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Abdominal circumference measurement by ultrasound does not enhance estimating the association of visceral fat with cardiovascular risk

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ABSTRACT

Objectives: To evaluate the association between visceral fat and cardiovascular risk factors and to compare the ultrasonographic measurements of abdominal visceral fat with abdominal circumference (AC).
Methods: This observational cross-sectional study categorized pubertal and postpubertal adolescents into a control group ($n = 49$) and an obese group ($n = 46$). Weight, height, AC, blood pressure, biochemical tests (lipid profile, triacylglycerols, fasting glucose for insulinemia, and serum uric acid), and ultrasound to measure visceral fat were assessed.
Results: We found significant differences in the vascular risk variables between the groups, except for total cholesterol and fasting blood glucose level. We also observed that 31 subjects in the control group presented abnormalities in cardiovascular risk factors. The correlations between abdominal visceral fat (measured by ultrasound or the AC) and cardiovascular risk factors were significant. In the entire sample, AC presented better sensitivity and specificity than the ultrasound-measured abdominal visceral fat for identifying the presence of a cluster of at least three cardiovascular risk factors (areas under the receiver operating characteristics curve 0.87 and 0.73, respectively).
Conclusion: Ultrasonographic measurements of visceral fat were correlated with cardiovascular risk factors, but this association was also demonstrable with AC measurements. Our results suggest that the measurement of visceral fat by ultrasound is unnecessary for the diagnosis of cardiovascular risk in well-nourished or obese adolescents.

Introduction

It is difficult to estimate the global prevalence of overweight and obesity in children and adolescents because the methods used in the evaluation of these two conditions vary among countries. In Brazil, studies carried out after the 1990s showed an increase in overweight of 0.5% per year. [1] An analysis based on four national Brazilian investigations (National Study on Family Expenditures, 1974–1975; National Research on Health and Nutrition, 1989; Research on Family Budget, 2002–2003 and 2008–2009) showed a continuous increase in the prevalence of overweight and obesity. In adolescents, the prevalence of overweight has tripled in the past 20 y, affecting one-fifth to one-third of all the young people who were analyzed in the investigations. In the 34-y span from the investigation in 1974 to 1975 until the more recent one in 2008 to 2009, the prevalence of overweight has increased by a factor of 6 in boys (from 3.7% to 21.7%) and by a factor of almost 3 in girls (from 7.6% to 19.4%) [2].

Obese adolescents are more likely to become obese adults than normal-weight adolescents [3,4]. Studies have suggest that the duration of obesity is directly associated with the morbidity and mortality related to metabolic, cardiovascular, respiratory, visceral, orthopedic, dermatologic, and neurologic factors and with the morbidity and mortality related to hormonal abnormalities [5,6].

The excess of adipose tissue in obesity, and especially the visceral adipose tissue (VAT), is associated with insulin resistance,

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hyperglycemia, dyslipidemia, hypertension, and prothrombotic and proinflammatory states [7]. During childhood and adolescence, the amount of VAT represents less than 10% of total abdominal fat, but it is known that the accumulation of VAT increases with age [8].

The use of weight- and stature-based indicators in the anthropometric evaluation of children is widespread, but to determine a better diagnosis, it is interesting to associate information obtained from other measurements and methods, such as physical and laboratory examinations [9].

The methods used most often to measure total fat (e.g., the body mass index [BMI]) do not predict the quantity of VAT [10]. Among the methods available to measure the quantity of VAT, the use of anthropometric measurements (circumferences) is widespread. These measurements, although at least in theory not as accurate as the evaluation by imaging methods, are more practical and have good reproducibility [10–12].

Although accurate and used as references in the evaluation of the VAT, imaging methods such as computed tomography (CT) and magnetic resonance imaging have the disadvantage of being more expensive and exposing individuals to radiation [6,13]. Ultrasound (US) has been proposed as an alternative method for the evaluation of visceral adiposity because it has a good correlation with the results obtained by CT and is simpler, less expensive, and free of radiation. Thus, it has been argued that the US evaluation of VAT improves the diagnosis of visceral adiposity [11,14].

