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RESEARCH

Mediating role of organized sports participation on the relationship between body fatness and arterial wall thickness among adolescents: ABCD Growth Study

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Abstract

Background Participation in sports is the main manifestation/subdomain of physical exercise in adolescents and affects cardiovascular health in different ways.

Objectives To analyze the relationship between body fatness and arterial wall thickness as well as the mediating role of sports participation in this relationship among adolescents.

Methods This cross-sectional study is linked to the ABCD-Growth Study conducted in Presidente Prudente, Brazil. The study sample included 402 adolescents (275 boys and 127 girls) aged 11–17 years recruited from schools (non-sport group) and sports clubs (sports group). Sex-stratified multivariate model was created using structural equation modelling (SEM) with carotid (CIMT) and femoral arterial wall thickness (FIMT) as dependent variables were assessed by an ultrasound device. Body fatness percentage (BF) as the independent variable and was assessed by whole-body dual-energy X-ray absorptiometry, and sports participation as a moderator was assessed by face-to-face interviews. The maturity offset and dyslipidemia were treated as confounders in the mediation models.

Results In girls, body fatness was positively associated with FIMT ($r = 0.210$ [95%CI: 0.035; 0.372]) but not with CIMT ($r = -0.148$ [95%CI: -0.314; 0.027]), whereas sports participation was not associated with vascular structure. In boys, body fatness was inversely related to CIMT ($r = -0.285$ [95%CI: -0.390; -0.172]) and positively to FIMT ($r = 0.129$ [95%CI: 0.011; 0.244]), whereas sports participation was inversely related to FIMT ($r = -0.142$ [95%CI: -0.256; -0.024]). Among boys, sports participation mediated 7.4% of the relationship between body fatness and FIMT, and the association between body fatness and FIMT remained significant ($r = 0.168$ [95%CI: 0.037; 0.299]).

Conclusions Sports participation mediates the relationship between BF and arterial thickness in adolescent boys.

Keywords Risk factors, Adiposity, Physical activity, Adolescents

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Introduction

Obesity is a common risk factor for several chronic diseases including dyslipidemia, hypertension, and metabolic syndrome [1–3]. Excessive adipose tissue increases systemic low-grade inflammation [1, 4], which can lead to higher blood pressure and arterial wall damage via the production of subendothelial atheroma plaques and remodeling of large arteries, increasing the risk of cardiovascular complications [5]. Anthropometric indexes have been widely used in clinical practice and research to estimate body adiposity, overweight, and obesity. However, the ability of those indexes to accurately assess adiposity has been criticized [6]. Although dual-energy X-ray absorptiometry (DEXA) is more expensive and is not commonly available in clinical settings, it is a relatively precise method for assessing body fat percentage [7].

Although obesity results in a significant increase in arterial wall thickness in early life [8, 9], lifestyle factors such as physical activity may influence arterial wall thickness throughout adolescence [10, 11]. The impact of physical activity on the vascular structure of adolescents is complex and depends on the characteristics of physical activity and the arterial wall being considered. For instance, evidence suggests that the volume of physical activity (number of daily steps) is less relevant to arterial wall thickness than adiposity among adolescents [12]. Organized sports are characterized by activities that follow specific rules (including formal practice and competition) and they account for a substantial proportion of moderate-to-vigorous physical activity in children and adolescents [13], positively influencing body composition and other health outcomes [14].

Sports participation (the most common manifestation of vigorous physical activity among adolescents [15–18]) can modify the relationship between obesity and cardiovascular outcomes by reducing low-grade inflammation and arterial thickening in adolescents [12]. Moreover, arterial wall thickness is commonly assessed as the intima-media of the carotid artery (CIMT), with the femoral intima-media thickness (FIMT) being less explored in the literature. Such an aspect seems relevant because FIMT has increased oscillation in wall shear rates compared to other arteries, increasing the propensity for atherosclerotic events [19], and seems to be more affected by physical exercise among adolescents [11]. In this way, it makes more sense to observe FIMT in adolescents because its shear rate pattern is different from that of other arteries, indicating that adaptation may occur at this specific site [20].

