

Diagnostic accuracy of anthropometric indicators to predict excess body fat in adolescents aged 11-14 years

Acurácia de indicadores antropométricos de obesidade para predição do excesso de gordura corporal em adolescentes de onze a catorze anos

Kethrin Maila Weiss¹
Danielle Biazi Leal²
Maria Alice Altenburg de Assis^{2,3}
Andreia Pelegrini⁴

Abstract – The aim of this study was to evaluate the diagnostic accuracy of body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR) and conicity index (C index) for the prediction of excess body fat (estimated by skinfold thickness) and determine the cutoffs of anthropometric indicators (BMI, WC, WHtR and C index) that best predict excess body fat. Overall, 1,589 students (11-14 years old) from public and private schools of Florianópolis (southern Brazil) participated in this study. Anthropometric measurements of body weight, height, WC, and skinfolds (triceps and medial calf) were collected. ROC curves were used to compare the discriminatory power of BMI, WC, WHtR and C index in detecting adolescents with excess body fat (relative body fat estimated with skinfold thickness). All anthropometric indicators, except for C index in females, obtained good performance in the detection of excess body fat in both sexes, expressed as the area under the ROC curve. Cutoffs for boys and girls, respectively, associated with high excess body fat were BMI (20.7 and 19.7kg/m²), WC (68.7 and 65.9cm), WHtR (0.43 and 0.41cm), and C index (1.13 and 1.11). The study showed that, except for C index in females, BMI, WC and WHtR can be used to identify excess body fat in adolescents, considering the suggested cutoffs from this research.

Key words: Adolescents; Adolescent health; Anthropometry; Body composition.

Resumo – O objetivo deste estudo foi verificar a acurácia diagnóstica do índice de massa corporal (IMC), perímetro da cintura (PerC), razão cintura estatura (RCEst) e índice de conicidade (ÍndiceC) para detectar excesso de gordura corporal (estimada por meio de dobras cutâneas) e determinar os pontos de corte dos indicadores antropométricos (IMC, PerC, RCEst e ÍndiceC) que melhor predizem o excesso de gordura corporal. Participaram do estudo 1.589 escolares (11-14 anos) da rede de ensino pública e privada de Florianópolis, SC. Foram coletadas massa corporal, estatura, PerC e dobras cutâneas (tríceps e panturrilha medial). As curvas ROC foram utilizadas para comparar o poder discriminatório do IMC, PerC, RCEst e ÍndiceC na identificação de adolescentes com excesso de gordura corporal. Todos os indicadores antropométricos, exceto o ÍndiceC para as moças, obtiveram bom desempenho na detecção do excesso de gordura corporal em ambos os sexos. Os pontos de corte para rapazes e moças, respectivamente, associados com a gordura corporal elevada foram IMC de 20,7 e 19,7kg/m², PerC de 68,7 e 65,9cm, RCEst de 0,43 e 0,41cm e ÍndiceC de 1,13 e 1,11. Todos os indicadores antropométricos, exceto o ÍndiceC para o sexo feminino, podem ser empregados em adolescentes, a partir dos pontos de corte sugeridos nessa pesquisa, na detecção de excesso de gordura corporal.

Palavras-chave: Adolescentes; Antropometria; Composição corporal; Saúde do adolescente.

1 State University of Santa Catarina. Health and Sport Science Center. Florianópolis, SC, Brazil.

2 Federal University of Santa Catarina. Sports Center. Graduate Program in Physical Education. Florianópolis, SC, Brazil

3 Federal University of Santa Catarina. Health Sciences Center. Graduate Program in Nutrition. Florianópolis, SC, Brazil

4 State University of Santa Catarina. Health and Sport Science Center. Graduate Program in Human Movement Sciences. Florianópolis, SC, Brazil

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INTRODUCTION

Obesity, considered a worldwide public health problem, has reached increasingly higher proportions in individuals of all age groups and both sexes, regardless of socioeconomic status¹. Estimates for Latin America indicate that 3.8 million children under five years, 22.2 to 25.9 million school children, and 16.5 to 21.1 million adolescents are overweight or obese².

These values are worrying due to the greater predisposition of obese children and adolescents for the development of cardiovascular and pulmonary diseases, diabetes mellitus, biliary problems and some cancers³. In this sense, screening overweight in childhood and adolescence has been widely recommended, since this problem tends to remain during adulthood⁴⁻⁶.