Because obesity is an increasing public health concern in adolescents, adequately treating excess weight and the metabolic syndrome is fundamental to decrease the risk of cardiovascular complications [15]. The identification of simple and accurate low-cost methods showing a better correlation with cardiovascular risk factors might play an important role in reaching an early diagnosis of these problems. The objectives of the present study were to 1) determine the association between visceral fat and cardiovascular risk factors and 2) evaluate comparatively the associations of visceral fat measurements by abdominal US and abdominal circumference (AC) in their relation to a cluster of cardiovascular risk factors.

Materials and methods

We carried out a cross-sectional study in pubertal and postpubertal adolescents. The Tanner sexual maturation stages IV and V were used for boys [16]; for girls, the postpubertal stage was defined as 2.5 y after menarche. The participants who took part in the study were selected by convenience among the patients who came to medical appointments in the pediatric outpatient units at the Federal University of São Paulo and had not undergone suppressed nutritional intervention previously. The study was approved by the university ethics and research committee (0462/020).

The patients were normal weight or obese, according to the curves and cutoffs from the Centers for Disease Control and Prevention [17]. Only patients above the 95th percentile were considered obese. The following exclusion criteria were adopted: 1) adolescents who presented with malnutrition, 2) pregnant women, 3) patients using medication to control blood pressure, and 4) patients who reported endocrine or neurologic disorders.

By convenience, we adopted a sample composed by 95 adolescents who were categorized into a control group (49 normal-weight adolescents, 25 boys and 24 girls) and an obese group (46 obese adolescents, 21 boys and 25 girls).

All the participants underwent evaluations of body weight (kilograms), height (centimeters), blood pressure (millimeter of mercury), AC (centimeters), and biochemical tests. Abdominal US was carried out to determine visceral and subcutaneous fat amounts. The BMI was obtained using the following formula: BMI = weight (kilograms)/height (meters) squared. The values of BMI were analyzed in percentiles and Z scores using Epi Info 3.5.3 (Atlanta, GA, USA).

The AC was measured with an inextensible measuring tape to an accuracy of 0.1 cm placed at the midpoint between the iliac crest and the last costal arch with the subject in a standing position. The values were analyzed in percentiles, as proposed by McCarthy et al. [18], and were considered cardiovascular risks carriers in those adolescents no older than 17 y old whose AC was above the 90th percentile [18]. For adolescents older than 17 y, we adopted the classification used for adults according to the National Institutes of Health [19].

The US technique described by Ribeiro-Filho et al. [11] was used to determine the visceral fat based on a previous study performed in our institution by the adult nephrology department [11]. In that study, visceral fat measured by US showed a high correlation with CT-determined visceral fat ($r = 0.67$, $P < 0.0001$). The US method showed good reproducibility, with an intraobserver variation coefficient lower than 2%. In short, using a 3.5-MHz probe located 1 cm from the umbilicus, the US measurement of intra-abdominal fat, defined as the distance from the internal face of the rectoabdominal muscle to the anterior wall of the aorta, was performed [11].

Blood pressure was measured three times with a semiautomatic oscillometric monitor (Microlife, [Clearwater, FL, USA] model BP 3BTO-A; registered at the National Agency of Sanitary Surveillance under no. 10222460029/0025 and the U.S. Food and Drug Administration under no. 5164820186) at the time of a volunteer's recruitment, and the arithmetic mean of the three values was used to interpret the results [20].

All volunteers were asked to fast for 12 h before the tests, and evaluations of serum fasting glucose, lipid profile, triacylglycerols, and uric acid were carried out by conventional methods. Fasting insulinemia was measured by immunofluorometric methods, and we adopted dosages lower than 15.0 mUI/mL as cutoff values of normality [21]. Tests evaluated the subjects' lipid profile, including total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, and triacylglycerols. The analysis of these results was based on the limits put forth by the First Brazilian Guidelines for Prevention of Atherosclerosis in Childhood and Adolescence [21]. All tests were performed in all 95 subjects, except for the serum uric acid dosage, which was executed in 94 adolescents.

Insulin resistance was evaluated using the homeostasis model assessment (HOMA) developed by Turner et al. [22]. We used the value of 3.16 as the cutoff for normality according to the First Brazilian Guidelines for Prevention of Atherosclerosis in Childhood and Adolescence [21].