In adults, CIMT is related to the percentage of body fat, suggesting that reducing body fat can reduce the thickness of the carotid artery and risk factors related to cardiovascular diseases, such as the risk of stroke [21]. The consistent impact of adipose tissue on vascular structure among adults is widely recognized in the literature, but its impact on vascular structure during human growth is not entirely clear, especially because maturational and behavioral variables also affect this phenomenon. In young people, an increase in arterial thickness over the years has already been established as a future marker of cardiovascular outcomes and mainly predicts the subclinical development of atherosclerosis [22]. The carotid artery is affected by elevated body weight and blood pressure, which, when increased, could signify arterial remodeling as reflected by an increased CIMT in younger individuals. In contrast, the femoral artery intima-media thickness (IMT) is primarily influenced by blood pressure and factors related to body growth, suggesting that individuals during the maturation process, the femoral artery adapts in response to vascular and physiological changes [23]. Thus, in adolescents, the shear indices may still be different owing to differences in the changes of both arteries throughout life [11].

Thus, this study aimed to analyze the relationship between body fatness and arterial wall thickness as well as the mediating role of sports participation in this relationship among adolescents.

Methods

Sampling and inclusion criteria

This cross-sectional study is part of an ongoing study entitled "Analysis of Behaviors of Children During Growth" (ABCD– Growth Study), which is being conducted in the city of Presidente Prudente (~200,000 inhabitants), western State of São Paulo. Data collection and analyses were performed by researchers at the Laboratory of InVestigation in Exercise (LIVE), which is part of the Department of Physical Education at UNESP, campus of Presidente Prudente.

The ABCD Growth Study is a pragmatic trial that assesses adolescents annually. More details regarding the sampling process can be found in previous publications [24]. Briefly, adolescents were contacted by researchers in 11 schools and sports clubs located in the metropolitan region of the city after the authorization of principals and coaches, respectively. Initially, all adolescents received detailed information about the objectives, procedures, and inclusion criteria adopted in the ABCD Growth Study. Adopted inclusion criteria were as follows: (1) being 11–17 years old; (2) parents' signed consent form; (3) adolescents in the "sports group" were recruited in sports clubs and at least one year of training experience in such sport was required for these adolescents; adolescents in the "non-sport group" were recruited in school units and at least one year of no regular practice of organized sports and exercise was required for these adolescents; and (4) absence of orthopedic diseases limiting physical activity. Adolescents who both agreed to participate (providing the written assent form properly signed) and fulfilled all the inclusion criteria were contacted by phone to schedule interviews at the university facilities. The adolescents were contacted to arrange a visit to the university, where researchers conducted face-to-face interviews, anthropometric measurements, body composition assessments, and ultrasound evaluations.

In 2017, 285 adolescents were assessed and 193 were reassessed in 2018. In 2018, 117 adolescents entered the ABCD Growth Study dataset as baseline measurements. This study used a cross-sectional dataset (baseline); thus, the dataset comprised 402 adolescents evaluated in 2017 ($n=285$) and 2018 ($n=117$). The sample of 402 adolescents granted statistical power of 80% and a significance level of 0.05 (Z = 1.96) to detect significant correlations of small magnitude (≥ 0.140) [25]. Such magnitude is smaller than the observed in previous studies assessing the relationship of sports participation with CIMT ($r=0.214$) and FIMT ($r=0.299$) [26, 27], denoting sufficient power to assess the relationships considered in this manuscript.

Ethical approval

All methods were carried out following relevant guidelines and regulations along with an ethical approval statement and informed consent to participation according to the Declaration of Helsinki. Ethical approval was obtained from the Ethics Research Committee of the Sao Paulo State University (process number: 1.677.938/2016 and Process number 02891112.6.0000.5402), the campus of Presidente Prudente, State of São Paulo, Brazil. Adolescents whose parents / legal guardians provided signed informed consent were eligible for participation. A letter with information about the study was provided to participants and was explained to eligible participants by trained researchers. Adolescents could at any time quit the study without negative consequences. There were no incentives for participation.