In reference curves for Brazil⁶ and the International Obesity Task Force (IOTF)⁷, cutoffs for body mass index (BMI) in adolescents vary according to sex and age. In national references⁶, cutoffs for overweight in boys and girls aged 11-14 years range from 19.68 kg / m² to 22.00 kg / m² and 19.51 kg / m² to 23.28 kg / m², respectively. Cutoffs for obesity range from 25.58 kg / m² to 27.74 kg / m² in boys and from 23.54 kg / m² to 28.04 kg / m² in girls⁶. International reference⁷ that uses data from six countries (including Brazil) presents cutoffs for overweight for age group from 11 to 14 years ranging from 20.55 kg / m² to 22.96 kg / m² for boys and from 20.74 kg / m² to 23.66 kg / m² for girls. Cutoffs for obesity range from 25.10 kg / m² to 27.98 kg / m² for males and from 25.42 kg / m² to 28.87 kg / m² for females⁷. Early diagnosis of overweight and obesity is important so that preventive measures can be adopted. For this, there are different methods that can be used to assess body composition such as indirect (hydrostatic weighing, dual energy X-ray absorptiometry (DXA), plethysmography, MRI) and doubly indirect measurements (anthropometry and bioelectrical impedance). However, indirect methods have high costs and require trained technical staff for the assessment of measures⁸, while doubly indirect techniques, such as anthropometry, have been considered one of the simplest, fast, low cost forms and can be applied in population studies⁸.

In this context, different anthropometric indicators have been used as indirect measure in the identification of adolescents with overweight, high blood pressure and abnormal serum lipemia⁹⁻¹², which can be considered an important strategy for screening in the school environment because these methods are simple, fast, also allowing referral to a more careful clinical evaluation. Among these indicators, BMI is the most widely used because it is a simple, non-invasive, inexpensive method and has shown good agreement with adiposity indicators⁸. However, for being a measure that identifies total body volume, BMI has some limitations, mainly for expressing the sum of all body weight components (lean body mass, bone mass and fat mass), without distinguishing components⁶.

BMI, waist circumference (WC), waist-to-height ratio (WHtR) and conicity index (C index) have been used for the detection of cardiovascular risk^{9,10} and high body fat^{8,11-13}. Studies verifying the accuracy of anthro-

pometric indicators in predicting excess body fat have been conducted in students of different age groups (children and adolescents)^{11,13} from different regions of the state of Santa Catarina¹¹ from public schools¹¹ and have used BMI, WC and WHtR as anthropometric indicators¹³. In this sense, this study advances in research including adolescent schoolchildren (11-14 years) from public and private schools.

Despite the large number of studies on the prevalence of overweight in children and adolescents, there is still controversy about the anthropometric indicator that best predicts excess body fat. Thus, this study aims to determine the diagnostic accuracy of BMI, WC, WHtR and C index to detect excess body fat (estimated by skinfolds) and determine the cutoffs of anthropometric indicators (BMI, WC, WHtR and C index) that best predict excess body fat in schoolchildren from Florianópolis, Santa Catarina.

METHODOLOGICAL PROCEDURES

This is a school-based cross-sectional study carried out in Florianópolis from April to October 2007. Participating schools were selected in a random sampling process performed in a previous survey conducted in 2002 on the prevalence of overweight and obesity in Florianópolis¹⁴. In the 2007 survey, the same schools as in the previous investigation were included because the aim was to assess the trend in the prevalence of overweight / obesity and the body composition evolution of schoolchildren from the comparison of data obtained in 2002 and 2007.

In this study, the sample was composed of two groups of students: 1) those who, in the 2002 survey, aged 7-10 years and in 2007 aged 11-14 years; 2) students aged 11-14 years randomly selected in 2007, with equal probability in each of the schools. The inclusion of the first group intended to carry out follow-up of students who participated in the study in 2002¹⁴. The census performed by the Municipal Department of Education located 1,100 adolescents belonging to the first group. All were invited to participate in the study; however, only 735 students provided data for the 2007 survey. The sample size of the second group was calculated considering a school population of 28,060 students aged 11-14 years, prevalence of excess weight of 12.6%¹⁵, margin of error of three percentage points and design effect of 1.5. This calculation totaled 700 adolescents. With margins of error for tests losses, the final sample was composed of 800 adolescents.

The sampling procedure resulted in the participation of 865 new adolescents for the year 2007, and 735 adolescents who already participated in 2002. Eleven participants were excluded due to the absence of complete anthropometric data.

All students aged 11-14 years with no physical or intellectual disabilities and present in classroom on the day of data collection were considered eligible.