We classified the metabolic syndrome according to the definition provided by the International Diabetes Federation [23] because it is specific to adolescents. Moreover, the adolescents who presented a cluster of at least three cardiovascular risk factors were considered as having a risk profile.

To compare proportions between groups (obese versus control), we used the chi-square test or the Fisher test. When we compared quantitative variables, Student's t test for independent samples was used. To evaluate the correlation between the visceral fat measurements (US VAT and AC) and the cardiovascular risk variables, we used the Spearman rank correlation. In all tests, a value of 5% ($\alpha < 0.05$) was used to reject the null hypothesis.

To estimate if US could be used to assess visceral obesity, we also performed CT visceral fat measurements in a subgroup of five subjects from the control group and the correlation coefficient between US- and CT-measured visceral fat was good ($\rho = 0.70$).

To compare the sensitivity and specificity of visceral fat measurements (US VAT and AC) for the identification of the cluster of at least three cardiovascular risk factors, we calculated the area under the receiver operating characteristics curve for each mode of visceral fat measurement.

Results

The study sample included 95 adolescents; 49 were normal weight and 46 were obese. The main demographic data of the sample are listed in Table 1.

We found significant differences in the cardiovascular risk variables between groups, except for total cholesterol values and fasting glucose, as presented in Table 2. Interestingly, we observed that 31 subjects from the control group classified as

Table 1
Demographic data for the obese and control groups

Variable	Obese ($n = 46$)	Min–Max	Control ($n = 49$)	Min–Max	P
Age	15.5 ± 1.5	12.6–19.1	16.2 ± 1.3	14.0–19.9	0.01
Weight (kg)	94.6 ± 19.4	64.4–170.8	59 ± 8.7	40.7–79.9	<0.01
Height (cm)	167.6 ± 8.7	149.5–191.0	167.6 ± 8.7	150.2–201.5	0.98
BMI (kg/m^2)	33.5 ± 4.9	26.9–52.7	20.9 ± 2.0	17.1–26.0	<0.01
BMI SDS	2.8 ± 0.7	2.0–5.6	0.6 ± 0.7	−1.5 to 1.1	<0.01
Height SDS	0.4 ± 0.9	−1.5 to 3.0	0.0 ± 1.0	−1.7 to 4.1	0.08

BMI, body mass index; Max, maximum; Min, minimum, SDS, SD score
Values are presented as mean ± SD

Table 2
Variables of cardiovascular risk in the obese and control groups

Variable	Obese ($n = 46$)	Min–Max	Control ($n = 49$)	Min–Max	P
AC (cm)	102.8 ± 12.2	86–153	74.4 ± 6.3	61–91	<0.01
USVAT (cm)	3.4 ± 1.5	1.3–8.0	2.3 ± 0.9	0.9–4.3	<0.01
USSCT (cm)	3.3 ± 0.9	1.7–5.1	1.1 ± 0.7	0.2–3.1	<0.01
Triacylglycerols (mg/dL)	109.0 ± 67.8	44–325	75.0 ± 41.5	36–301	<0.01
Total cholesterol (mg/dL)	153.3 ± 34.9	113–264	144.5 ± 27.7	96–217	0.18
HDL cholesterol (mg/dL)	39.6 ± 9.3	28–77	50.8 ± 12.9	32–89	<0.01
LDL cholesterol (mg/dl)	92.0 ± 28.2	52–173	79.6 ± 21.1	44–129	0.02
Fasting glucose (mg/dL)	88.0 ± 7.1	74–107	86.6 ± 10.4	67–108	0.43
Insulinemia (μUI/mL)	16.9 ± 10.2	3.8–47.8	7.9 ± 3.3	2.4–17.3	<0.01
HOMA	3.7 ± 2.3	0.8–10.3	1.7 ± 0.8	0.6–3.8	<0.01
Serum uric acid (mg/dL)	6.2 ± 1.4	3.6–9.6	5.2 ± 1.5	2.4–10.1	<0.01
SBP (mmHg)	121.2 ± 11.2	93–143	109.2 ± 8.9	89–132	<0.01
DBP (mmHg)	70.5 ± 7.4	60–88	63.6 ± 8.3	47–88	<0.01