Outcome: arterial wall thickness

CIMT and FIMT were assessed on the same day using an ultrasound device (Figlabs, model FP 102, Brazil) equipped with a high-resolution, multi-frequency linear transducer, set to 12 MHz. When the common carotid artery was tested, the right neck was slightly hyperextended and inclined at an angle of 45°. For the femoral artery, the adolescent's right leg was stretched out on the bed and the measurement was conducted near the inguinal line. A trained researcher completed all the measurements according to the guidelines proposed by the Brazilian Society of Cardiology [28, 29]. CIMT and FIMT were expressed in millimeters (mm). The ultrasound device automatically calculated the resistance index (RI).

Exposures: body fatness

BF was estimated using whole-body dual-energy X-ray absorptiometry (General Electrics brand, Lunar DPX-NT) and analyzed using GE Medical System Lunar software, version 4.7. The device has been calibrated according to manufacturer guidelines. During the examination, the participants remained barefoot in the supine position and in light clothing with no metal object close to the body. The test lasted approximately 15 min, and the radiation dose was not harmful to health (less than 0.05 mrem) [30–32].

Meditators: sports participation

Sports participation was assessed by face-to-face interviews, and the sports considered were baseball, basketball, judo, karate, kung-fu, gymnastics, swimming, tennis, and track and field. Adolescents were recruited at sports clubs, and coaches provided additional data on their sports participation (previous time of engagement, number of days practicing per week, and time per day of practice). The "non-sport group" was composed of adolescents who were recruited in school units and declared no engagement in any routine of exercise over the last one year, except in physical education classes which happen 1–2 days/week, being mandatory to all Brazilian students. For statistical purposes, sports participation was coded as 0 = non-sports and 1 = sports participation.

Confounders

Members of the research team were previously trained to carry out face-to-face interviews with the adolescents. The interviews were conducted in a quiet room in the university, and the adolescents reported their chronological age, sex, and previous experience in organized sports. Anthropometric measures were taken immediately after the interviews. Somatic maturation was estimated as the peak height velocity based on anthropometric measurements using the following formula [33]: Years from PHV for boys (maturity offset) = – 8.128741 + (0.0070346 * [Age * Sitting Height]) and years from PHV for girls (maturity offset) = – 7.709133 + (0.0042232 * [Age * Height]). These equations determine whether the adolescent reached (positive values) or did not reach (negative values) maturity offset.

Blood sampling was performed in a private laboratory that has all the certifications of the Brazilian Ministry of Health [34]. Blood samples were collected with the patient sitting comfortably, with the arm supported and elbow straight, and fasting venous blood (10 mL) was drawn from the elbow crease in the morning by a trained nurse after 12 h of nocturnal fasting. Serum blood samples were used to measure high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), total cholesterol (TC), triacylglycerol (TG), and glucose levels. For statistical purposes, the dyslipidemia Z-score was created by converting the values of lipids of our adolescents (HDL-c, LDL-c, TG, and TC) into standardized Z-score values ([individual value – group mean] / group standard deviation) and summed to generate a single indicator of dyslipidemia as described in a previous study [35]. In the z-score calculation, HDL-c values were multiplied by -1 to follow the same clinical interpretation as the other variables (higher values indicate greater damage to health).

Statistical analyses

Descriptive statistics included mean values, standard deviation, and 95% confidence intervals (95%CI). Student's t-tests for independent samples were used to compare the metabolic and cardiovascular aspects according to sports participation. Sex-stratified multivariate models were created using Structural Equation Modeling (SEM), which requires the prior definition of dependent variables (CIMT and FIMT) as independent variables (body fatness), the variable of mediation (sports participation), and confounders (maturation and Z-score of dyslipidemia). As a mandatory assumption, SEM was run only when dependent, independent, and mediation variables were significantly related to each other. Measures of effect size were expressed using standardized coefficients (correlation coefficients [r]) and 95% confidence intervals (95%CI). Analyses were performed using the Stata software (version 17.0). Statistical significance was set at 5% (p-value < 0.05).

