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ORIGINAL RESEARCH

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Added sugar and trans fatty acid intake and sedentary behavior were associated with excess total-body and central adiposity in children and adolescents with congenital heart disease

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Abstract

Background: Over the past three decades, the prevalence rate of overweight and obesity has increased in survivors with congenital heart disease, and little is known about the body composition and its association with clinical characteristics and lifestyle factors.

Objectives: To evaluate excess total-body adiposity and central adiposity and, to describe associated factors.

Methods: Cross-sectional study with children and adolescents who underwent procedure to treat congenital heart disease, from January to July 2017. Sociodemographic and clinical characteristics, and lifestyle factors (dietary intake, physical activity, and sedentary behavior) were assessed. Adiposity was assessed using air-displacement plethysmography and waist circumference. Factors associated with excess total-body adiposity and central adiposity were analyzed using logistic regression models.

Results: Of 232 patients, 22.4% were identified with excess total-body adiposity and 24.6% with central adiposity. Significant factors positively associated with excess total-body adiposity were intake of added sugar and trans fatty acids, adjusted for confounding factors. Similarly, lifestyle factors were positively associated with central adiposity: intake of added sugar and trans fatty acids, sedentary behavior, and family history of obesity.

Conclusions: Lifestyle factors were associated with excess total-body adiposity and central adiposity. Assessment of body composition and healthy-lifestyle counseling into outpatient care may be the key point to prevent obesity in children and adolescents with congenital heart disease.

KEYWORDS
Body fat, congenital heart disease, diet, lifestyle, obesity, pediatrics, waist circumference

1 | INTRODUCTION

Obesity in childhood and adolescence is a public health concern, since its prevalence has increased in the past four decades.[1] Moreover, childhood obesity tends to remain into adulthood and is considered an important risk factor for dyslipidemia, hypertension, diabetes mellitus, and cardiovascular diseases.[2] The effect of obesity on cardiovascular health may be particularly harmful in survivors with congenital heart disease, since, it is recognized that children and adolescents with congenital heart disease can develop overweight and obesity over time.[3]

There are unique risk factors for obesity that affect children and adolescents with congenital heart disease, as such, the perception by their families as vulnerable and are overprotected, the encouragement increased caloric intake even after reaching the adequate weight,[4] physical activity restrictions result of the beliefs that physical activity may lead "stress" in heart,[3,5] and unique clinical characteristics (eg, abnormal coronary artery anatomy, inflammation from cardiac procedure, cyanosis and reperfusion injuries, and altered hemodynamic from underlying anatomic abnormalities).[6] Thus, these unique risk factors may contribute to higher risk for obesity and acquired cardiovascular disease in this population. A cohort study from the *German National Register for Congenital Heart Defects* has confirmed that adults with congenital heart disease have a higher risk of mortality from acquired cardiovascular disease than the general population.[7] In addition, a report shows concern about the association between congenital heart diseases, obesity, and acquired cardiovascular disease in children and adolescents.[8]

The prevalence of overweight and obesity, assessed by body mass index (BMI) for age, range from 7.6% to 33% in children and adolescents with congenital heart disease.[9-11] However, BMI does not distinguish between lean and fat body mass, and no study has investigated objectively body fat in children and adolescents with congenital heart disease. Thus, alternative methods with higher accuracy may be useful for early detection of obesity in children and adolescents with congenital heart disease, considering the association between body fat percentage and cardiometabolic markers.[12] Air displacement plethysmography shows accuracy and validity method to assess body fat percentage in children and adolescents.[13] Furthermore, waist circumference, a simple and low-cost measurement for analyzing excess abdominal fat, which characterizes central adiposity, is considered also an important risk factor for cardiovascular diseases.[14]

Moreover, children and adolescents with congenital heart disease may have additional risk factors for obesity. A longitudinal study has shown that postoperative body weight and physical activity restrictions were associated with an increased risk of obesity, which can be associated with an increased risk of acquired cardiovascular disease and early mortality.[3] Nevertheless, other studies reported no association between obesity and clinical characteristics of congenital heart disease.[9,10,15] Despite this, no investigation has explored an association of traditional risk factors for obesity, as dietary intake and sedentary behavior with objective body fat measurement using air-displacement plethysmography in children and adolescents with congenital heart disease.

Identifying the risk factors to excess total-body and central adiposity may assist in strategies in primary prevention for acquired cardiovascular disease in survivors with congenital heart disease.[8] Therefore, the aims of this study were to evaluate excess total-body adiposity and central adiposity, and to describe associated factors with excess total-body adiposity and central adiposity in children and adolescents with congenital heart disease. In the present study, we hypothesized that traditional risk factors for obesity are associated with a higher risk of excess total-body adiposity and central adiposity, whereas clinical characteristics of congenital heart disease are not in children and adolescents with congenital heart disease.

2 | POPULATION AND METHODS

2.1 | Study design and patients

A cross-sectional study was carried out among children and adolescents, who underwent surgery or interventional catheterization for congenital heart disease, attended in the outpatient care of two referral hospitals in southern Brazil, from January to July 2017.