Through a questionnaire, adolescents self-reported information related to gender and age. Anthropometric measurements (weight, height, waist circumference and skinfold thickness of triceps and medial calf) were

collected according to standard procedures recommended by Lohman, Roche and Martorell¹⁶ by a team of evaluators trained by a PhD in Physical Education with level-2 certification by the International Society for the Advancement of Kinanthropometry (ISAK). Technical measurement errors were calculated in order to minimize the possibility of evaluation errors. Intra-class (intra-observer) and inter-class (between observers) correlation coefficients were > 0.95 for skinfolds, values considered acceptable for beginners and intermediate-level anthropometrists¹⁷.

Anthropometric measurements were performed with barefoot adolescents wearing light clothes. Body mass was obtained with the use of electronic scale (MARTE®, model P) with capacity of 180 kg and resolution of 100 grams. Height was measured with a portable stadiometer fixed to the wall (AlturaExata®) with zero point at ground level and resolution of 0.5 cm.

BMI was calculated using the ratio between body weight (kg) and squared height (in meters). WC was measured at the midpoint between the last rib and the upper edge of the iliac crest (natural waist), with an inelastic tape. This measurement was performed in duplicate and in the case of difference by more than 5%, a third measurement was performed. WHtR was determined by the ratio between waist circumference (cm) and height (cm). The C index was determined using body mass, height and waist circumference according to the equation of Valdez¹⁸: $C \text{ index} = \text{waist circumference (m)} / (0.109) * (\sqrt{\text{body mass (kg)} / \text{height (m)}})$.

Skinfold thickness (triceps and medial calf) were carried out with scientific skinfold caliper (Cescorf®) with resolution of 0.1 mm on the right side of the body. Measurements were performed in duplicate, and a third measurement was taken when skinfolds differ more than 1 mm. The average of readings at each location and the nearest two readings were used for analysis.

Body fat was assessed by relative body fat (% BF)¹⁹ for boys and girls using the sum of skinfold of triceps (TR) and medial calf (MC). Cutoffs used for excess body fat classification were recommended by Lohman¹⁶ according to sex and age. % BF above 20% for boys and 25% for girls was considered high¹⁶.

Data were processed using Epi-Data 3.2 software with double entry and typing errors being reviewed and corrected. The normality of frequency distribution of anthropometric measurements was verified by the Kolmogorov-Smirnov test. Descriptive statistics by mean, standard deviation, frequency distribution and 95% confidence intervals (95% CI) were used in data analysis. Gender differences in the means of anthropometric variables were analyzed using the Mann Whitney U test (nonparametric data).

The ROC curve analysis was used to evaluate the overall BMI, WC, WHtR and C index performance in detecting excess body fat (estimated by skinfolds). The area under the curve (AUC) was used as a global measure of BMI, WC, WHtR and C index accuracy the screen excess body fat. To determine the BMI, WC, WHtR and C index values that showed greater accuracy in the detection of excess body fat (best cutoffs), sensitivity and

specificity with respective 95% CI were calculated. The significance level for all analyses was $p < 0.05$. Statistical analyses were performed using the SPSS version 20.0 and MedCalc version 13.1.

The study was approved by the Ethics Committee for Research with Human Beings of the Federal University of Santa Catarina (Protocol No. 028/2006), and followed requirements and procedures of Resolution No. 466/12 of the National Council of Health, which regulates research involving humans²⁰. All participants agreed to participate in the study and their parents or guardians signed the Informed Consent Form.

RESULTS

Overall, 1,589 children (747 boys and 842 girls) with mean age of 12.9 years were evaluated. Students who refused to participate or for which parents have not provided written consent totaled 289 (148 males and 141 females), but were replaced by students previously indicated for replacement in the sampling process.

All anthropometric measurements showed significant differences in mean values between boys and girls, which are higher for male adolescents, except for skinfold TR and MC, sum of two skinfolds and % BF (Table 1).

Table 1. Comparison of the main general characteristics of the study population according to sex. Florianopolis, Santa Catarina (2007).

Characteristics	Boys (n=747)	Girls (n=842)	p-value*
	Mean (sd)	Mean (sd)	
Age (years)	12.93 (1.12)	12.94 (1.11)	0.201
Body mass (Kg)	50.32 (12.21)	47.85 (10.44)	<0.001
Height (cm)	157.95 (10.48)	155.87 (8.05)	<0.001
BMI (kg/m ²)	19.93 (3.29)	19.55 (3.29)	<0.001
WC (cm)	68.13 (7.92)	64.51 (6.73)	<0.001
WHtR	0.43 (0.04)	0.41 (0.03)	<0.001
C index (cm)	1.11 (0.05)	1.07 (0.04)	<0.001
TRSF (mm)	12.15 (5.46)	14.69 (5.04)	<0.001
MCSF (mm)	13.04 (6.25)	15.50 (5.92)	<0.001
2SF (mm)	25.20 (11.31)	30.20 (10.46)	<0.001
%BF	19.53 (8.32)	23.52 (6.38)	<0.001

BMI: body mass index; WC: waist circumference; WHtR: waist-to-height ratio; C index: Conicity index; TRSF: triceps skinfold; MCSF: medial calf skinfold; 2SF: sum of TR and MC skinfolds; % BF: relative body fat; * Mann-Whitney U test

In both sexes, it was possible to observe that all anthropometric indicators showed good performance in the identification of excess body fat, as indicated by AUC higher than 0.80, except for the C index. However, no significant values were observed only for C index of females ($p = 0.390$) (Table 2).

