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Research Article

Ultrasonographic Analysis of Subcutaneous and Intra-Abdominal Fats in Children of 6 To 10 Years (Prepubertal Phase) is Highly Correlated with Anthropometric Measures

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Abstract

Objectives: To verify the correlation of anthropometric data body measure Index (BMI), waist circumference (WC) and subcutaneous of abdominal fat and intra-abdominal or visceral fat measure by fat by ultrasonography. Methods: Cross-sectional study with 100 children aged between 6 and 10 years of age from a public school. US measurement of subcutaneous and intra-abdominal fat was used (Logiq S7 Expert, General Electric Company, Germany). Spearman correlation was utilized in the analyses and data are presented as median and standard deviation. Results: High or moderate correlation between anthropometric measurements of BMI and WC with US measurements ($p<0.05$) [BMI with: Fat sum (0.75), SCF (0.78), SCFmax (0.81), PPFmax (0.58), IPFa (0.59) and IPFp (0.61); and WC with: Fat sum (0.83), SCF (0.82), SCFmax (0.84), PPFmax (0.62), IPFa (0.65) and IPFp (0.67)]. The BMI and WC measurements was high correlated (0.88). Conclusions: Anthropometric measurements of BMI and WC showed a high correlation with US measurements, Fat sum, SCF, SCFmax, and should be used as an assessment of abdominal fat in children aged 6 to 10 years.

Keywords: Pediatric obesity; Anthropometry; Subcutaneous fat; Intra-abdominal fat; Visceral fat; Ultrasonography.

Introduction

Childhood obesity affects 5% of children in the world, which represents approximately 100 million children.[1, 2] Among the problems of the development of childhood obesity, we highlight that it is strongly associated with increased rates of premature death.[3, 4] The prevalence of childhood obesity has increased in most regions and countries over the past 40 years,[4, 5] and comparisons performed every 10 years indicate that the number of children with obesity or severe obesity has increased steadily5, 6. The prevalence of childhood obesity in countries such as Brazil has increased by more than 200% in the period mentioned,1 which means that approximately 15% of Brazilian children between 5 and 10 years of age are overweight or obese, numbers that are above the world average.

All the studies cited used BMI, totaling more than 200 million body composition measures. BMI percentiles and z scores should be used to determine BMI status for ages up to 18 years.[7, 8] WHO BMI standards define the ideal BMI and use z scores based on the median distance to determine the BMI classification, that is, 1 z score above the average classifies a child as '' at risk of being overweight '', 2 = '' overweight '' and 3 = '' obese ''.[7]

Despite being easily accessible, BMI presents an important limitation, as it does not differentiate between increased body weight and abdominal fat.[9, 10] Thus, the use of specific measures for subcutaneous and intra-abdominal fat is necessary, and magnetic resonance imaging (MRI) and computed tomography (CT) is the gold standard method.[7, 11] Considering the different limitations of MRI and CT, such as the need for a long immobile period for evaluation (which is a challenge for children) and exposure to radiation, respectively; in addition the high cost, these evaluations are often unfeasible in the clinical environment.[12]

However, two other methods of assessing subcutaneous and intra-abdominal fat can be highlighted: ultrasonography an indirect method, which allows quantification of subcutaneous and intra-abdominal fat from different regions, and presents good agreement with the gold standard (correlation coefficients ranging from 0.75-0.97 <0.001);[13] waist circumference (WC), a doubly indirect method, which not only indicates the amount of abdominal fat, but the total circumference (includes muscle, organs, bones, and fat), and can also be used as an indicator of body fat.12 Ultrasonography is a validated method in relation to computed tomography and is a valid method for epidemiological studies.[14]

Given the above, it is relevant to diagnose childhood obesity using simple and quick methods and the use of BMI is widely recommended. Especially in children between 6 to 10 years of age (prepubertal phase), there is much information still to be investigated, since a recent meta-analysis indicates 29 studies involving the correlation of laboratory measures and anthropometric measures, with only 1 study in children between 7 to 16 years old.[15]

However, it is relevant to understand whether a diagnosis of childhood obesity (6 to 10 years of age - prepubertal phase), performed using BMI correlates with a diagnosis of subcutaneous and intra-abdominal fat by ultrasound (US) measurements and WC, which is the objective of the current study. Waist circumference is used as an indicator of central obesity to identify children at risk for obesity-related morbidity later in life.7 We emphasize that especially due to the possibility of discarding the need for laboratory tests such as US in this population, the proposal is justified, since based on our findings, we will demonstrate that a simple clinical examination is sufficient. Thus, the hypothesis of this study is that childhood obesity determined by BMI will demonstrate a high correlation with the verification of subcutaneous and intra-abdominal fat by US and WC.

Materials and Methods

Study design

Prospective, cross-sectional study, single center, single group.