Inclusion criteria were as follows: (a) children and adolescents with congenital heart disease, who underwent surgery or interventional catheterization for congenital heart disease; (b) age between 5 and 18 years. Exclusion criteria were as follows: (a) those with clinical conditions that interfere with the anthropometric assessment, (b) the presence of genetic syndromes, and (c) the presence of chronic or acute inflammatory disease 15 days prior to the assessment, on the basis of C-reactive protein level and patient's medical record. The presence of genetic syndrome was also assessed by patient's medical records.

This study was approved by the Ethics Committee for Human Research at the Federal University of Santa Catarina (No. 1.672.255/2016). Informed written consent was obtained from the parents or guardians of the patients. Children and adolescents gave their assent to participate in the study.

3 | OUTCOMES

3.1 | Excess total-body adiposity

Fat mass percentage was estimated using air-displacement plethysmography (BodPod Body Composition System; COSMED, California, USA), following procedures and calibrations according to the manufacturer.[16] If necessary, ergonomic seat and calibration cylinder with a volume of 19.345 L for children under 12 kg (Pediatric OptionTM accessory, COSMED, California, USA) were used. Patients were evaluated wearing a swimming suit and swimming cap to minimize the effects of volume in the air displacement analysis. The air-displacement plethysmography is a valid and reliable method to measure body composition.[17] Also, the air-displacement plethysmography is easy-to-apply, noninvasive, safe, and accurate to determine body fat in children and adolescents.[13] The fat mass percentage was calculated based on weight and volume obtained with the air-displacement plethysmography and using child-specific equation proposed by Lohman.[17] Excess total-body adiposity was defined as fat mass percentage above the 85th centile using body fat reference curves for children.[18]

3.2 | Excess central adiposity

Central adiposity was determined by waist circumference measured with an inelastic tape with an accuracy of 0.1 cm (TBW, São Paulo, Brazil) at the superior border of the right iliac crest at the end of a normal expiration, by a single trained dietitian, and classified as excess central adiposity when ≥75th percentile.[19]

4 | EXPOSURE

4.1 | Socio-demographic characteristics

Age, sex, and per capita income (based on the Brazilian minimum wage, sum of all resident's income divided by the number of residents at same household) were obtained.

4.2 | Clinical characteristics

Clinical characteristics related to the congenital heart disease were evaluated based on congenital heart disease diagnosis (if cyanotic or acyanotic),[20] complexity (if simple, moderate or complex),[21] type of cardiac procedure (interventional cardiac catheterization and cardiac surgery), and postoperative time of surgery or interventional catheterization (if ≤1 year or >1 year) were obtained. Positive family history for obesity was also evaluated. BMI for age and percentile were calculated using the software WHO Anthro Plus. Overweight and those with obesity were classified as BMI for age > 85th percentile[22]

4.3 | Lifestyle factors

4.3.1 | Dietary intake

The usual dietary intake was assessed using three nonconsecutive 24-hour recall (two weekdays and one weekend day), using multiple-pass method,[23] and photographic album to assist in reporting portion sizes of food intake. The first 24-hour recall was applied in data collection and the subsequent ones, in weeks following data collection by telephone (mean time interval between the first and last 24-hour recall was 7.3 weeks [SD of 3.21]). Dietary intake was estimated using the Nutrition Data System for Research (NDSR) grad pack 2017 (NCC Food and Nutrient Database, University of Minnesota, Minneapolis, MN, USA). Because the software is North American and uses the United States Department of Agriculture (USDA) database, before entering the 24-hour recall data in the NDSR software, based on the Brazilian charts, nutritional equivalences of the foods available in the software were checked,[24,25] as well as standard Brazilian typical recipes were manually inserted into the software. For entering the 24-hour recall data in the NDSR software, the standardized methodological for dietary intake assessment was used. Several studies that evaluated food intake in Brazil have used NDSR to assess dietary intake[26-29] To adjust dietary intake for intra-and-interpersonal variability with the intention to reduce information bias (adjusting variability for day of the week, sex, age, mother's education, BMI, and per capita income) and to estimate individual's usual food intake, it was used the method developed by the Iowa State University.[30] Moreover, all nutrients were adjusted for total energy.[31] The variables assessed in the current study were average energy (kcal/d), carbohydrate, total fat, saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, trans fatty acids (% of energy), protein (g/kg/d), sodium and cholesterol (mg/d), and total fiber and added sugar (g/d) intakes.

4.3.2 | Physical activity

Physical activity was assessed using the Physical Activity Questionnaire for Children (PAQ-C). This questionnaire considers the practice of physical activity in the last 7 days and classified as insufficiently active (one to three scores) or active (four to five scores).[32]

4.3.3 | Sedentary behavior

Sedentary behavior was assessed by hours of inactive activities, such as hours concerning leisure in front of the television, computer/similar and/or in electronic games plus sitting time per day. Sedentary behavior was considered those who spend over 8 hours with inactive activities per day.[33]

4.4 | Statistical analysis

Sample size was calculated using the OpenEpi (Atlanta, Georgia, United States), accepting a type 1 error (α) of 0.05, the type 2 error (ß) of 0.20, and 95% confidence interval (CI). Based on the prevalence of 26.9% of obesity assessed by BMI in children and adolescents with congenital heart disease[9] this study needed 110 patients.

