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Sensitivity and specificity of criteria for classifying body mass index in adolescents

ABSTRACT

OBJECTIVE: To estimate the prevalence of overweight among adolescents using different body mass index (BMI) classification criteria, and to determine sensitivity and specificity values for these criteria.

METHODS: Weight, height, and tricipital and subscapular skinfolds in 934 adolescents (462 males and 472 females) aged 14-18 years (mean age 16.2; SD=1.0) of the city of Florianópolis, Southern Brazil, in 2001. Percent fat estimated based on skinfold measurements (≥25% in males and ≥30% in females) was used as a gold-standard for determining specificity and sensitivity of BMI classification criteria among adolescents.

RESULTS: The different cutoff points used for classifying BMI in general resulted in similar prevalence of overweight ($p>0.05$). Sensitivity of the evaluated criteria was high for males (85.4% to 91.7%) and low for females (33.8 to 52.8%). Specificity of all criteria was high for both sexes (83.6% to 98.8%).

CONCLUSIONS: Estimates of prevalence of obesity among adolescents using different BMI classification criteria were similar and highly specific for both sexes, but sensitivity for females was low.

DESCRIPTORS: Adolescent. Body Mass Index. Sensitivity and Specificity. Overweight, diagnosis. Obesity, diagnosis. Nutritional Status.

INTRODUCTION

Screening for excess weight (overweight/obesity) among youths has been widely recommended,[24] given the rapid increase in prevalence, its health-related implications, and the possibility of transfer to adult age. This has underscored the need for a simple, safe, valid, and precise instrument for evaluating nutritional status.

The Body Mass Index (BMI) is recommended by the World Health Organization (WHO)[24] as an indicator for evaluating the nutritional status of adolescents, and has been widely employed in epidemiological studies.[5,6] This is due to the fact that BMI is based on easily obtained measures, has high precision, does not require sophisticated equipment or specialized personnel, and shows good ability to discriminate excess body fat in adolescents.[13,14,19]

In spite of the consensus surrounding BMI, there is substantial divergence with respect to the cutoff points that should be employed to define excess body weight in adolescents based on this indicator. Among the several criteria available in the literature, those proposed by the International Obesity Task Force (IOTF – Cole et al[2] 2000), WHO[24] (1995), the Centers for Disease Control and

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Prevention (CDC – Kuczmarski et al[11] 2002), and Must et al[15] (1991), are the most widely used. More recently, Conde & Monteiro[3] (2006) proposed critical BMI values for Brazilian children and adolescents.

Unlike those for adults,[24] cutoff points for adolescents have been established in an arbitrary manner, not grounded on health considerations.[17] Moreover, there is limited information on the validity of such criteria, especially among populations different from those for which they were developed.[17]

Studies comparing prevalence of excess weight according to different BMI classification criteria and evaluating the sensitivity and specificity of these criteria in adolescents are scarce,[16,19] especially in Brazil.[21] The aim of the present study was to investigate prevalence of overweight among adolescents using five different BMI classification criteria, and to determine sensitivity and specificity values for these criteria.

METHODS

Sampling in this survey was carried out in two stages. In the first, the 98 secondary schools (both public and private) in the municipality of Florianópolis, Southern Brazil, were listed in increasing order of number of students (small, up to 200 students; medium, 200 to 499 students; large, 500 or more students). Twenty-one schools were then systematically selected, of which 14 were public and seven private. In the second stage, after obtaining authorization from the schools' managers, classes were randomly selected so as to compose the sample.

As the present study was nested within a larger survey, sample size was determined by assuming 60% prevalence of physical inactivity, with 95% confidence intervals (95%CI), a four percentage point error, and an additional 30% to allow for potential losses and refusals (population estimated at 22,067 based on data from 2001). These assumptions led to a sample size of 731 subjects. The final sample included 1,062 adolescents of both sexes, aged 14-18 years, previously authorized by a parent or guardian to take part in the survey. Adolescents with limitations that prevented anthropometric measurement or who were pregnant were excluded from the sample. According to previous work,[18] this sample size would suffice for the present analysis. Of the 1,062 adolescents that participated in data collection, seven were excluded due to lack of information on sex and/or age, and 121 (52 males and 69 females) refused to undergo anthropometric measurement. The final sample included 934 adolescents (462 males and 472 females) aged 14 to 18 years (mean age 16.2; sd = 1.0).

Data collection was carried out between May and August 2001 by a team of four previously trained researchers. Weight and height measures were always obtained by the same researcher (intraclass correlation coefficients (ICC): weight = 0.99; height = 0.98). Subscapular (SB) and tricipital (TR) skinfold (SF) thickness (ICC SB = 0.96; TR = 0.98) was measured exclusively by another researcher. Measurements were recorded by the other researchers.