Ethics approval and consent to participate

This project was approved by the Ethics Committee of Santo Amaro University, protocol number 1.103.468 - 11/06/2015. For inclusion, parents were required to agree to their child's participation (signing the consent form). The investigation was conducted in accordance with the Declaration of Helsinki.

Participants

Children aged 6 to 10 years, of both sexes, enrolled from the 1st to the 5th year in a public school in the city of São Paulo, Brazil (convenience sample), were invited to participate in this research between November and December 2016. For inclusion, parents were required to agree to their child's participation (signing the consent form - Ethics approval and consent to participate¬) and answer a questionnaire to determine sample characteristics and exclusion criteria. The sample excluded children with a clinical suspicion of a secondary cause of obesity (Cushing's syndrome, hypothyroidism, or others), those with a Tanner's stage not compatible with prepubertal phase, that is, with sexual characteristics secondary to the evaluation, and children with some type of physical disability.

Assessments

Body weight was measured in kilograms (kg) and height in centimeters (cm), using a mechanical scale for people (Filizola brand, Brazil). The evaluations were conducted individually, in a classroom. The children were barefoot, wearing light clothes, and were positioned on the scale with their backs to it in an orthostatic position, looking at a fixed point 3 meters distant. The BMI expressed in kg/m2 was calculated for each child.

WC was measured in cm, using a flexible and inelastic measuring tape (Vonder brand, Brazil) with the midpoint between the iliac crest and the costal rim as a reference. All measurements were performed by the same evaluator with the same equipment.

The measurement of subcutaneous and intra-abdominal fat was performed using ultrasound (Logiq S7 Expert, General Electric Company, Germany) with a linear transducer and convex transducer following appropriate methodology.[16] The device was adjusted with a time gain compensation curve in the neutral position and the general gain was calibrated so that liquid structures such as the content of the gallbladder, the inferior vena cava, and the aorta were anechoic.16 All US measurements were performed without pressure on the transducer and determined in centimeters (cm). The following US measurements were evaluated using the arithmetic mean of three measurements SCF (Subcutaneous fat); SCFmax (Maximal subcutaneous fat); PPF (Preperitoneal fat); PPFmax (Maximal preperitoneal fat); IPFa (Intraperitoneal fat in relation to the anterior wall of the Aorta); IPFp (Intraperitoneal fat in relation to the posterior wall of the Aorta); and IPFo (minor omentum thickness, intraperitoneal fat with posterior relation of the left lobe of the liver and the anterior wall of the aorta). One sum of three measurements (SCF + PPF + IPFp) was used for Fat sum indicator.

To determine pubertal development, Tanner's evaluation was performed by the researching physician, immediately before the US evaluation, in an appropriate room, with consent, in the presence of the legal guardian and a nursing assistant.[17, 18]

Determination of nutritional status

Nutritional status was determined using BMI measures, considering the World Health Organization (WHO) recommendation for children aged 5 to 19 years with normal weight ≥ 3th and < 85th percentile; overweight ≥ 85th percentile and < 97th percentile; and obesity ≥ 97th percentile and ≤ 99.9th percentile.[19, 20] Children were classified as eutrophic, overweight, or obese through the stratification of nutritional status obtained from the percentiles in the BMI/age ratio according to sex, using AnthroPlus software (AnthroPlus,WHO., Geneva, Switzerland).[21]

Statistical analysis

The Shapiro–Wilk and Levene's test will be used to determine normality and variance equality, respectively. Because the Nonnormal distribution, Spearman's correlation was performed. Data are presented as means and standard deviations. The significance level of 0.05 or 5% was adopted for all tests.

Results

In the initial screening, 318 students attended the school, of which 155 were female and 163 male. Of the 318 children evaluated in the school environment, 100 children between 6 and 10 years old attended the specialized US center. All the children evaluated were in pubertal stage M1P1 (girls) or G1P1 (boys).[17, 18]

Table 1 shows the sample characteristics of the children included in the research.

Table 1 - Sample characterization.

Variable	**Eutrophic (n = 42)**	**Overweight (n = 23)**	**Obesity (n = 35)**
Girls (n)	22	10	17
Age (y)	7.79 ± 1.28	7.78 ± 1.24	7.54 ± 1.07
Weight (kg)	24.95 ± 3.74	29.99 ± 4.85	37.69 ± 9.62
Height (cm)	123.13 ± 7.38	125.85 ± 7.89	126.66 ± 10.19
WC (cm)	55.26 ± 3.75	60.37 ± 3.95	71.50 ± 8.62
BMI (kg/m^2)	16.38 ± 1.31	18.80 ± 0.95	23.10 ± 3.03
Fat sum (cm)	4.44 ± 0.96	4.94 ± 1.16	6.97 ± 1.67
SCF (cm)	0.39 ± 0.33	0.57 ± 0.35	1.61 ± 0.80
SCFmax (cm)	0.49 ± 0.37	0.68 ± 0.39	1.80 ± 0.82
PPF (cm)	0.11 ± 0.04	0.11 ± 0.03	0.16 ± 0.09
PPFmax (cm)	0.58 ± 0.25	0.63 ± 0.23	0.90 ± 0.26
IPFa (cm)	3.17 ± 0.81	3.47 ± 0.91	4.29 ± 1.08
IPFp (cm)	3.95 ± 0.86	4.26 ± 0.96	5.20 ± 1.14
IPFo (cm)	0.83 ± 0.20	0.90 ± 0.20	1.11 ± 0.31

