Anthropometric Predictors of Abdominal Adiposity in Adolescents

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ABSTRACT

Sousa NPS, Salvador EP, Barros AK, Polisel CG, Carvalho WRG. Anthropometric Predictors of Abdominal Adiposity in Adolescents. JEPonline 2016;19(4):66-76. The aim of this study was to assess the predictive power of anthropometric indices and propose cut-off points for the diagnosis of abdominal adiposity in adolescents. This is a cross-sectional study with a sample of 516 students aged 10 to 19 yrs from 16 public schools of São Luís, Maranhão, Brazil. The following indicators were assessed: weight, height, body mass index (BMI), waist circumference (WC), conicity index (C Index), and weight-to-height ratio (WHtR). Abdominal adiposity was estimated by a cut-off score based on age and sex, and was further used as a reference to the ROC curve analysis. Of the anthropometric indicators assessed, WC and WHtR presented the largest areas under the ROC curve in the prediction of abdominal adiposity in both sexes. Cut-off points of abdominal adiposity for men and women were, respectively, BMI 21.82 kg·m⁻² and 22.30 kg·m⁻², WC 73.20 cm and 72.55 cm, and C index 1.13 and 1.04. WHtR was 0.45 for both sexes. The findings indicate that WHtR, WC, C index, and BMI can be used as high-sensitivity screening methods for assessing abdominal adiposity in adolescents.

Key Words: ROC Curve, Body Composition, Sensitivity, Specificity
INTRODUCTION

Obesity in childhood and adolescence is a complex public health problem. Its prevalence has increased worldwide over the past decades (17). According to the 2008-2009 Consumer Expenditure Survey (20), the prevalence of overweight and obesity among Brazilian adolescents was 20.5% and 4.9%, respectively. Obesity and metabolic diseases are at an alarming level globally and increasingly affect children and adolescents (24). Clinical and epidemiological studies have reported that body fat distribution is related to cardiovascular risk factors in adults, children, and adolescents (4,11,27).

Body fat distribution can be assessed by different methods, especially by anthropometric measurements since they have the advantage of being relatively simple, inexpensive, and non-invasive. They also have a good performance in the prediction of visceral fat and cardiovascular risk (26,33,36). Several anthropometric indicators are used to assess body composition, including BMI, which is the most widely used index to assess the nutritional status of adolescents given its low cost, simplicity, and high reproducibility. Also, BMI is recommended by the World Health Organization (28).

However, the literature reports that BMI should not be used alone for the assessment of body fat distribution, especially since normal weight individuals do not always have an adequate body fat percentage. This makes it necessary to consider the use of other instruments for such assessment (10,15). In addition to BMI, waist circumference (WC) in children and adolescents is correlated with abdominal adiposity and is associated with risk factors for cardiovascular disease (CVD) and metabolic disorders (29). It may also be used as a tool for identifying children and adolescents more likely to have these conditions (5).

The waist-to-height ratio (WHtR) is increasingly used as an indicator that considers the increase in waist relative to height (15). It is a commonly used measure to identify adolescents with high metabolic and cardiovascular risk. Its use is justified by the assumption that for a given height there is an acceptable amount of fat in the trunk area (26). The conicity index (C index), which assesses the relationship between body weight, height, and waist circumference, is a key indicator of central obesity. Individuals with a lower accumulation of fat in the central area have a body shape like a cylinder and those with greater accumulation of fat have a body shape like a double cone (i.e., two cones with common base) (31).

Anthropometric indicators emerge as simple, easily accessible, and non-invasive measures that can diagnose central adiposity. The analysis of the accuracy of these anthropometric indicators in the diagnosis of central adiposity is justified by the fact that function of adipose tissue can be influenced by its location (subcutaneous and visceral) (14). The subcutaneous tissue that is primarily located in the hips and thighs fulfills the classic requirements of adipose tissue, such as maintaining body temperature. The viscerally located fat, particularly in the region of the trunk (waist), is more metabolically active and exerts more influence on the development of insulin resistance, metabolic syndrome, type 2 diabetes mellitus, and cardiovascular disease (9,14). Thus, the purpose of this study was to assess the predictive power of anthropometric indices and propose cut-off points for the diagnosis of abdominal adiposity in adolescents.
METHODS

Subjects
This is a cross-sectional study. The target population of this study consisted of adolescents of both sexes (aged 10 to 19 yrs) enrolled in municipal, state and federal schools of São Luís, Maranhão, Brazil. The sample size was determined by estimating a proportion (22) based on a prevalence of overweight in adolescents of 20.5% (20), a suggested outcome prevalence of 26.9% (16), tolerable error of 5% (type I error), and power of the test of 85% (type II error), reaching 427 individuals with an additional 20% for possible losses or refusals, which resulted in a sample of 512 adolescents. According to the plan, the result was a final sample of 516 students.