The normality was evaluated with the Kolmogorov-Smirnov test, histograms, and coefficient of variation. Descriptive data were expressed as mean, SD (SD) or median, and interquartile range (IQR) for continuous variables or as proportions for categorical variables. In addition, to check the differences in dietary intake between the classification of excess total-body adiposity and central adiposity, the

TABLE 1 Socio-demographic, clinical characteristics, and sedentary behavior

	Total n = 232	*Excess Adiposity*[a] Absence n = 172 (74.1%)	Presence n = 52 (22.4%)	Central Adiposity[b] Absence n = 170 (73.3%)	Presence n = 57 (24.6%)
	n (%)	n (%)	n (%)	n (%)	n (%)
Sex					
Female	122 (52.6)	100 (58.1)	21 (40.4)	84 (49.4)	36 (63.2)
Male	110 (47.4)	72 (41.9)	31 (59.6)*	86 (50.6)	21 (36.8)
Income (wages)[c]					
≤1 wage	157 (67.7)	118 (68.6)	33 (63.5)	112 (65.9)	41 (71.9)
>1 wage	75 (32.3)	54 (31.4)	19 (36.5)	58 (34.1)	16 (28.1)
Congenital heart disease					
Cyanotic	79 (34.1)	58 (33.7)	20 (38.5)	60 (35.3)	18 (31.6)
Acyanotic	153 (65.9)	114 (66.3)	32 (61.5)	110 (64.7)	39 (68.4)
Cardiac procedure					
Cardiac catheterization	41 (17.7)	32 (18.6)	8 (15.4)	34 (20.0)	6 (10.5)
Cardiac surgery	191 (82.3)	140 (81.4)	44 (84.6)	136 (80.0)	51 (89.5)
Complexity					
Simple/moderate	185 (79.7)	139 (80.8)	39 (75.0)	133 (78.2)	48 (84.2)
Complex	47 (20.3)	33 (19.2)	13 (25.0)	37 (21.8)	9 (15.8)
Postoperative time					
≤1 year	19 (8.2)	12 (7.0)	4 (7.7)	14 (8.2)	3 (5.3)
>1 year	213 (91.8)	160 (93.0)	48 (92.3)	156 (91.8)	54 (94.7)
Family history of obesity[d]					
Absent	147 (63.4)	116 (67.4)	27 (51.9)	116 (69.9)	27 (47.4)
Present	81 (34.9)	52 (30.2)	25 (48.1)*	50 (30.1)	30 (52.6)*
Physical activity[e]					
Active	10 (4.3)	7 (4.1)	2 (3.8)	8 (4.8)	2 (3.6)
Insufficiently active	217 (93.5)	161 (93.6)	49 (94.2)	159 (95.2)	54 (96.4)
Sedentary behavior					
No	85 (36.6)	69 (40.1)	12 (23.1)	72 (42.4)	11 (19.3)
Yes	147 (63.4)	103 (59.9)	40 (76.9)*	98 (57.6)	46 (80.7)*

Student's t test was used. Bivariate tests were used to evaluate the association between exposure variables and excess total-body adiposity and central adiposity; the chi-square test and logistic regression were applied. The dietary intake variables were standardized (standard score) to facilitate the interpretation of the logistic regression results.

Multivariate logistic regression by hierarchical model, backward selection was applied to identify the factors associated with excess total-body adiposity and central adiposity. First, variables that had a moderate association with the outcomes in bivariate tests were offered into the models ($P < .20$). We used also the difference between regression coefficients and their variances and covariances to decide the variables offered into the models. As the correlation between some dietary intake variables was strong ($r \geq 0.80$), which indicates variables with multicollinearity (Table S1), we decided to maintain in the multivariate logistic regression model the nutrient with the highest significant odds for the outcome. Thus, variables with multicollinearity were excluded from the multivariate logistic regression model. Second, in multivariate-adjusted models, we further adjusted for some potential sociodemographic and clinic characteristics for risk factors of obesity in congenital heart disease based in previous studies[3,34,35]: in Model 1 adjusted for age (years), sex, and per capita income; in Model 2 adjusted for age (years), sex and per capita income, type of congenital heart disease (acyanotic and cyanotic), cardiac procedure (interventional cardiac catheterization and cardiac surgery), and postoperative time (years). Finally, the Hosmer-Lemeshow goodness of fit test for logistic regression was used. The results were expressed as odds ratios (OR) and respective 95% confidence interval (95%CI). Statistical analyses were performed by using the Statistical Package for Social Sciences-SPSS version 23.0 (IMB SPSS Inc., Chicago, IL, USA) and were considered significant $P < .05$.

5 | RESULTS

5.1 | Patients characteristics

A total of 232 children and adolescents with congenital heart disease were included in the study. Some participants declined to perform the assessment of excess total-body adiposity by air-displacement plethysmography (n = 8) and central adiposity by waist circumference (n = 5) (Figure S1). The median age was 10.02 years (IQR; 7.09; 13.05), 52.6% were girls, 72.4% with acyanotic congenital heart disease, and 82.3% suffered cardiac surgery. The mean postoperative time was 6.73 (3.84) years. Among the patients of this study, 22.4% were identified with excess total-body adiposity and 24.6% with central adiposity. According to BMI for age, 19% (n = 44) were overweight or had obesity. Characteristics of the total study population and subgroups according to excess total-body adiposity and central adiposity are shown in Table 1.