Results

The final sample comprised 275 boys and 127 girls, aged 11–17 years. Individuals participating in sports reported engaging in sports for 4.2 (1.7) days per week, spending 141.6 (69.5) minutes per session, and having 61.8 (37.7) months of previous involvement in sports. Adolescents engaged in sports were two years younger (p-value = 0.001), less mature (p-value = 0.001), and presented lower body fatness (p-value = 0.026) than adolescents not engaged in sports (Table 1). In terms of metabolic aspects, adolescents engaged in organized sports exhibited higher TC (p-value = 0.046), LDL-c (p-value = 0.004), and glucose (p-value = 0.001) levels than those adolescents not engaged in organized sports. Adolescents who were not engaged in organized sports had higher DBP (p-value = 0.008), FIMT (p-value = 0.006), and TG (p-value = 0.037) than their peers engaged in sports.

Among girls, body fatness was positively associated with FIMT (r = 0.210 [95%CI: 0.035; 0.372]; p-value = 0.019) but not with CIMT (r= -0.148 [95%CI: -0.314; 0.027]; p-value = 0.097), whereas sports participation was not associated with vascular structure (Table 2). In boys, body fatness was inversely related to CIMT (r= -0.285 [95%CI: -0.390; -0.172]; p-value = 0.001) and positively to FIMT (r = 0.129 [95%CI: 0.011; 0.244]; p-value = 0.032), whereas sports participation was inversely related to FIMT (r= -0.142 [95%CI: -0.256; -0.024]; p-value = 0.019).

In both sexes, CIMT and sports participation were not associated, and thus, mediation analyses were not conducted. Moreover, FIMT and sports participation were not associated among girls, and therefore, the criteria for mediation analysis was not met. Among boys (Fig. 1), sports participation mediated 7.4% of the relationship

Table 1 Characteristics of sample

	Non-sport group (n = 135)	Sports group (n = 267)	p-value
	Mean ± SD	Mean ± SD	
Boys/Girls	88/47	187/80	
Chronological age (years)	15.7 ± 2.0	13.7 ± 2.1	0.001
Body weight (kg)	60.2 ± 13.5	57.4 ± 16.0	0.079
Height (cm)	166.9 ± 11.1	164.6 ± 12.9	0.080
Maturity offset	2.1 ± 1.6	0.6 ± 1.8	0.001
BF (%)	25.5 ± 13.4	22.5 ± 11.0	0.026
Metabolic aspects			
TC (mg/dL)	138.1 ± 24.2	143.8 ± 28.6	0.046
HDL-c (mg/dL)	52.9 ± 13.3	52.0 ± 11.5	0.525
LDL-c (mg/dL)	68.9 ± 21.5	76.3 ± 23.6	0.004
TG (mg/dL)	80.2 ± 52.1	71.2 ± 30.8	0.037
Glucose (mg/dL)	80.9 ± 7.1	85.4 ± 9.6	0.001
Dyslipidemia $_{Z\ score}$	-0.581 ± 2.9	0.276 ± 2.6	0.005
Cardiovascular aspects			
SBP (mmHg)	113.3 ± 15.6	111.6 ± 11.7	0.225
DBP (mmHg)	64.4 ± 9.5	61.9 ± 6.6	0.008
CIMT (mm)	0.505 ± 0.084	0.513 ± 0.094	0.435
FIMT (mm)	0.482 ± 0.072	0.460 ± 0.081	0.006

SD: standard deviation; BF: body fatness; TC: total cholesterol; HDL-c: high-density lipoprotein-cholesterol; LDL-c: low-density lipoprotein-cholesterol; TG: triglycerides; SBP: systolic blood pressure; DBP: diastolic blood pressure; CIMT: carotid intima-media thickness; FIMT: femoral intima-media thickness

Table 2 Correlation between sports participation and body fatness with arterial thickness