BMI= Body mass index; WC= Waist circumference; Fat sum= (SCT + PPF + IPFp); SCF=Subcutaneous fat; SCFmax= Maximal subcutaneous fat; PPF= Preperitoneal fat; PPFmax= Maximal preperitoneal fat; IPFa= Intraperitoneal fat in relation to the anterior wall of the Aorta; IPFp= Intraperitoneal fat in relation to the posterior wall of the Aorta; IPFo= Intraperitoneal fat with posterior relation of the left lobe of the liver and the anterior wall of the aorta (minor omentum thickness).

Table 2 shows the Spearman correlation between BMI, WC, and fat measurements evaluated by ultrasound included in the research (Fat sum= (SCT + PPF + IPFp); SCF=Subcutaneous fat; SCFmax= Maximal subcutaneous fat; PPF= Preperitoneal fat; PPFmax= Maximal preperitoneal fat; IPFa= Intraperitoneal fat in relation to the anterior wall of the Aorta; IPFp= Intraperitoneal fat in relation to the posterior wall of the Aorta; IPFo= Intraperitoneal fat with posterior relation of the left lobe of the liver and the anterior wall of the aorta (minor omentum thickness).

Table 2 - Spearman correlation between BMI, WC, and fat measurements evaluated by ultrasound.

	BMI (Kg/m^2)	WC (cm)	Weight (kg)	Fat sum (cm)	SCF (cm)	SCF max (cm)	PPF (cm)	PPF max (cm)	IPFa (cm)	IPFp (cm)	IPFo (cm)
BMI (kg/m^2)		0.88*	0.82*	0.75*	0.78*	0.81*	0.22*	0.58*	0.59*	0.61*	0.44*
WC (cm)	0.88*		0.92*	0.83*	0.82*	0.84*	0.24*	0.62*	0.65*	0.67*	0.40*
Weight (kg)	0.82*	0.92*		0.75*	0.71*	0.75*	0.18	0.61*	0.58*	0.61*	0.35*
Fat sum (cm)	0.75*	0.83*	0.75*		0.77*	0.78*	0.28*	0.58*	0.91*	0.93*	0.40*
SCF (cm)	0.78*	0.82*	0.71*	0.77*		0.96*	0.32*	0.64*	0.52*	0.53*	0.32*
SCFmax (cm)	0.81*	0.84*	0.75*	0.78*	0.96*		0.33*	0.62*	0.53*	0.54*	0.38*
PPF (cm)	0.22*	0.24*	0.18	0.28*	0.32*	0.33*		0.13	0.15	0.18	0.01
PPFmax (cm)	0.58*	0.62*	0.61*	0.58*	0.64*	0.62*	0.13		0.42*	0.42*	0.41*
IPFa (cm)	0.59*	0.65*	0.58*	0.91*	0.52*	0.53*	0.15	0.42*		0.98*	0.34*
IPFp (cm)	0.61*	0.67*	0.61*	0.93*	0.53*	0.54*	0.18	0.42*	0.98*		0.36*
IPFo (cm)	0.44*	0.40*	0.35*	0.40*	0.32*	0.38*	0.01	0.41*	0.34*	0.36*	

*=$p<0.05$. BMI= Body mass index; WC= Waist circumference; Fat sum= (SCT + PPF + IPFp); SCF=Subcutaneous fat; SCFmax= Maximal subcutaneous fat; PPF= Preperitoneal fat; PPFmax= Maximal preperitoneal fat; IPFa= Intraperitoneal fat in relation to the anterior wall of the Aorta; IPFp= Intraperitoneal fat in relation to the posterior wall of the Aorta; IPFo= Intraperitoneal fat with posterior relation of the left lobe of the liver and the anterior wall of the aorta (minor omentum thickness).