5.2 | Dietary intake and excess total-body adiposity and central adiposity

Patients with excess total-body adiposity had significantly higher intakes of energy from carbohydrates (*P* = .03), total fat (*P* = .002), saturated fatty acids (*P* = .01), monounsaturated fatty acids (*P* < .001), polyunsaturated fatty acids (*P* = .02), trans fatty acids (*P* < .001), and added sugar (*P* = .04), as well as significantly lower intakes of total energy (*P* = .01) and protein per kg/day (*P* < 0.02), in comparison to patients with absence of excess total-body adiposity. The results were similar for central adiposity (Table 2).

5.3 | Clinical characteristics and lifestyle factors with excess total-body adiposity

Bivariate analysis showed that the sex (male), family history of obesity (presence), dietary intake (intake of carbohydrate, total fat, saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, trans fatty acids, sodium, and added sugar) and sedentary behavior were associated with increased odds of excess total-body adiposity, while a decreased odds of excess total-body adiposity was observed with intake of energy and protein (Table S2). After adjustment (for age, sex, income, congenital heart disease diagnosis, cardiac procedure and postoperative time) that trans fatty-acids intake (OR: 1.84, $CI_{95\%}$:1.19-2.87, $p < 0.001$) and added sugar intake (OR: 2.63, $CI_{95\%}$: 1.78-3.88, $P = 0.01$) remained significantly associated with the increased odds for excess total-body adiposity. Associations of the family history of obesity and sedentary behavior with excess total-body adiposity were attenuated and became nonsignificant after adjustment for confounders (Figure 1C).

5.4 | Clinical characteristics and lifestyle factors with central adiposity

An increased odds of central adiposity was found with family history of obesity, intake of monounsaturated fatty acids, trans fatty acids, and added sugar, those with sedentary behavior, while a decreased odds of central adiposity was observed with intake of energy. There was no association between socio-demographic and clinical characteristics and central adiposity (Table S2). In Figure 2C, multivariable logistic regression analyses adjusted for all confounding factors showed an

TABLE 2 Dietary intake according to excess adiposity and central adiposity

	Total	Excess Adiposity[a]			Central Adiposity[b]		
		Absence	Presence		Absence	Presence	
	Mean (SD)	Mean (SD)	Mean (SD)	*P*	Mean (SD)	Mean (SD)	*P*
Energy (kcal/d)	1807.74 (149.68)	1822.04 (135.67)	1749.74 (182.40)	**.010**	1837.20 (132.61)	1717.15 (164.42)	**<.001**
Carbohydrate (%E/d)	53.29 (4.74)	52.90 (4.35)	54.79 (5.77)	**.03**	52.62 (4.29)	55.35 (5.47)	**.001**
Protein (g/kg/d)	2.29 (0.93)	2.37 (0.90)	2.00 (0.97)	**.02**	2.45 (0.95)	1.80 (0.70)	**<.001**
Total fat (%E/d)	32.60 (3.15)	32.20 (2.64)	34.17 (4.20)	**.002**	31.81 (2.54)	35.03 (3.64)	**<.001**
Saturated fatty acids (%E/d)	10.99 (1.21)	10.86 (1.09)	11.47 (1.46)	**.01**	10.72 (1.07)	11.83 (1.24)	**<.001**
Monounsaturated fatty acids (%E/d)	10.57 (1.11)	10.38 (0.83)	11.27 (1.56)	**<.001**	10.26 (0.81)	11.53 (1.37)	**<.001**
Polyunsaturated fatty acids (%E/d)	8.05 (0.75)	7.98 (0.61)	8.35 (1.06)	**.02**	7.90 (0.58)	8.51 (0.98)	**<.001**
Trans fatty acids (%E/d)	1.10 (0.16)	1.07 (0.10)	1.25 (0.25)	**<.001**	1.06 (0.08)	1.25 (0.26)	**<.001**
Cholesterol (mg/d)	221.14 (24.08)	220.81 (24.17)	224.13 (24.36)	.39	217.83 (23.93)	231.32 (22.22)	**<.001**
Sodium (mg/d)	2726.02 (105.13)	2716.36 (82.65)	2756.79 (158.79)	.08	2725.03 (74.98)	2731.51 (168.02)	.78
Total fibers (g/d)	16.93 (1.52)	16.97 (1.50)	16.81 (1.65)	.52	17.03 (1.48)	16.63 (1.63)	.09
Added sugar (g/d)	71.34 (7.57)	70.83 (7.05)	73.56 (8.91)	**.04**	69.98 (6.68)	75.51 (8.74)	**<.001**

The text in boldface refers to variables with statistically significant difference between the groups.