	Girls (n = 127)		Boys (n = 275)	
	r (95%CI)	p-value	r (95%CI)	p-value
Sports participation				
CIMT (mm)	0.010 (-0.164 to 0.184)	0.908	0.038 (-0.081 to 0.156)	0.535
FIMT (mm)	-0.108 (-0.278 to 0.069)	0.232	**-0.142 (-0.256 to -0.024)**	0.019
Body fatness (%)				
CIMT (mm)	-0.148 (-0.314 to 0.027)	0.097	**-0.285 (-0.390 to -0.172)**	0.001
FIMT (mm)	**0.210 (0.035 to 0.372)**	0.019	**0.129 (0.011 to 0.244)**	0.032

95%CI: 95% confidence interval; CIMT: carotid intima-media thickness; FIMT: femoral intima-media thickness. Sports participation was coded as 0 = non-sports and 1 = sports participation. Statistically significant values (p < 0.05) are given in bold

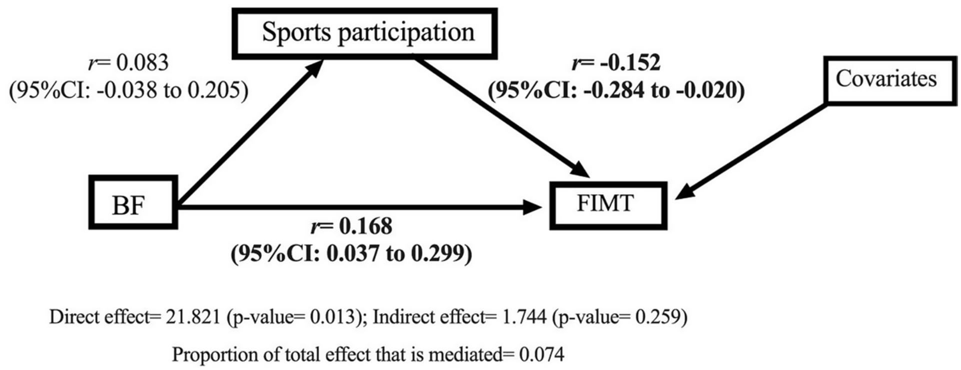

Fig. 1 Mediation analysis of sport participation between the relationship of BF and arterial thickness among boys. Notes: 95%CI: 95% confidence interval; BF: body fatness; CIMT: carotid intima-media thickness; FIMT: femoral intima-media thickness. Adjusted by maturity offset and dyslipidemia $_{Z\ score}$. Sports participation was coded as 0 = non-sports and 1 = sports participation. Statistically significant values ($p < 0.05$) are given in bold

between body fatness and FIMT, and the association between body fatness and FIMT remained significant ($r = 0.168$ [95%CI: 0.037; 0.299]).

Discussion

In our cross-sectional study considering adolescents of both sexes, we investigated the mediating role of sports participation in the relationship between adiposity and arterial thickness. The main findings were that sports participation during adolescence is related to lower femoral arterial wall thickness, mediating the association between adiposity and arterial wall thickness in boys, but not girls. These findings suggest that regular participation in sports during adolescence can reduce the negative effects of excess body fatness on the vascular health in boys, probably by enhancing cardiovascular risk factor levels, lowering inflammation, and decreasing body fatness [11, 36–38].

In the respective sample, the adolescents involved in sports participation were younger and less mature [39]. Adolescents start participating in sports under the influence of family, friends, and information provided by the media, which can be in schools, sports clubs, in the community, and through private programs [40]. These adolescents engaged non-professionally in sports, do not usually adapt the intake or quality of their food choices to the demands of training load or different training sessions, which may explain why these adolescents engaged in sports had unfavorable lipid profiles compared to their peers not engaged in sports [41]. Apparently, in more competitive/professional settings, adolescents who participate in sports tend to adopt healthier dietary habits, including a higher intake of fruits and vegetables, as well as more regular meal patterns [42]. However, some studies suggest that there is a risk of disordered eating behaviors, especially in weight-sensitive sports [43, 44].