All adolescents and their parents/guardians were informed about the study procedures and the possible risks before giving written informed consent to participate. The study was designed in accordance with the declaration of Helsinki for human studies and was approved by the Ethics Committee of the Federal University of Maranhão through the protocol number 251/11. The exclusion criteria included the presence of physical deficiencies (permanent or temporary) that made assessment impossible, pregnancy, breastfeeding, use of contraception, non-agreement of parents or students, and absence on the assessment day. All measurements were taken by a single investigator with same instrument, thus intra and inter observer variability for taking measurements were not significant. Decimal age was calculated as the difference between date of birth and date of data collection (13).

Evaluation
Anthropometric measurements of weight, height, and waist circumference (WC) were obtained using standardized techniques by well-trained researchers (21). Measurements were taken in duplicate and the mean considered for analysis. Body weight was measured and recorded within 0.1 kg with a calibrated electronic flat scale (Seca® 803, Hamburg, Germany). Height was measured and recorded with an accuracy of 1 mm with a portable stadiometer (Seca® 213, Hamburg, Germany). Body mass index (BMI) was calculated as weight (kg) divided by squared height (m²). Waist circumference was measured using a non-stretchable measuring tape without any pressure to body surface. It was recorded to the nearest 0.1 cm (Seca® 213, Hamburg, Germany) and measured as the smallest horizontal girth between the costal margins and the iliac crests at minimal respiration. For the classification of abdominal adiposity, the criteria proposed by Taylor et al. (33) were used and was further used as a reference to the ROC curve analysis. Waist-to-height ratio (WHR) was calculated by using the formula: [WC (cm)/height (cm)] (1). To avoid subjective error, all measurements were taken by the same person. Conicity index (C index) was determined by measuring weight, height, and waist circumference using the following mathematical equation: C index = WC (cm) / 0.109√body weight (kg)/height (m) (34).

Statistical Analyses
The SPSS version 19.0 (Statistical Package for the Social Sciences, Chicago, IL, USA) was used for database and statistical analysis. The results were expressed as mean, median, and standard deviation (mean or median ± SD). The normal distribution of the data was tested using the Kolmogorov-Smirnov test. The assessment of the means between the two groups was carried out with the Student's t-test for 2 independent samples (in case of normally
distributed variables) or Mann-Whitney U-test for 2 independent samples (if variables were not normally distributed). To evaluate the diagnostic performance of BMI, WC, C Index, and WHtR in detecting central adiposity, the ROC curve analysis was performed. The accuracy refers to the ability of BMI, WC, C Index, and WHtR to discriminate adolescents with central adiposity from those without excess body fat. Areas under the ROC curve and confidence intervals were determined. To better determine the optimal critical values of anthropometric indicators with greater accuracy in the overweight detection, sensitivity, and specificity were considered for each gender. For all tests, statistical significance was set at P< 0.05.

RESULTS

General features of the sample are reported in Table 1. The study contained 516 subjects (152 boys and 364 girls) with a mean age of 14.1 ± 2.4 and 14.7 ± 2.1, respectively. Girls were significantly older than boys. Body weight, BMI, WC, and WHtR were not significantly different between boys and girls. As expected, girls had a significantly lower height and C index than boys. Height and C index were significantly different between boys and girls (161 ± 0.1 cm vs. 157 ± 0.1 cm for height, P<0.001 and 1.14 ± 0.1 vs. 1.12 ± 0.1 for C Index, P=0.025, respectively).

Table 1. Anthropometric Characteristics of Boys and Girls Aged 10-19 Yrs (n = 516).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Boys (n = 152)</th>
<th>Girls (n = 364)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>14.1 ± 2.4</td>
<td>14.7 ± 2.1</td>
<td>0.003</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>57.2 ± 17.3</td>
<td>54.8 ± 11.7</td>
<td>0.128</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161 ± 0.1</td>
<td>157 ± 0.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>21.8 ± 4.6</td>
<td>22.3 ± 4.1</td>
<td>0.227</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>73.4 ± 11.6</td>
<td>72.1 ± 10.8</td>
<td>0.235</td>
</tr>
<tr>
<td>C Index</td>
<td>1.14 ± 0.1</td>
<td>1.12 ± 0.1</td>
<td>0.025</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.50 ± 0.1</td>
<td>0.50 ± 0.1</td>
<td>0.900</td>
</tr>
</tbody>
</table>