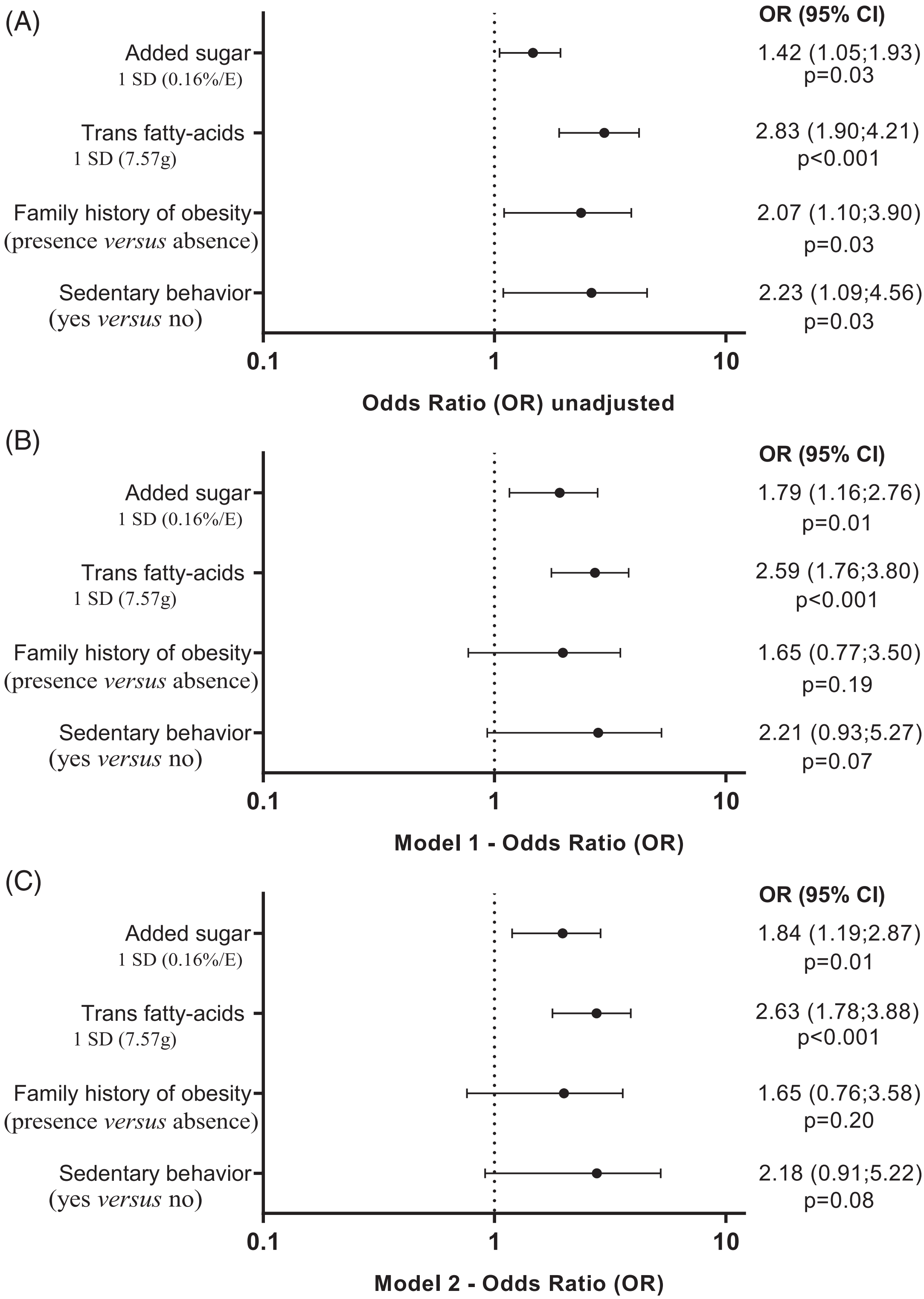

FIGURE 1 Multivariate logistic regression by hierarchical model, backward selection; Missing = 12; OR: odds ratio; 95% CI: 95% confidence interval; SD = SD; %/E = percentage of energy. A, Unadjusted Model. B, Model 1 adjusted by age (years), sex, per capita income. C, Model 2 adjusted by model 1 + congenital heart disease (acyanotic and cyanotic), cardiac procedure (cardiac catheterization and cardiac surgery) postoperative time (years). Homes-Lemeshow = goodness of fit for logistic regression models (*P* > .05 as considering as adjusted model); R2 = proportion of variance in the outcome explained by the model (R2 = 1.000, explains all the variability and R2 = 0.000 explains none of the variability); Homer and Lemeshow: model 1 = 0.570; model 2 = 0.771e R^2 model 1 = 0.356; model 2 = 0.362

