indicator (compatible to avoid collinearity) did not improve the goodness of fit of the prediction equation. Therefore, the linear equation for the theoretical determination of global EAT thickness is shown in Table 4, where BMI is calculated by dividing the weight (kg) by the height (m^2), sex equals one for boys and zero for girls, and age is included in years (Model 1: Determination of global EAT thickness: Global EAT thickness (mm) = 0.82 + 0.055 (BMI) + 0.17 (sex) − 0.014 (age)).

DISCUSSION

This paper examined the association between sex, age, cardiovascular risk factors (anthropometric measures and BP), and EAT thickness.

The current study indicated a high prevalence of overweight and obese children (approximately 25% each), which was associated with sex, BP, physical activity, and EAT thickness. Another factor related to EAT thickness and BMI was hypertension, which has also been increasing in this population. These outcomes have shown that weight alteration is complex and effects affect EAT thickness at similar levels as in adults.[10,23]

In addition, the ANOVA tests and ROC curves highlighted the effect of BMI and BP on EAT thickness (short, long, and global)

Table 3. Epicardial adipose tissue (EAT) thickness measured by ultrasound and sex for obesity and arterial hypertension was determined using three- and two-way ANOVA.

	Epicardial adipose tissue (EAT) thickness					
	LPA	***p***	**SPA**	***p***	**Global**	***p***
Sex (boys)	1.9 ± 0.6	0.021	2.0 ± 0.7	0.1	2.3 ± 0.6	0.044
Sex (girls)	1.7 ± 0.5		1.8 ± 0.5		1.7 ± 0.5	
Obesity (yes)	2.2 ± 0.7	<0.001	2.4 ± 0.7	<0.001	2.3 ± 0.6	<0.001
Obesity (no)	1.75 ± 0.5		1.8 ± 0.6		1.8 ± 0.5	
HBP (yes)	2.2 ± 0.9	0.034	2.3 ± 0.6	0.06	2.2 ± 0.7	0.031
HBP (no)	1.8 ± 0.5		1.9 ± 0.6		1.8 ± 0.5	
Obesity and HBP (yes)	2.3 ± 0.7	0.002	2.4 ± 0.8	0.5	2.7 ± 0.6	0.05
Obesity and HBP (no)	1.6 ± 0.4		1.7 ± 0.5		1.7 ± 0.5	
Obesity (yes) and HBP (yes) and sex (boys)	3.1 ± 1	0.8	2.6 ± 0.6	0.3	2.9 ± 0.8	0.6
Obesity (yes) and HBP (yes) and sex (girls)	2.2 ± 0.6		2.4 ± 0.9		2.6 ± 0.6	
Boys						
Obesity (yes)	2.3 ± 0.7	<0.001	2.4 ± 0.8	<0.001	2.4 ± 0.7	0.006
Obesity (no)	1.8 ± 0.5		1.86 ± 0.6		1.8 ± 0.5	
HBP (yes)	2.3 ± 0.95	0.24	2.4 ± 0.5	0.11	2.4 ± 0.7	0.12
HBP (no)	1.9 ± 0.6		2 ± 0.7		1.95 ± 0.6	
Obesity and HBP (yes)	3.1 ± 1.0	0.04	2.7 ± 0.6	0.14	2.8 ± 0.8	0.39
Obesity and HBP (no)	1.8 ± 0.5		1.9 ± 0.6		1.8 ± 0.6	
Girls						
Obesity (yes)	2 ± 0.6	<0.05	2.2 ± 0.6	<0.001	2.1 ± 0.4	<0.001
Obesity (no)	1.7 ± 0.4		1.7 ± 0.5		1.7 ± 0.4	
HBP (yes)	2 ± 0.8	0.12	2.2 ± 0.7	<0.05	2.1 ± 0.7	0.12
HBP (no)	1.7 ± 0.4		1.8 ± 0.5		1.7 ± 0.4	
Obesity and HBP (yes)	2.5 ± 0.7	0.019	2.7 ± 0.5	0.14	2.6 ± 0.6	0.036
Obesity and HBP (no)	1.7 ± 0.4		1.7 ± 0.5		1.6 ± 0.4	

BMI body mass index, *HBP* high blood pressure, *LPA* long parasternal axis, *SPA* short parasternal axis, *Global* arithmetic mean of values of both sexes.