Discussion

Our principal results was high or moderate correlation between anthropometric measurements of BMI and WC with US measurements ($p<0.05$) [BMI with: Fat sum (0.75), SCF (0.78), SCFmax (0.81), PPFmax (0.58), IPFa (0.59) and IPFp (0.61); and WC with: Fat sum (0.83), SCF (0.82), SCFmax

(0.84), PPFmax (0.62), IPFa (0.65) and IPFp (0.67)]. The BMI and WC measurements was high correlated (0.88).
Criteria for assessing abdominal fat measurements should consider the accuracy of the measurement, present small variation in the measurement error, be able to predict risks of health consequences, and be accessible and acceptable. Diagnosing childhood obesity is important, and our findings showed that a simple measure using BMI and WC correlated with US measurements.

To our knowledge, the study with the largest number of participants which considered the correlation between anthropometric measures (BMI and WC) and visceral and subcutaneous fat measurements was proposed by Ping et al., (2018), in a meta-analysis with 29 selected studies, which totaled 16,129 participants.[15] In that study, correlations were verified considering children, adults and older adults (0.75, visceral adipose tissue - WC, 0.65, visceral adipose tissue - BMI, 0.76 subcutaneous adipose tissue - WC, and 0.80, subcutaneous adipose tissue-BMI). An important limitation in the comparison of the correlations verified by Ping et al., (2018) and the current study is the age group. However, in the analysis with a group of children and adolescents (7–18 years) that included 3 studies, there was a correlation for measures of visceral adipose tissue - WC of 0.69 and subcutaneous adipose tissue - WC of 0.88, which seems to indicate that stronger correlations are found between the measures of WC and visceral and subcutaneous adipose tissue when comparing only groups under 18 years of age. Only one study was identified with children, which compared visceral adipose tissue and subcutaneous adipose tissue with BMI, with no summary by meta-analysis.[15]

Additionally, to Ping et al., (2018), other study of Semiz et al. (2006),[22] with a group of 51 obese children (11.5 2.6 years) and control group of 33 non-obese children (12.2 2.7 years), showed in obese group, BMI significantly correlated with US measurements of fat thicknesses. According to these findings they suggested that BMI is a useful parameter to predict body fat in children and adolescents.

Koot et al. (2014) studied a prospective cohort of 92 severely obese children and adolescents (age 13.9 ± 2.2 years, body mass index z score of 3.29 ± 0.33), evaluated the performance of US and two different methods measurement of waist circumference, using magnetic resonance as a reference standard.[23] They concluded that measuring waist circumference is the preferred non-invasive technique in daily clinical practice to assess the accumulation of visceral fat in children and adolescents with severe obesity. Vogelezang et al. (2015) evaluated 393 children aged 2 and 6 years, and observed a relationship between the thickness of subcutaneous and preperitoneal fat with overweight or obesity.[14] Gishti et al. (2015) studied 6523 6-year-old children and showed that the body mass index, the percentage of fat mass and the measurements of abdominal fat (subcutaneous and preperitoneal) were strongly positively correlated.[24] And they mention that the correlations between body mass index, fat mass percentage and waist circumference previously shown in adults and older children are also present in school-aged children.

Martin-Calvo et al. (2016), in a systematic review with meta-analysis that included 5 original articles, whose sample size ranged from 83 to 5355, and the age of the participants ranged from 4.9 to 19 years old, showed a strong correlation between the measurements of abdominal fat by DEXA and the BMI.[25] Thus, they conclude that BMI can be useful to define obesity when more sophisticated techniques are not available. Pirimoglu et al. (2019) rated 25 children aged 9 to 17 years. In conclusion, they evaluated the relationship between the volume of subcutaneous and visceral fat, diagnosed by MRI, overweight and obesity.[26] Novais et al. (2018) studied 423 adolescents from 14 to 19 years of age.[27] The intra-abdominal fat measurement by ultrasonography showed a positive and statistically significant correlation with waist circumference ($p < 0.001$).

Another important limitation found in the literature is that to date, no studies on this theme are available with children between 5 and 10 years of age. One study, by Brambilla et al., (2006) evaluated 407 children (7 to 16 years) and found a correlation between visceral adipose tissue with WC of 0.64, and visceral adipose tissue with BMI of 0.90, concluding that both WC and BMI can be considered good predictors of visceral adipose tissue. Our data corroborate the data from Brambilla et al (2006), with a high correlation between anthropometric BMI and WC (0.88), BMI and SCF (0.78), and WC and SCF (0.82) ($p<0.05$).[13]

Among the limitations of our study, we highlight that even though this is the first study with a population between 6 and 10 years of age, our sample of 100 children is considered small. Another important limitation that can be verified in studies with a larger sample is the influence of moderators such as sex, ethnicity, and social level.

Thus, we conclude that the use of anthropometric measures such as BMI and WC present a correlation with SCF, SCFmax, PPFmax, IPFa and IPFp measured by ultrasonography and should be widely used in the clinical environment as an indicator of abdominal fat in children aged 6 to 10 years (prepubertal phase).

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