According to Figure 1, it is observed that in both sexes, the probability of detecting excess body fat, indicated by AUC was higher for all indicators except for C index in girls.

Table 2. Diagnostic accuracy of anthropometric indexes of obesity to detect excess body fat in adolescents according to sex. Florianópolis, Santa Catarina (2007).

Anthropometric Indicators	Boys			
	AUC ROC (95%CI)	BC	Sensitivity % (95%CI)	Specificity % (95%CI)
BMI	0.89 (0.86-0.91)*	20.7	71.4 (65.7-76.6)	90.5 (87.5-93.0)
WC	0.86 (0.83-0.88)*	68.7	75.2 (69.7-80.1)	81.1 (77.2-84.6)
WHtR	0.89 (0.87-0.91)*	0.43	81.2 (76.1-85.6)	84.8 (81.2-87.9)
C index	0.69 (0.66-0.72)*	1.13	51.8 (45.8-57.7)	79.1 (75.1-82.8)
Anthropometric Indicators	Girls			
	AUC ROC (95%CI)	BC	Sensitivity % (95%CI)	Specificity % (95%CI)
BMI	0.90 (0.88-0.92)*	19.7	82.8 (78.0-86.9)	79.4 (75.8-82.8)
WC	0.85 (0.83-0.88)*	65.9	70.6 (65.1-75.7)	83.1 (79.7-86.2)
WHtR	0.81 (0.79-0.84)*	0.41	73.3 (67.9-78.3)	74.3 (70.4-77.9)
C index	0.52 (0.48-0.55)	1.11	30.1 (24.9-35.6)	80.7 (77.2-84.0)

AUC: area under the curve; BMI: body mass index; WC: waist-to-height ratio; C index: Conicity index; BC: best cutoff; * P <0.05 (area under the ROC curve).

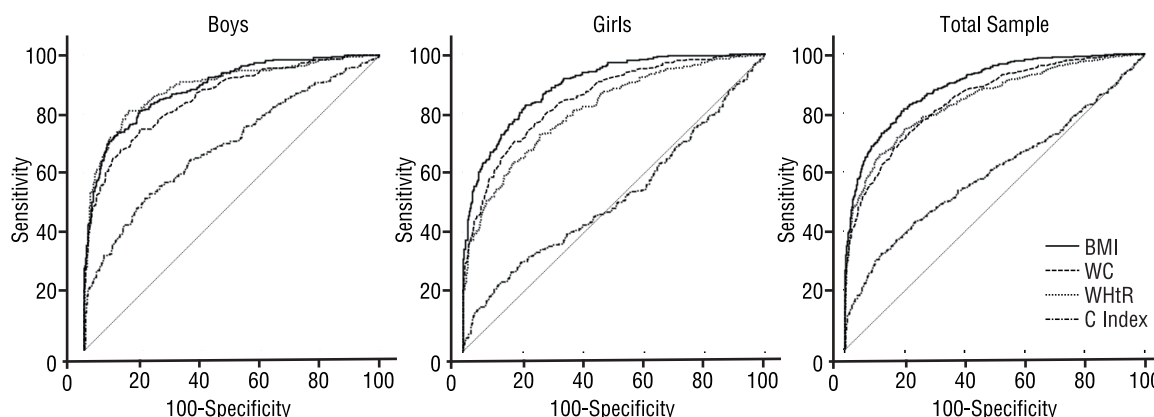


Figure 1. Areas under the ROC curve of BMI (body mass index), WC (waist circumference), WHtR (waist-to-height ratio), C Index (conicity index) in the prediction of excess body fat in boys, girls and total sample. Florianópolis, Santa Catarina (2007).

DISCUSSION

In the present study, all anthropometric indicators have obtained good results to diagnose high body fat, except for C index in girls. These results showed that excess body fat can be measured either by BMI, characterized as a general indicator of obesity, as by WHtR, WC and C Index (for males), the central obesity indicators.