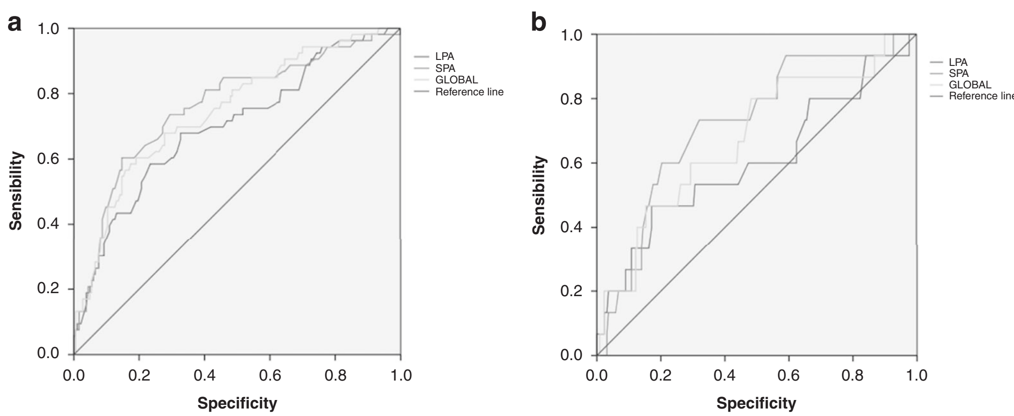

Fig. 3 ROC curve and areas under the curve of epicardial adipose tissue thickness for obesity and hypertension. Representation of the association and significant values based on the logistic regression between obesity rate (**a**) and hypertension (**b**) related to the long, short and global epicardial adipose tissue thickness (represented in the figures as different colours lines) including the sensibility (axis Y) and specificity (axis X).

among children, although the significant factor in girls and both sexes was BMI. In this sense, the EAT measures (short, long, and global) indicated to be related to different associations with sex, BP, and obesity prediction, being the most relevant the global and long EAT thickness for boy and global and short EAT thickness for girls. Moreover, based on multivariant analysis, the model showed that age, sex, and BMI could be among the most significant factors related to the EAT thickness and was represented in the model in one out of four children.

The obesity and overweight rates we detected in our study were highly unexpected since previous studies have indicated lower frequencies.[35,36] The prevalence of obesity in children (5–17

Table 4. Predictive model for global EAT thickness using multiple linear regression adjusted for age, sex, and anthropometric index.

Variable	Constant	Beta Coef.	CI 95%	EE	Adjusted r^2	F	p
BMI	0.82	0.055	0.04 to 0.07	0.008	0.2	20.8	<0.001
WC	0.56	0.023	0.016 to 0.03	0.003	0.184	18.8	<0.001
WHtR	0.033	3.2	2.1 to 4.3	0.57	0.145	14.5	<0.001
BF%	1.03	0.024	0.02 to 0.03	0.004	0.159	15.8	<0.001
FF%	2.3	−0.036	−0.06 to 0.01	0.01	0.074	6.2	<0.01

BMI body mass index, *WC* waist circumference, *WHtR* waist-to-height ratio, *BF%* body fat percentage, *FF%* free-fat mass percentage.

years old) was found to be between 10.2 and 12.6%;[35,36] moreover, previous Spanish studies conducted in the 2000s showed that the combination of obese and overweight children was 26.3%,[37] with an obesity rate of approximately 15%.[37,38]

Despite the previous findings from the early 2000s, the current research is more in sync with a recent Spanish study that the prevalence of overweight was 29.4% (9-18 years old) and obesity was 7.0 (9-18 years old), being higher in boys compared to girls (35.6 vs. 22.8 and 8.5 vs. 5.3).[39] The obesity rate among Spaniards between 9 to 18 years old in the ENPE's research[39] was higher by five points than the enKid's study (2006).[40] All these results highlight how the tendency of overweight and obesity among Spaniards is highly increasing achieving concerning values.