Participation in organized sports among boys is linked to healthier vascular structures, which include reduced thickness of the femoral and carotid intima-media [11, 38]. Biological and physiological differences between the sexes, such as hormonal influences, cardiac size, and vascular function, lead to distinct cardiovascular adaptations to physical activity [45, 46]. Females generally show a lower stroke volume, reduced vasoconstriction, and different cardiac remodeling compared to males [47]. Moreover, due to reproductive purposes, in the human species the expansion of adipose tissue is different between boys and girls [33, 45]. Such characteristics may help to explain the sex-dependent findings of our study.

Previous studies indicate an inverse association between body fat and CIMT in obese boys, as metabolism markers are connected to lower CIMT [48]. Fat-free mass is positively associated with CIMT, whereas fat mass shows either a negative association or no significant relationship with CIMT, suggesting that CIMT may indicate vascular remodeling rather than atherosclerosis [22, 49].

The mediation analysis indicated that in male adolescents who engaged in sports had lower values for the relationship between body fat and femoral arterial thickness. Considering this finding, the detrimental impact of body adiposity on arterial thickness [5, 8] may be boosted by the absence of sports participation, whereas engagement in sports seems to reduce the negative impact of adiposity on the arterial wall in adolescents [50]. The role of sports participation in this phenomenon seems to rely on its anti-inflammatory properties [51]. Adiposity exacerbates low-grade inflammation and higher infiltration of lipids in the subendothelial space, which may increase the risk of metabolic diseases and is a predictor of ischemic events, and sports practice may be inversely related to low-grade inflammation, characterizing it as a potential protective factor [51]. Moreover, the observed small magnitude of the mediation analysis might be attributed to the fact that other variables related to sports participation were not controlled (e.g., intensity, frequency, daily amount), while other relevant actors were also not included in our model (e.g., low-grade inflammation and cytokines).

Individuals with cardiovascular disease usually have greater CIMT, with a linear relationship between advancing age and CIMT [52]. Men have higher risk factors for coronary heart disease throughout their lives and, therefore, a greater chance of developing atherosclerotic plaques compared to women [53]. In the pediatric population with overweight/obesity, there are differences between the sexes in terms of body measurements, metabolic abnormalities, and the amount and thickness of adiposity [54]. The characteristics of boys include thicker intima and media layers in childhood, possibly explaining the earlier cardiovascular outcomes in men than in women [53]. In prepubertal children, the femoral artery is widely evaluated, suggesting that it is affected by factors such as obesity, insulin resistance, and lack of physical activity, increasing arterial stiffness and vascular injury; however, in older individuals, in the femoral artery, these factors contribute to increased arterial stiffness and vascular damage due to aging and previous medical interventions [55].

The present study revealed a relationship between femoral arterial thickness, but not carotid artery thickness, and body fatness. This finding is different from what has been observed in studies on adults, in which the carotid artery is the most assessed artery. Differences in CIMT and FIMT could be attributed to the caliber of the femoral artery, which has a smaller diameter than the carotid artery, leading to higher shear stress caused by the higher oscillations in blood flow than the other arteries [5, 51]. Another point to note is that the carotid artery is responsible for consuming nutrient-rich blood to the brain, while the femoral artery takes it to the lower limbs, which are used during exercise [56]. In studies of flow-mediated dilation, physical activity/training interventions improved endothelium-dependent vasodilator function in adults [57]. Our findings highlight the relevance of considering different vascular walls in the screening of cardiovascular health in pediatric groups.