These results corroborate the findings of Pelegrini et al.¹¹, who investigated adolescents aged 15-17 years of Florianópolis / SC and concluded that of the four anthropometric indicators (BMI, WC, WHtR and C Index), the first three had the highest AUC in relation to high body fat in both sexes. On the other hand, a study conducted in children aged 7-10 years in the same city using the sum of four skinfolds found that BMI had better diagnostic performance in screening excess body fat than WC or WHtR, although the three anthropometric indicators (BMI, WC or WHtR) showed significant AUC values¹³. Such comparisons should be made with caution, especially for different age groups analyzed in each study.

Regarding international studies, a study conducted with American children and adolescents (5-18 years), participating in The National Health and Nutrition Examination Survey (NHANES: 1999-2004), also found that BMI and % BF derived from skinfolds showed reasonable agreement in adiposity classification²¹. Neovius et al.²² conducted a study with Swedish adolescents aged 17 in 2005 using plethysmography (indirect method of assessing body composition) as the gold standard and found that BMI and WC are good obesity indicators in adolescence. In Iranian adolescents aged 10-18 in 2007²³, the analysis of the accuracy of BMI, WC, WHtR and the sum of four skinfolds (triceps, biceps, subscapular and supra-iliac) as predictors of % BF (estimated by bioimpedance) showed that BMI was better than other anthropometric indicators in predicting % BF and diagnosing excess adiposity. In Turkish adolescents aged 10-15 years, a study investigated BMI, WC and waist-to-hip ratio in screening obesity estimated by % BF by skinfolds, BMI and WC were considered the most important indicators to predict high % BF²⁴.

The findings of this study indicate that the best cutoffs for detecting excess body fat (based on the sum of two skinfolds) were for BMI 20.7 kg / m² for boys and 19.7 kg / m² for girls. Therefore, the values in this sample are within cutoffs suggested by national⁶ and international⁷ references for overweight classification except for females for the IOTF reference⁷. The cutoffs for obesity according to these references are greater than those of the present study. However, the proposed cutoffs are indicating that even below values proposed by Conde and Monteiro⁶ and IOTF⁷, adolescents already have excess body fat.

For WHtR, it was observed that the best cutoff to detect excess body fat was 0.43 cm and 0.41 cm for males and females, respectively. These cutoffs corroborate those found in adolescents aged 15-17 years living in Florianópolis (SC) and in midwestern state of Santa Catarina (0.43 cm for boys and 0.41 cm for girls)¹¹. It is noteworthy that such cutoffs are below those internationally recommended to detect abdominal obesity in both sexes and at all ages (0.50 cm)²⁵. However, a recent study in children aged 7-10 years of Florianópolis (SC)¹³ also showed lower values (0.46 for boys and 0.45-0.43 for girls) compared to this proposal.

It was observed that the C Index proved to be a good predictor of high body fat only for boys, indicating a cutoff of 1.13. In Florianópolis (SC) and midwestern state of Santa Catarina, it was observed that for the diagnosis of excess body fat, cutoffs for C Index were 1.12 for boys and 1.06 for girls¹¹. These data, especially for boys, may be justified because boys tend to have more central body fat distribution compared to girls, whose largest fat tissue deposit occurs in the regions of thighs and hips.

This study used the ROC curve analysis to determine cutoffs of anthropometric indicators of obesity that best predict excess body fat in adolescents. The comparison of the results of this study with previous studies should be analyzed with caution, because while some studies used skinfolds as a reference measure to estimate body fat, others used indirect

methods such as DXA and plethysmography. In addition, differences in sample size and age range of participants should also be considered.

Among the strengths of this study, the representative sample of adolescents of Florianópolis, SC stands out. One limitation was the fact of not using an indirect method considered “gold standard” for analysis of body composition. The use of this type of method impairs its use in population studies due to the high cost. However, skinfold measurements have been used in other diagnostic performance studies as a reference measure^{11,24}.

Despite the cross-sectional design of the study, which does not allow identifying causality among variables, it is emphasized that in diagnostic accuracy studies, as is the case of this study, the study design does not seem to influence the results, because variables are collected at the same time.

CONCLUSION

This study showed that all analyzed anthropometric indicators can be used to detect high body fat in this population, except for C Index for women. Thus, these findings support the use of anthropometric indicators as a non-invasive, low-cost and easy-to-apply assessment for use in the nutritional monitoring of adolescents.

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CORRESPONDING AUTHOR

Andreia Pelegrini
Centro de Ciências da Saúde e do
Esporte - CEFID
Rua Pascoal Simone, 358 -
Coqueiros -
CEP: 88080-350 - Florianópolis -
SC, Brasil.
E-mail: andreia.pelegrini@udesc.br