AC, abdominal circumference; DBP, diastolic blood pressure; HDL, high-density lipoprotein; HOMA, homeostasis model assessment; LDL, low-density lipoprotein; Max, maximum; Min, minimum; SBP, systolic blood pressure; USSCT, ultrasound-measured subcutaneous tissue; USVAT, ultrasound-measured visceral abdominal tissue
Values are presented as mean ± SD score

having a normal weight exhibited abnormalities involving at least one cardiovascular risk factor (19 presented one factor, 11 presented two factors, and 1 presented four abnormalities): triacylglycerols ($n = 5$), total cholesterol ($n = 22$), fasting glucose ($n = 3$), insulinemia ($n = 1$), serum uric acid ($n = 2$), low high-density lipoprotein ($n = 20$), and a high HOMA index ($n = 2$). Blood pressure was high in two subjects in this group.

When we analyzed the data by sex, most variables behaved similarly to the total sample, except for fasting glucose, which exhibited comparable values between obese and control subjects in the total sample but significant differences between groups in girls only. In contrast, serum uric acid showed significant differences in boys only (data not shown).

It is also worth noting that the classification of AC in 13 normal-weight subjects indicated a risk for cardiovascular diseases (boys, $n = 4$; girls, $n = 9$).

As presented in Table 3, the correlations between the fat measurements and the cardiovascular risk indicators were significant and comparable, except for the correlations between VAT and diastolic blood pressure and between VAT and low-density lipoprotein cholesterol, which were not statistically significant. No significant correlation was observed between fasting glucose/total cholesterol and any of the fatty tissue measurements we analyzed.

When we tested the AC and US VAT measurements for the diagnosis of a cluster of at least three cardiovascular risk factors, we observed that AC presented better sensitivity and specificity than US VAT for the entire sample (Table 4). After analyzing the subgroups by sex, this difference was observed only in boys, whereas AC and US VAT were comparable in girls.

Discussion

The clustering of cardiovascular risk factors in subjects from the obese group stands out in the analysis of the present data, emphasizing the known association of obesity with a higher cardiovascular risk [24,25]. In childhood and adolescence, this behavior is not different, and this phenomenon is all the more worrying because of its early onset. In this regard, Berenson et al. [26] highlighted that when metabolic changes are already present in adolescence, the risk of developing cardiovascular diseases increases over time [6,26].

Although obese adolescents on average showed more pronounced changes in cardiovascular risk factors, an analysis of the minimum and maximum values in the present data showed that the subjects classified as having a normal weight by BMI also showed changes in their metabolic profile and blood pressure. In this sample, 31 (63.3%) of the normal-weight subjects showed some degree of change in their metabolic profile or blood pressure, and one subject was classified as having metabolic syndrome. The BMI has been described as insufficient to indicate health risk and body fat accumulation, despite its widespread use [6]. In 1981, Ruderman et al. [27] described the profile of a normal-weight, metabolically obese individual ("metabolically obese,"

Table 3
Correlation coefficients between AC, USVAT, and indicators of cardiovascular disease risk

	AC		USVAT		USSCT	
	Correlation coefficient	P	Correlation coefficient	P	Correlation coefficient	P
SBP	0.53	<0.01	0.41	<0.01	0.51	<0.01
DBP	0.39	<0.01	0.19	0.06	0.39	<0.01
TG	0.39	<0.01	0.31	<0.01	0.22	0.04
TC	0.17	0.10	0.09	0.41	0.14	0.18
HDL	−0.50	<0.01	−0.37	<0.01	−0.41	<0.01
LDL	0.31	<0.01	0.16	0.12	0.28	<0.01
Fasting glucose	−0.00	0.96	0.1	0.09	−0.07	0.50
Fasting insulinemia	0.58	<0.01	0.51	<0.01	0.50	<0.01
HOMA	0.55	<0.01	0.60	<0.01	0.47	<0.01
Uric acid	0.40	<0.01	0.33	<0.01	0.31	0.02

AC, abdominal circumference; DBP, diastolic blood pressure; HDL, high-density lipoprotein; HOMA, homeostasis model assessment; LDL, low-density lipoprotein; Max, maximum; Min, minimum; SBP, systolic blood pressure; TC, total cholesterol; TG, triacylglycerol; USSCT, ultrasound-measured subcutaneous tissue; USVAT, ultrasound-measured visceral abdominal tissue