Abbreviations: BMI = body mass index; WC = waist circumference; C Index = conicity index; WHtR = waist-to-height ratio; *Student t test for independent samples; †Mann-Whitney test; aValues are given as mean ± SD (standard deviation); bValues are given as median ± SD (standard deviation)

The prevalence of excess abdominal adiposity in students was 32.8%, with 34.9% in boys and 31.9% in girls. There was a statistically significant difference in relation to anthropometric indices between the groups with and without central adiposity in both sexes (Table 2).
Table 2. Comparison of the Anthropometric Characteristics between No Adiposity and High Adiposity Groups.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Boys (n = 152)</th>
<th>Girls (n = 363)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Abdominal Adiposity (n = 99)</td>
<td>High Abdominal Adiposity (n = 53)</td>
<td>P</td>
<td>No Abdominal Adiposity (n = 248)</td>
</tr>
<tr>
<td><strong>BMI (kg·m⁻²)</strong></td>
<td>19.50 ± 3.9</td>
<td>23.8 ± 4.2</td>
<td>&lt;0.001</td>
<td>20.2 ± 3.2</td>
</tr>
<tr>
<td><strong>C Index</strong></td>
<td>1.11 ± 0.1</td>
<td>1.23 ± 0.1</td>
<td>&lt;0.001</td>
<td>1.09 ± 0.1</td>
</tr>
<tr>
<td><strong>WHtR</strong></td>
<td>0.42 ± 0.04</td>
<td>0.53 ± 0.04</td>
<td>&lt;0.001</td>
<td>0.42 ± 0.04</td>
</tr>
</tbody>
</table>

Abbreviations: BMI = body mass index; WC = waist circumference; C Index = conicity index; WHtR = waist-to-height ratio; Mann-Whitney test; Values are given as median ± SD (standard deviation).

The area under the ROC curve, the cut-off points, sensitivity, and specificity are presented in Table 3 and Figure 1. All anthropometric indices performed well in the identification of abdominal adiposity (confidence interval of 95% of the area under the ROC curve > 0.50).

Table 3. Area Under the ROC Curve, Sensitivity, and Specificity of Cut-Off Points According to Anthropometric Indicators.

<table>
<thead>
<tr>
<th>Anthropometric Index</th>
<th>ROC Curve (CI 95%)</th>
<th>Cut-Off Point</th>
<th>Sensitivity % (CI 95%)</th>
<th>Specificity % (CI 95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Boys</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>0.82 (0.76-0.89)</td>
<td>21.82</td>
<td>79.2 (CI 95%)</td>
<td>24.2 (CI 95%)</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>0.94 (0.91-0.97)</td>
<td>73.20</td>
<td>94.3 (CI 95%)</td>
<td>22.2 (CI 95%)</td>
</tr>
<tr>
<td>C Index</td>
<td>0.94 (0.90-0.97)</td>
<td>1.13</td>
<td>98.1 (CI 95%)</td>
<td>35.4 (CI 95%)</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.98 (0.97-1.00)</td>
<td>0.45</td>
<td>98.1 (CI 95%)</td>
<td>20.2 (CI 95%)</td>
</tr>
<tr>
<td><strong>Girls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>0.87 (0.83-0.91)</td>
<td>22.30</td>
<td>85.1 (CI 95%)</td>
<td>25.5 (CI 95%)</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>0.98 (0.97-0.99)</td>
<td>72.55</td>
<td>98.2 (CI 95%)</td>
<td>20.2 (CI 95%)</td>
</tr>
<tr>
<td>C Index</td>
<td>0.89 (0.85-0.92)</td>
<td>1.04</td>
<td>99.1 (CI 95%)</td>
<td>73.7 (CI 95%)</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.96 (0.95-0.98)</td>
<td>0.45</td>
<td>99.1 (CI 95%)</td>
<td>30.8 (CI 95%)</td>
</tr>
</tbody>
</table>

Abbreviations: CI95% = confidence interval; BMI = body mass index; WC = waist circumference; C Index = conicity index; WHtR = waist-to-height ratio. *Area under the ROC curve demonstrating discriminatory power for high abdominal adiposity (lower limit of CI95%>0.50).
Figure 1. Area Under the ROC Curve of Anthropometric Indicators in Predicting High Abdominal Adiposity for Girls and Boys.

DISCUSSION

In the present study, all anthropometric indices were able to predict central adiposity in the sample studied. However, BMI, an index widely used to define obesity in the adolescent population (12), presented lower accuracy. The use of BMI has been criticized for not being correlated with body fat composition and distribution (18), which allows for assessment errors. Individuals with a high amount of muscle mass may present high BMI values even if body fat is not excessive.