An unexpected finding was the negative relationship between body fatness and CIMT in boys. This relationship seems to be based on the divergent impact of age on both variables. Among boys, age was inversely related to adipose tissue (-0.308 [95%CI: -0.411 to -0.196]), positively related to carotid resistance index (0.251 [95%CI: 0.136 to 0.359]), and marginally related to CIMT (0.104 [95%CI: -0.015 to 0.220]). Therefore, in our sample, older male adolescents tended to have lower adiposity (owing to biological maturation) and higher CIMT. Inflammation and adipose tissue, particularly epicardial adipose tissue, play a significant role in arterial thickness and dysfunction [8]. This effect is driven by cytokine secretion, adipocyte hypertrophy, and oxidative stress, all of which are exacerbated by obesity and metabolic disorders [58, 59]. To get a clearer picture of this pathophysiological process, further studies should investigate the impact of both different ages and other types of physical activity on arterial structure. Traditionally, risk factors (blood lipids) increase arterial dysfunction/remodeling, but here, even with higher lipid values, participation in sports protects adolescents. This study highlights the significance of engaging in regular sports participation as an essential preventive approach for managing cardiovascular risk factors linked to elevated body fat in youth. By focusing on this monitoring, we can enhance long-term cardiovascular health outcomes for young individuals.

This study has some limitations. First, sampling was based on sports clubs of the metropolitan area; thus, caution is necessary regarding inferences to school adolescents from the whole city. Second, parameters of sports participation were not monitored (e.g., intensity, frequency, daily amount, and previous time of engagement), limiting the understanding of the pathways by which sports participation mitigates the harmful impact of adipose tissue on arterial thickness or its independent associations over overall physical activity. Third, the absence of additional data about the pathways by which adipose tissue affects arterial thickness should be considered (e.g., inflammatory markers and cytokines). Fourth, we focused solely on organized sports and physical education classes, while physical activity outside sports participation was not controlled. Such an aspect limits a deep understanding of the impact of other non-organized and sporadic activities on our findings. Thus, future studies should consider these variables in their models to explore the pathways linking adiposity and participation in sports.

This study has several strengths. First, adiposity was assessed using DEXA, which is an accurate method for estimating body fatness, while most studies running similar models have their measures of adiposity relying on anthropometric indexes. In large populations, future studies should investigate the cost-effectiveness of combining methods, such as anthropometric measures for screening and DEXA for in-depth analysis in subsets of the population. Second, our models were adjusted by biological maturation and a thorough assessment of blood markers (a methodological aspect not covered by many similar studies [5, 11, 51]).

Conclusion

Sports participation mediates the relationship between adipose tissue and arterial thickness in boys.

Abbreviations

95%CI 95% confidence interval
ABCD Analysis of behavior of children during growth

BF	Body fatness
CIMT	Carotid intima-media thickness
DEXA	Dual-energy x-ray absorptiometry
FIMT	Femoral intima-media thickness
HDL	High-density lipoprotein
LDL	Low-density lipoprotein
LIVE	Laboratory of InVestigation in Exercise
PHV	Peak height velocity
RI	Resistance index
SEM	Structural equation modelling
TC	Total cholesterol
TG	Triacylglycerol
UNESP	São Paulo State University

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Author contributions
WT, and RAF were responsible for the study concept, design, and ethics applications. SMV, and JBU were involved in the conception, data collection, made substantial contributions to the analysis and interpretation of data and revising it critically for important intellectual content; DRPS, RSO, and EAH made substantial contributions to the conception and acquisition of data and analysis and interpretation of data and was involved in revising it critically for important intellectual content. All authors understand that they are accountable for all aspects of the work and ensure the accuracy or integrity of this manuscript.

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Data availability
The authors store the data collected and analyzed during this study upon authorization by the first author (Wésley Torres) or the leader (Rômulo Araújo Fernandes) of the Laboratory of InVestigation in Exercise (LIVE), which involves the ABCD Growth Study. The data that supports the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
All methods were carried out following relevant guidelines and regulations along with an ethical approval statement and informed consent to participation according to the Declaration of Helsinki. The study was approved by the Ethics Research Committee of the Sao Paulo State University (process number: 1.677.938/2016 and Process number 02891112.6.0000.5402), Campus of Presidente Prudente. Informed consent was obtained in writing from all individual participants included in the study and their parents or legal guardians. The data used and/or analyzed in the present study are not publicly available due to ethical restrictions related to the consent provided by participants. An ethically compliant dataset may be made available by the corresponding author upon reasonable request and upon approval by the Ethics Research Committee of the São Paulo State University.

Informed consent
Informed consent was obtained from all subjects involved in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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