Table 4
Receiver operating characteristics curves for interaction of visceral fat measurements and cluster of cardiovascular risk factors

Variables	USVAT × Cluster*	AC × Cluster*
Total ($n = 95$)	0.73 (0.61–0.84)	0.87 (0.81–0.94)
Girls ($n = 49$)	0.75 (0.57–0.93)	0.82 (0.70–0.95)
Boys ($n = 46$)	0.68 (0.52–0.85)	0.92 (0.84–0.99)

AC, abdominal circumference; USVAT, ultrasound-measured visceral adipose tissue
Data are presented as area under the curve (95% confidence interval)
* Patients presenting a cluster of at least three cardiovascular risk factors.

normal weight) as being a normal-weight person by the BMI classification who nonetheless develops complications associated with obesity, such as hyperinsulinemia, hyperglycemia, and hypertriglyceridemia. According to these investigators, these individuals may benefit from a calorie-restricted diet or increased physical activity because they display characteristics that are similar to those of obese individuals, such as hyperinsulinemia and an increase in adipocytes [27]. In agreement with our findings, Kelishadi et al. [28] found some adolescents who, although classified as having a normal weight by BMI, displayed biochemical abnormalities [28], and Li et al. [29] found hyperglycemia (0.7%), hypertriglyceridemia (17.5%), low high-density lipoprotein (56.0%), and hypertension (14.3%) in normal-weight adolescents.

In the present study, the measurement of fasting glucose was not different among subjects from the two groups; this finding was also seen by Carneiro et al. [3]. Weiss et al. [30] observed that fasting glucose values above 100 mg/dL during adolescence are rare. In the pediatric population, insulin resistance seems to precede the decrease in the function of β-cells in the development of diabetes. It is well established that the pancreas, for a determined period, can adequately compensate for peripheral insulin resistance by increasing the production of this hormone until the capacity of these β-cells becomes insufficient to produce insulin and compensate for the degree of insulin resistance. As a consequence, hyperglycemia emerges, changing a patient's condition from glucose intolerant to type 2 diabetic [31].

We also found significantly higher values of insulin and HOMA in the obese group, which suggests a high production of insulin by pancreatic β-cells in these individuals and insulin resistance. High values of fasting insulinemia and HOMA were also found in other studies carried out in adolescents [32,33]. Sen et al. [32] found a high prevalence of metabolic syndrome and insulin resistance in obese adolescents. In a study of Brazilian postpubertal obese adolescents, high values of fasting blood glucose and HOMA were also found, with scores at 40.2% and 57.1%, respectively. In this same study, a correlation between insulin resistance and the quantity of body fat ($r = 0.46$) was observed [33].

Since the 1980s, hyperuricemia has been described as a marker of cardiovascular risk, regardless of the presence of obesity [34]. Nonetheless, this criterion is not used very often as a classification factor for metabolic syndrome. The correlation between hyperuricemia and visceral fat has been observed in adults. Hikita et al. [35] found an association between a greater concentration of serum uric acid and VAT dimension. In our sample, we noticed an association between obesity and higher levels of serum uric acid, and similar results were found in children and adolescents with average age of 10 y in a study by Pacifico et al. [36]. Japanese studies also have reported such an association, and hyperuricemia was included as a criterion for metabolic syndrome classification [35,37,38].

Subjects from the obese group in our sample showed higher values for blood pressure than normal-weight subjects, and we found a positive correlation between fat measurements (AC and US VAT) and blood pressure, except for diastolic blood pressure. These findings are in agreement with other studies in adolescents in which a correlation between body weight and systolic blood pressure was observed [4,39].

The association between visceral fat and cardiovascular risk factor markers has been described very well in the literature [11,24]. In 2001, Ribeiro-Filho et al. [11] reported the correlation of US measurements of visceral fat to cardiovascular disease risks. In their study in adults, these investigators reported that the cardiovascular risk markers used to classify metabolic syndrome were significantly correlated with the VAT measurement. Similarly, in their study in adults, Leite et al. [40] observed that the VAT measurement has greater sensitivity and specificity in identifying individuals with cardiovascular risk factors compared with the AC, mainly in individuals classified as having a moderate to high risk of developing cardiovascular diseases.