Weight was measured using a Filizola electronic scale with 100 g precision, with the subject wearing light clothing and no shoes. Height was measured using a non-extensible tape measure with 1 cm precision, fixed to the wall, on a plain support surface. Subjects were measured without shoes, arms held straight alongside the body, and in apnea. Both measures were taken in duplicate, according to the procedures described by Gordon et al[9] (1988), the final value being considered as the mean of the two measurements.

SB and TR SF thickness was measured according to Harrison[10] (1988), using a Cescorf-type caliper with 0.01 mm resolution. We performed three separate measurements in the same place, in an alternate manner. A further series of three measurements was performed in case the three previous measures diverged by more than 5%. The mean of the three measurements was used as the final value for skinfold thickness.

BMI was determined based on the ratio between weight and height (BMI = weight [kg]/height [m^2]). The quantity of fat in relation to the body mass (%F) was estimated using equations specific for adolescents, proposed by Lohman[12] (1986), based on the measures of TR and SB SF thickness.

For data analysis, we used Student's t test for unpaired measurements in order to compare the mean anthropometric measures of males and females. We determined prevalences of excess weight (grouped into the risk categories *overweight* and *obesity*), with their respective 95%CI, based on the critical BMI values derived from the five criteria analyzed*:* Conde & Monteiro[3] (2006); IOTF[2] (2000); CDC[11] (2002); WHO[24] (1995); and Must et al[15] (1991). Differences between these prevalences were evaluated using the McNemar test.

We estimated the sensitivity and specificity of each BMI classification criterion using %F as a gold-standard. Excess weight was defined as body fat values greater than 25% in male, and 35% in female adolescents. These cutoff points have been used in other works assessing the validity BMI classification criteria in adolescents,[16,21] and are shown to be associated with risk of disease.[23]

Sensitivity was defined as the percentage of adolescents classified as with excess body fat (excess weight) using the BMI classification criteria and by the gold-standard (true positives). Specificity was defined as the percentage of adolescents classified as without excess body fat (non-excess weight) using the BMI classification criteria compared to the gold-standard (true negatives).

Statistical analyses were carried out using Stata 10.0 software and adopting a 5% significance level.

The study was approved by the Research Ethics Committee of the Federal University of Santa Catarina (process no. 066/2000).

RESULTS

Mean SF thickness (SB and TR) and %F were statistically higher among females (p<0.001), whereas mean BMI was higher among males (p=0.02) (Table 1).

No significant differences were found in terms of excess weight prevalence when using the different BMI classification criteria, with the exception of male subjects, for whom the critical BMI values proposed by Conde & Monteiro[3] yielded prevalences 4% to 8% higher than the remaining criteria (p<0.05) (Table 2).

Table 3 presents values of sensitivity and specificity for the five BMI classification criteria. Assuming %F ≥ 25% for males and ≥ 30% for females as the gold-standard for excess weight, for all five criteria, specificity was higher than sensitivity among both males and females.

Sensitivity was high for males (> 85%) and low for females (< 60%). The criteria proposed by Conde & Monteiro[3] showed higher sensitivity when compared to the remaining criteria. However, these differences were small (≈6%), especially when compared to those of IOTF,[2] Must et al,[15] and WHO,[24] for males, and when compared to IOTF[2] for females.

All BMI criteria evaluated (Table 3) showed high specificity. Specificity was higher for females (> 95%) than for males (> 80%). The critical values proposed by Conde & Monteiro[3] showed slightly lower specificity (≈7%) for males than the remaining criteria. Among females, sensitivity was similar in for all criteria evaluated.

DISCUSSION

The use of the critical BMI values for defining excess weight among adolescents proposed by IOTF,[2] CDC,[11] WHO,[24] and Must et al,[15] resulted in similar prevalences of excess weight. The critical values proposed by Conde

Table 1. Mean and standard deviation of anthropometric indicators among adolescents. Florianópolis, Southern Brazil, 2001.

Variable	All (n= 934)	Male (n= 472)	Female (n= 462)	p
	Mean (sd)	Mean (dp)	Mean (sd)	
BMI (kg/m²)	21.1 (3.1)	21.3 (3.3)	20.9 (2.8)	0.021
Subscapular skinfold (mm)	10.8 (6.0)	9.2 (5.8)	12.3 (5.8)	<0.001
Tricipital skinfold (mm)	12.9 (6.1)	9.2 (4.8)	16.4 (5.3)	<0.001
%F (%)	20.1 (8.0)	15.2 (6.8)	24.8 (6.0)	<0.001

BMI: Body mass index
%F: percent fat estimated based on skinfold thickness

Table 2. Prevalence of excess body weight according to body mass index classification criteria among adolescents. Florianópolis, Southern Brazil, 2001.