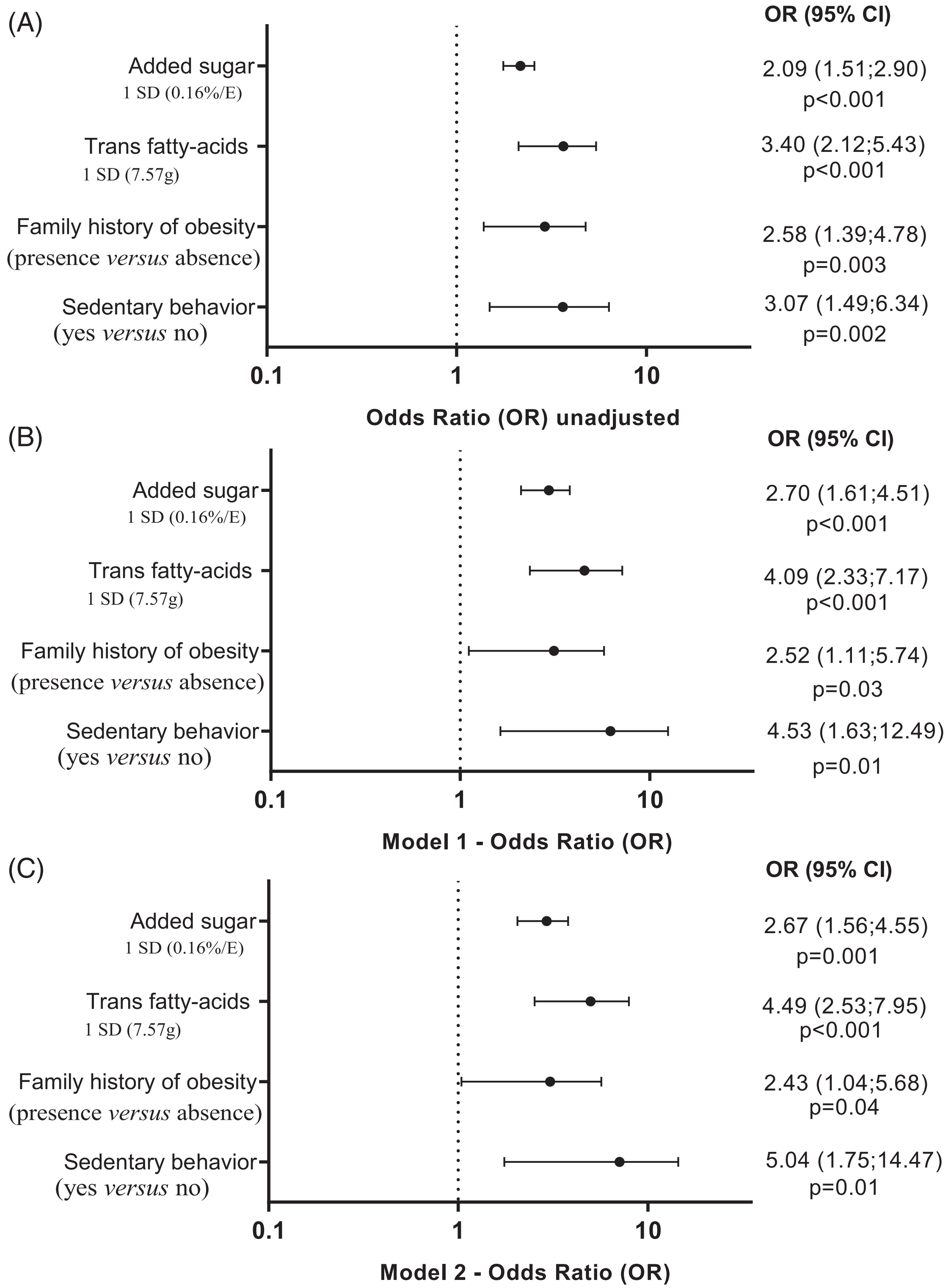

FIGURE 2 Multivariate logistic regression by hierarchical model, backward selection; Missing = 9; OR: odds ratio; 95% CI: 95% confidence interval; SD = SD; %/E = percentage of energy. A, Unadjusted Model. B, Model 1 adjusted by age (years), sex, per capita income. C, Model 2 adjusted by model 1 + congenital heart disease (acyanotic and cyanotic), cardiac procedure (cardiac catheterization and cardiac surgery) postoperative time (years). Homes-Lemeshow = goodness of fit for logistic regression models (*P* > .05 as considering as adjusted model); R2 = proportion of variance in the outcome explained by the model (R2 = 1.000, explains all the variability and R2 = 0.000 explains none of the variability); Homer and Lemeshow: model 1 = 0.888; model 2 = 0.665e R^2 model 1 = 0.518; model 2 = 0.547

increased odds of central adiposity associated with family history of obesity (OR: 2.43, $CI_{95\%}$: 1.04-5.68, P = .04) and lifestyle factors, such added sugar intake (OR: 2.67, $CI_{95\%}$: 1.56-4.55, P = .001), trans fatty acid intake (OR: 4.49, $CI_{95\%}$: 2.53-7.95, P < .001), and sedentary behavior (OR: 5.04,$CI_{95\%}$: 1.75-14.47, P = .01).