In our study, the US measurement of VAT was correlated with most parameters for metabolic syndrome. As a method, however, the simple AC measurement was comparable to the US VAT measurement, and the coefficients of correlation of the AC with most variables studied were higher than those obtained by VAT measurement by US. The quantity of VAT seems to increase with age [8], and the role of the US measurement of VAT in identifying individuals with a higher cardiovascular risk may not be the same for adolescents and adults.

Conversely, when using the AC, it is important to standardize the evaluation points and to adopt the correct technique. In a review written in 2003, Wang et al. [41] found 14 different points for obtaining this measurement, which makes the classification of individuals all the more difficult. In our practical experience, we observed that the measurement of the AC in obese adolescents, in addition to being observer dependent, is difficult to perform owing to the excessive amount of adipose tissue in the central area and the shyness exhibited by some individuals when exposed to this kind of measurement.

Central obesity has been described as the main factor of the metabolic complications that cause cardiovascular diseases [26], and in many consensus protocols and groups, it has been used as a factor to classify metabolic syndrome [23,42]. The VAT is known as the most metabolically active factor and the factor with the strongest relation to metabolic syndrome [43]. In our sample, the US VAT and the AC showed a significant correlation with most metabolic parameters analyzed, which suggests that these two techniques are plausible methods for assessing the association of central obesity with cardiovascular disease risk factors.

Reinehr and Wunsch [24] compared VAT US and AC measurements with biochemical markers of cardiovascular disease risks in 89 obese children and adolescents 6 to 18 y old and found coefficients of significant correlations only with the AC [24]. Conversely, in a study of a sample comprised of 30 obese children at least 6 y old, all were in the first pubertal stage of the Tanner classification, Reyes et al. [12] found a better correlation of VAT measurements by abdominal US with insulin, HOMA, and triacylglycerols compared with the AC. However, when correlated with the criterion for metabolic syndrome, the two measurements showed significant correlations [12]. It is important to note that in the study by Reyes et al. the AC measurements were performed over the umbilical scar, thus differing from our study. The differences between the study by Reyes et al. and the present study (sample size, AC measurement location, and average age) may justify the

different results obtained by these studies despite the similar goals.

When we evaluated the sensitivity and specificity of the AC and US VAT with regard to the cluster of cardiovascular risk factors by sex, the AC showed better sensitivity and specificity for indicating cardiovascular risk in the male group. In contrast, the two methods were comparable in indicating cardiovascular risk in the female group. This may have occurred as a result of pubertal differences because some adolescents may be in a pubertal stage longer than others and because of the differences in fat distribution in the body caused by hormonal differences. A review of differences in body composition between boys and girls according to sexual maturation has indicated that hormonal differences between genders cause the development of the muscle tissue in boys to surpass the concentration of adipose tissue differently from in girls, in whom the amount of adipose tissue is larger [44].

Our study has methodologic constraints and these should be pondered when considering the results. Our sample was selected by convenience, thus our results are more susceptible to the effect of selection bias. Moreover, the small sample does not allow us to make more elaborate inferences about this important problem for the general population because the statistical power to show subtle differences is restricted in a study sample of 95 subjects. Also, our study involved exclusively Brazilian adolescents, so our results may not be applicable to other populations because the genotypic distribution appears to differ among races. In performing a cross-over study, we have provided merely a picture of the risk factors that are clustered in a patient, but we do not have any information about the actual cardiovascular outcomes. Nevertheless, we hope the present study serves as a tool for elaborating questions for future researches, and it is not intended to be a set of definitive answers. The presence of a control group allowed the establishment of clear gradients of contrast of the cardiovascular risk factors associated with obesity, and this is an aspect of the present study that seems positive to us.

In short, this study supports the clustering of cardiovascular risk factors in obese adolescents. Moreover, our findings suggest that an evaluation by US is not superior to the AC measurement to assess the risks related to obesity. This finding is important for future studies for possibly decreasing costs and simplifying research projects. For the medical practice, it strengthens the notion that the AC measurement should be incorporated in the anthropometric evaluation of pediatric patients.

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