Variable	Critérios de classificação do IMC				
	Conde & Monteiro[3] % (95% CI)	IOTF[2] % (95% CI)	CDC[11] % (95% CI)	WHO[24] % (95% CI)	Must et al[15] % (95% CI)
Todos	16.8 (14.3;19.3)	13.7 (11.5;15.9)	12.7 (10.6;14.9)	12.9 (10.7;15.1)	12.9 (10.7;15.1)
Male	22.6 (18.8;26.5)	16.8 (13.3;20.2)	15.9 (12.5;19.2)	16.2 (12.8;19.6)	16.2 (12.6;19.6)
Female	11.0 (8.2;13.9)	10.7 (7.9;13.5)	9.6 (6.7;12.2)	9.5 (6.8;12.2)	9.5 (6.8;12.2)
Male (years)					
14-15	24.0 (18.1;29.9)	16.7 (11.5;21.8)	15.7 (10.7;20.7)	16.7 (11.8;22.1)	16.7 (11.8;22.1)
16-18	21.6 (16.5;26.7)	16.9 (12.2;21.5)	16.0 (11.5;20.7)	15.6 (11.1;20.1)	15.5 (11.1;20.1)
Female (years)					
14-15	10.7 (6.5;14.9)	9.3 (5.4;13.2)	8.8 (5.0;12.7)	8.8 (5.0;12.7)	8.8 (5.0;12.7)
16-18	11.4 (7.5;15.4)	11.8 (7.8;15.8)	10.2 (6.5;14.0)	10.1 (6.4;13.9)	10.1 (6.4;12.9)

BMI: Body mass index
IOTF: International Obesity Task Force
CDC: Centers for Disease Control and Prevention
WHO: World Health Organization

Table 3. Sensitivity and specificity of body mass index classification criteria in comparison to percent fat estimated based on skinfold thickness. Florianópolis, Southern Brazil, 2001.

BMI classification criteria	Male ≥25 %G		Female ≥30 %G	
	Sensitivity (95%CI)	Specificity (95%CI)	Sensitivity (95%CI)	Specificity (95%CI)
All				
Conde & Monteiro[3]	91,7 (80,0;97,7)	85,3 (81,4;88,6)	42,1 (32,6;52,0)	97,1 (96,0;99,2)
IOTF[2]	87,5 (74,8;95,3)	91,4 (88,2;93,3)	41,1 (31,7;51,0)	98,3 (96,4;99,4)
CDC[11]	85,4 (72,2;93,9)	90,3 (89,1;94,6)	36,4 (27,4;46,3)	98,3 (96,4;99,4)
WHO[24]	87,5 (74,8;95,3)	91,0 (88,9;94,4)	37,4 (28,2;47,2)	98,6 (96,8;99,6)
Must et al[15]	87,5 (74,8;95,3)	91,0 (88,9;94,4)	37,4 (28,2;47,2)	98,6 (96,8;99,6)
14-15 years				
Conde & Monteiro[3]	95,0 (75,1;99,9)	83,6 (77,4;88,7)	52,8 (35,5;69,6)	97,8 (94,3;99,4)
IOTF[2]	90,0 (68,3;98,8)	91,3 (86,2;94,9)	47,2 (30,4;64,5)	98,3 (95,2;99,7)
CDC[11]	85,0 (62,1;96,8)	91,8 (86,8;95,3)	41,7 (25,5;59,2)	97,8 (94,3;99,4)
WHO[24]	90,0 (68,3;98,8)	90,8 (85,7;94,6)	44,4 (27,9;61,9)	98,3 (95,2;99,7)
Must et al[15]	90,0 (68,3;98,8)	90,8 (85,7;94,6)	44,4 (27,9;61,9)	98,3 (95,2;99,7)
16-18 years				
Conde & Monteiro[3]	89,3 (71,8;97,7)	86,6 (81,4;90,8)	36,6 (25,5;48,9)	96,4 (95,3;99,7)
IOTF[2]	85,7 (67,3;96,0)	92,5 (87,1;94,8)	38,0 (26,8;50,3)	98,4 (95,3;99,7)
CDC[11]	85,7 (67,3;96,0)	92,4 (88,1;95,5)	33,8 (23,0;46,0)	98,8 (96,1;99,9)
WHO[24]	85,7 (67,3;96,0)	91,9 (88,7;95,9)	33,8 (23,0;46,0)	98,8 (96,1;99,9)
Must et al[15]	85,7 (67,3;96,0)	91,9 (88,7;95,9)	33,8 (23,0;46,0)	98,8 (96,1;99,9)