6 | DISCUSSION

The main findings of this study were the positive association of modifiable lifestyle behaviors, as added sugar and trans fatty acid intake and sedentary behavior with excess total-body adiposity and central adiposity in children and adolescents with congenital heart disease. These findings are important considering that excess total-body adiposity and central adiposity in childhood and adolescence may contribute to cardiovascular disease risk factors in adulthood.[36] Also, mortality from acquired cardiovascular diseases has increased in adult with congenital heart disease compared with the general population.[7]

In this study, the excess total-body and central adiposity were 22.8% and 24.6%, respectively, lower than 48.3% of prevalence of excess total-body adiposity by the dual-energy X-ray absorptiometry method in healthy children from Southeastern Brazil,[37] but higher than 12.2% of central adiposity in another cross-sectional study with Brazilian healthy adolescent from public schools of the southern region in Brazil.[38] The *National Adolescent School-based Health Survey* (PeNSE) 2015 in five macro-regions from Brazil found 22.2% of prevalence of overweight by BMI in healthy adolescents.[39] Previous studies among children and adolescent with congenital heart disease found a prevalence of overweight and obesity between 7.6% and 33% assessed by BMI for age.[9-11,40] However, for the first time in children and adolescents with congenital heart disease, we assessed excess total-body adiposity by objective body fat measurement, which may explain these disparities. Another possible reason is the variability across region[39] and the comparison with studies of healthy children,[37-39] which could contribute to difference in prevalence of overweight and obesity. The central adiposity in this study was higher than the 9% of central obesity found in a previous study with children and adolescents with congenital heart disease.[41] Our findings indicate that the prevalence of excess total-body and central adiposity children and adolescents with congenital heart disease is alarming.

In this study, the added sugar and trans fatty acid intakes were positively associated with excess total-body and central adiposity. These results are similar to previous cross-sectional study with healthy children and adolescents, which showed that 10 g of added sugar intake from liquid source was associated with increased 0.52-kg fat mass and 0.87-cm waist circumference.[42] This association is supported by several mechanisms, such as the compensation at later food intake for calories consumed as sugar-sweetened beverages, poor stimulation of satiety signals,[43] and the early stimulation of lipogenesis.[44] Moreover, added sugar[45] and trans fatty acids[46] are derived mainly from ultraprocessed foods, suggesting a high ultraprocessed foods intake in this population. Ultraprocessed foods are characterized by ready-to-eat products that require minimal preparation, which has undergone several stages and processing techniques at industrial having a high energy density and higher amount of sugars, sodium, saturated fatty acids and trans fatty acids, and lower amount of fiber and micronutrients.[46] There is evidence that ultraprocessed food intake is associated with increased body fat[47] and is a cardiovascular risk factor.[48,49]

One relevant finding of this study was that the mean added sugar intake was 71.3 g/d, almost three times higher than the daily intake recommendation of 25 g/d for children according to *American Heart Association* to prevent cardiovascular disease risk.[49] However, the mean daily intake of added sugar in this study was lower than the 110.1 g/d of daily intake of free sugar found in HELENA study with healthy adolescents.[50] Similarly, the patients exceed the trans fatty acid intake recommendation of 1% of energy according to *World Health Organization* to reduce cardiovascular disease risk.[51] Moreover, a fact that deserves to be highlighted is that trans fatty acid intake was associated with increased to fast 5 times the odds of central adiposity. These results suggest that unhealthy eating habits may be one of the major causes related to excess total-body adiposity and central adiposity in children and adolescents with congenital heart disease.

In the present study, the family history of obesity was positively associated with central adiposity. These findings support both the genetic[52] and environmental factors for the development and maintenance of obesity, since overweight family members may have unhealthy food choices,[53] determining the type of foods available to their children. Parents play a crucial role in modeling the lifestyle of their children and adolescents in relation to diet, physical activity, and sedentary activities. These behaviors affect nutritional status,[54] suggesting the importance of the family being involved actively in monitoring nutrition habits to prevent obesity in children and adolescents with congenital heart disease.

Many hours in sedentary behaviors is a frequent characteristic in congenital heart disease patients, and few of them reach the recommendations of physical activity.[55] However, not always assigned to congenital heart disease, it is often the result of the parents or guardian beliefs or even the health professionals team.[5] Our results showed that sedentary behavior was positively associated with central adiposity. In agreement with our results, a previous cross-sectional study found that each increment in 1 hour of sedentary behaviors was associated with 0.05 cm higher waist circumference in healthy children and adolescents from Europe, the United States of American, Brazil, and Australia.[56]

In this study, there was no association between clinical characteristics of congenital heart disease and excess total-body adiposity and central adiposity. However, previous studies in children and adolescents with congenital heart disease described that altered metabolism and high energy expenditure in the perioperative period return to normal status after cardiac procedure,[57] promoting weight gain and rapid catch-up growth[3] and cardiac procedure, as well as, its complications might lead the parents or guardian to overprotect children and adolescent with congenital heart disease, which may lead a tendency to restrict physical activity and unhealthy eating habits,[4] a context that may favor to development of excess total-body adiposity and central adiposity. This context is supported by the diet with high added sugar and trans fatty acid intakes and sedentary behavior observed in this study.