Waist circumference (WC) is one of the measures most commonly used to assess central obesity because it serves both as a standard measure in the definition and diagnosis of metabolic syndrome (32) in adolescents and as a screening tool for cardiovascular risk in adolescents (3). When compared to BMI, WC is the best indicator of visceral fat and cardiovascular risk factors (35).

The WHtR is an indicator that has been increasingly used as a good marker for assessing overweight in adolescents (3,15). Also, it has been proposed as a measure of cardiovascular risk regardless of age (1,30). Brambilla et al. (7), in a study involving 2,339 children and adolescents aged 8 to 18 yrs from the U.S. National Health and Nutrition Examination Survey 2003/2004, found that WHtR was the best predictor of central adiposity in children and adolescents and may be used for assessing body adiposity in the absence of skin folds.
In the present study, WC and WHtR showed high accuracy in the characterization of central adiposity in adolescents. Pelegrine et al. (25), in a survey of 1,268 adolescents aged 15 to 17 yrs in Southern Brazil, found that WC and WHtR have enough similarity to discriminate body fat. Likewise, Carneiro et al. (9), assessed the power to predict insulin resistance in a sample of 148 students aged 10 to 19 yrs from Western São Paulo/São Paulo, Brazil, and observed that the greatest ROC accuracy (>0.7) was obtained by WC and WHtR. Thus, WHtR and WC appear to be simple measures of central obesity that are associated with visceral fat and cardiometabolic risk factors (6,29) and can be used in the screening of adolescents of both sexes.

When compared to other parameters, the C index was not considered a good predictor of abdominal adiposity, except in boys. Pereira et al. (27), in a study of 113 female adolescents aged 14 to 19 yrs from Viçosa/Minas Gerais, observed that the C index was not a good indicator of body mass and total body fat. Similarly, Pelegrine et al. (25), found that the C index had lower capacity to discriminate body fat in adolescents. The C index was probably not a good indicator of central obesity in girls because the relationships between its measures are not good indicators of obesity (27). Moreover, the fat reserve in women tends to accumulate preferentially in the gluteofemoral region, while in men it accumulates in the central region of the body (19).

With regard to the cut-off point of these anthropometric indices, there is still no consensus on which should be used to define obesity (29) and central adiposity in children and adolescents. The cut-off points proposed in this study showed high sensitivity. However, although a certain cut-off point is often represented by the point where sensitivity and specificity are simultaneously higher, it is not always correct because the use of a very sensitive test in clinical practice can lead to indeterminate diagnoses (23). It is observed that the studies conducted with adolescents propose the cut-off point of WC and BMI through percentiles established according to age and sex (33,37).

However, Pellegrini et al. (25) proposed, as cut-off points of WC and BMI, the values of 75.7 cm and 22.7 kg·m⁻² for boys and 67.7 cm and 20.1 kg·m⁻² for girls, respectively. The cut-off points proposed by Pelegrine et al. (25) were close to those found in the present study (73.2 cm and 21.82 kg·m⁻² for boys, and 72.55 cm and 22.30 kg·m⁻² for girls). The cut-off point of WHtR suggested in the present study was 0.45 for both sexes, which is lower than the one proposed internationally (1). However, it is very close to the values presented by Beck et al. (4), who suggested a cut-off point of 0.40 for both sexes, and by Pelegrine et al. (25), who suggested cut-off points of 0.43 and 0.41 for men and women, respectively. With regard to the C index, the cut-off points proposed in the present study were 1.13 for boys and 1.04 for girls. Pelegrine et al. (25), proposed cut-off values of 1.12 for men and 1.06 for women, corroborating the values found in the present study.

The methodological diversity with respect to the measurement of anatomical measures can influence the values proposed by the studies, justifying the variety of existing cut-off points. In the case of Pelegrine et al. (25), for example, measurements were made according to the procedures of the Canadian Society for Exercise Physiology (8). In the present study, procedures were based on the Anthropometric Standardization Reference Manual (21). In this context, it is deemed important to conduct studies, particularly in the Brazilian population,
in order to standardize cut-off values and procedures to be used in the analysis and measurement of anthropometric indices.

CONCLUSIONS

The findings indicate that the anthropometric indicators WHtR, WC, C index, and BMI can be used as screening methods with high sensitivity in the assessment of abdominal adiposity in adolescents, with WHtR and WC presenting the highest sensitivity among boys and girls.

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