Besides, the BP results and other anthropometric data, such as WC or BMI, were consistent with other authors regarding the prevalence of hypertension and the relevance of BMI as a relevant indicator of cardiovascular risk factors in children.[39,41,42] The physical condition of the sample matched that described in previous studies, showing a value under the health standards for adequate growth,[41,42] which seemed related to EAT thickness.

High levels of BMI and BP provoke structural changes in cardiac geometry, mainly causing increased wall thickness,[43] which seems to be reflected by EAT thickness. In this sense, previous studies have linked BMI, SBP, and WC, as cardiovascular risk factors, to thicker EAT and, therefore, a higher risk of CVD.[10,23,24,44] The previous results and the current findings were in agreement in regard to the relevance of cardiovascular risk factors and cardiac modifications in children. Moreover, the associations between EAT thickness and sex, BP, and obesity prediction match a previous study focused on adults (30 to 64 years) that indicated how long parasternal axes were associated with males.[45] These differences between EAT thickness might be caused by age-related changes in sex hormones, although no research in children has indicated such differences.[44]

In general, most studies focused on the associations between variables but did not differentiate between sexes and assessed only one arthrometric variable (BMI or WHtR) in relation to EAT thickness.[44,46] Most studies have focused on the associations between a few arthrometric variables and EAT thickness[47,48] and its potential for detecting other diseases, such as metabolic syndrome. Nevertheless, complex models with multiple variables are scarce,[23,25,46] indicating the need for more research in this field. In this sense, the model created could have significant value for healthcare professionals in primary care. This model could provide an effective tool for preventing cardiac modifications in 1 out of 4 children, helping to avoid excess adiposity and allowing for early detection of such changes among children or preadolescents.

Even though this research has highlighted some interesting findings, there are some limitations. First, the sample was homogeneous and focused on children from southern Spain who were mainly Caucasian; therefore, the findings should not be applied to other ethnic groups or adolescents. Additionally, the data indicated that BP and BMI were relevant to EAT thickness, and BMI in the model had a predictive factor lower than desirable. Moreover, the model is theoretical, which implies the need for further validation before it can be applied in healthcare or other fields.

Despite these limitations, the implications of this paper are exciting since the study explored associations with more variables (i.e., FF%, BMI, or EAT thickness) in a broader sample of children and conducted a more in-depth analysis resulting in a predictive model. Moreover, the findings may help healthcare workers understand the implications of overweight and obesity and the possible use of noninvasive screening instruments such as BMI, sex, and age to determine EAT thickness. Additionally, the differences regarding the EAT measures (short, long, and global) and sex, BP, and obesity prediction could be highly relevant for physicians since the EAT thickness (short for girls or long for boys and global for both sexes) should be measured, instead of using the long axis for both sexes which is more is most likely to be used. Finally, it would be necessary to assess whether these findings are significantly associated with future events and whether an intervention in this population can reverse the high prevalence of these modifiable cardiovascular risk factors and prevent future events.

CONCLUSIONS

In summary, the findings indicated a high rate of overweight and obesity, with high values of various measurements. Additionally, there were associations between cardiovascular risk factors, mainly high weight and BP, and greater EAT thickness. Finally, a model that explained one out of four children was obtained, which could be useful in the future, although it requires further research.

DATA AVAILABILITY

The datasets analyzed during the current study are not publicly available due to the inclusion of personal details, identification numbers from the health care system, and further data for future research. Still, they are available from the corresponding author on reasonable request

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Conceptualization, I.M.B.S., F.J.F.P., and M.D.M.R.; methodology, I.M.B.S., F.J.F.P., and M. D.M.R.; validation, I.M.B.S., FJ.F.P., and P.A.-M.; formal analysis, P.A.-M., M.R.O., I.M.B.S., and M.D.M.R.; investigation, I.M.B.S., C.H.A.-D., J.F.C.; resources, I.M.B.S., C.H.A.-D., J.F.C., FJ.F.P., and M.D.M.R.; writing—original draft preparation, P.A.-M., FJ.F.P., and I.M.B.S.; writing—review and editing, P.A.-M., M.R.O., FJ.F.P., and I.M.B.S.; supervision, FJ.F.P. and M.D.M.R. All authors have read and agreed to the published version of the manuscript.

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