The factors associated with excess total-body adiposity and central adiposity may have consequences on the cardiovascular health in children and adolescents with congenital heart disease, considering that obesity,[58] central obesity,[14] high intakes of added sugar[49] and trans fatty acids,[48] and family history of obesity[59] are associated with cardio-metabolic markers. Previous studies report cardio-metabolic markers altered in children and adolescents with congenital heart disease.[3,9,10] Therefore, the findings of this study indicate the need for nutritional counseling after cardiac procedure and increase of physical activity levels to prevent obesity and its deleterious consequences on cardiovascular health. Since the nutritional and lifestyle interventions are recommended to obesity treatment in childhood.[60] Our results suggest to avoid ultraprocessed foods intake, decrease the time of sedentary behavior, practice physical activity daily, and actively involve the family that plays a vital role in prevention obesity; in other words, education strategies focused on nutrition and healthy lifestyle seem to be the key point to prevent childhood obesity in congenital heart disease. As a consequence, there is decreased early mortality from acquired cardiovascular disease in congenital heart disease patients.

Among the strengths, this is the first study to assess objectively body fat using air-displacement plethysmography in children and adolescents with congenital heart disease. It is known that air displacement plethysmography has advantages for various aspect for assessment of body fat, such a quick, comfortable, noninvasive, and save measurement and ability to accommodate a wide range of subject (eg, children and obesity)[17] In addition, the air displacement plethysmography has a high correlation with deuterium dilution ($r = 0.91$).[61] However, compared with dual-energy X-ray absorptiometry and multicompartment model, the plethysmography underestimates body fat percentage[17] particularly in thinner subjects.[62,63] Another strength of the study, use of 24-hour recalls for the first time in children and adolescents with congenital heart disease, as well, to explore dietary intake variables associated excess total-body adiposity and central adiposity, which may provide information for specific nutritional education strategies for these patients.

The study presents some limitations that should be mentioned. First, there is no currently accepted reference standard for the definition of excess total-body adiposity by air-displacement plethysmography in children and adolescents, as well as there are no national or/and specific curves for children and adolescents with congenital heart disease to define central adiposity; thus, we defined excess total-body adiposity[18] and central adiposity[19] using body fat reference curves for children according to age and sex-specific. Second, postoperative time was varied in the sample, which may influence due distinct exposure time to factors associated with excess total-body adiposity and central adiposity; however, the analyses were adjusted to postoperative time. Third, the inherent limitation of method to assess dietary intake. However, all the methodological care in the collection, tabulation, and analysis data, including the multiple pass method, were taken. Fourth, sedentary behavior and physical activity were assessed by an indirect method. Fifth, air displacement plethysmography has limitations to evaluate underweight subjects; however, only 5.2% ($n = 12$) are underweight in this study (data not shown). Finally, lifestyle factors usually coexist, and specific behaviors (eg, poor sleep and smoking) that might account for changes within the obesity risk factor were not explored. Also, information about the diet and/or lifestyle counseling after the surgery from any clinicians was not explored. Additionally, the specific population of the study may limit the generalizability of findings to other populations. This study has other limitation. We used $P < .05$ as significant, although it was needed more stringent P value, due to the number of exposures and outcomes were investigated. This study also has the limitation of cross-sectional design such that it is not possible to establish a cause-and-effect relationship. Thus, the results in present study are exploratory. Other possible limitations in this study were residual confounding and reverse causation.

In conclusion, we found that added sugar and trans fatty acid intake were positively associated with excess total-body adiposity and central adiposity. Sedentary behavior and family history of obesity were also positively associated with central adiposity in children and adolescents with congenital heart disease. The results highlight the need for assessment and monitoring of nutritional status as part of medical care and implementation of lifestyle interventions are important as a nonpharmacological treatment and to prevent excess total-body and central adiposity and its deleterious consequences on cardiovascular health. Further prospective studies with a control group are needed to confirm our results. Future studies may consider exploring dietary patterns and the effect of fats from plant and animal sources in relation to risk of obesity and cardio-metabolic markers and also the impact of excess total-body adiposity and central adiposity on cardio-metabolic markers to evaluate the efficacy of lifestyle interventions in children and adolescents with congenital heart disease.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

I.C.B., M.H., S.M.C., and Y.M.F.M. contributed to conception and design of the study. L.R.A.L., M.H., and S.M.C. contributed to acquisition of the data. M.H. and Y.M.F.M. contributed to analysis and interpretation of the data. M.H. and Y.M.F.M. contributed to drafting the manuscript. F.G.K.V., I.C.B., L.R.A.L., S.G.I.O., and S.M.C. critically revised the manuscript. All authors read and approved the final manuscript and agree to be fully accountable or ensuring the integrity and accuracy of the work.

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n = absolute frequency; % = relative frequency; IRQ = interquartile range; [a]n = 8 patients did not perform air-displacement plethysmography; [b]n = 5 patients did not measure waist circumference; [c]Brazilian minimum wage in February 2017 (US$295.00); [d]n = 4 patients did not know to report [e]n = 5 patients did not respond; *chi-square test $P < .05$ **chi-square test $P < .001$.

SD = SD; p = Student's t test; [a]n = 8 patients did not perform air-displacement plethysmography; [b]n = 5 patients did not measure waist circumference; kcal/d: kilocalorie per day; g/kg/d: gram per kilogram per day; %E/d: percentage of energy per day; mg/d: milligram per day; g/d: gram per day. All nutrients were adjusted for to intra-and-interpersonal variability[33] and total energy.[34]

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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