%F: percent fat estimated based on skinfold thickness
BMI: Body mass index
IOTF: International Obesity Task Force
CDC: Centers for Disease Control and Prevention
WHO: World Health Organization

& Monteiro[3] yielded higher prevalences among males than the remaining criteria. It is likely that the small differences in the cutoff points of IOFT,[2] CDC,[11] Must et al,[15] and WHO[24] for adolescents aged 14 to 18 years, in addition to the distribution of BMI values in the studied population, have led to the differences in prevalence of excess weight detected between these criteria. However, the higher prevalences found using the criteria proposed by Conde & Monteiro[3] can be explained by the critical BMI values adopted by these authors, which are lower than those of the other criteria.

Our results are similar to those reported in other surveys with adolescents,[8,22] including a study carried out in Brazil,[1] which also failed to detect significant differences in prevalence of excess weight as defined by the criteria proposed by IOTF,[2] WHO,[24] and Must et al.[15]

Though not significant, Vieira et al[21] (2006) found discrepancies (differences of up to 21.3%) between excess weight prevalences determined using different BMI classification criteria (percentile 85 of Brazilian youths, IOTF,[2] CDC,[11] and Must et al[15]), among Brazilian adolescents (12-19 years).

We were unable to locate any studies comparing prevalence of excess weight determined based on the critical values recommended by Conde & Monteiro[3] with the other criteria evaluated in the present study. However, the use of BMI percentile 85 from the same population studied by Conde & Monteiro[3] generated prevalences of excess weight that were higher than those detected using other criteria.[20,21]

Differences in age group, sampling procedures, and distribution of BMI values in the population/sample may explain part of the divergence between different studies of prevalence of BMI in adolescents determined using different criteria.[8]

There is no consensus regarding the establishment of a universal criterion for classifying BMI in adolescents. This is due to the changes in body composition resulting from the process of sexual maturation, which vary greatly according to age, sex, and ethnicity, and which are not captured precisely by the BMI.[4,13]

As described in other Brazilian[1,20,21] and international[8,16] studies, the BMI classification criteria for adolescents evaluated here show higher specificity than sensitivity.

The sensitivity of different the criteria evaluated in the present study was higher to that reported in some studies[1,16,20] and similar to that reported in others.[19,21] The use of these criteria for diagnosing excess weight as determined by excess body fat should accurately classify approximately 85-90% of males (10-15% false positives) and results in a large proportion of false-negative results among females (50-70%).

The low sensitivity of BMI classification criteria among females, especially those aged 16-18 years, may be a consequence of the use of a single value to define excess body fat at all ages, which may lead to overestimation of the prevalence of excess body fat. On the other hand, the critical BMI values evaluated may be too high to diagnose excess body fat in this subgroup.[16]

The slightly higher sensitivity found for the critical values proposed by Conde & Monteiro[3] resulted in differences below 10% in the number of false-negatives when compared to the remaining criteria, especially IOTF,[2] Must et al,[15] and WHO[24] for males and IOTF[2] for females.

Other studies using BMI percentile 85, specific for sex and age, of the same reference population used by Conde & Monteiro[3] (Brazilian adolescents), also found that critical values of BMI for the Brazilian population were more sensitive than those suggested by Must et al,[15] IOTF,[2] and CDC.[11]

Part of the variability in the sensitivity of BMI classification criteria for adolescents in the different studies may be explained by differences in the methods employed for estimating %F; in the critical values used to define excess body fat based on this indicator;[17] and on the age group of the study population; as well as by the influence of factors such as ethnicity, culture, and environment on indicators of body composition.[17]

As seen in previous work,[1,8,16,20,21] the BMI classification criteria evaluated in the present study were highly specific (between 83.6% and 98.8% specificity), especially for females, with little variation between the different criteria. Although they result in lower specificity, the cutoff points suggested by Conde & Monteiro[4] strengthen the results of previous studies that used BMI percentile 85 of the same reference population.[20,21]

Irrespective of the criteria used to classify BMI, we found that the number of false-positive results was always below 10%.

Given the good ability of BMI to discriminate excess body fat in adolescents,[13,14,19] the major challenge remains that of establishing cutoff points that will allow us to reduce the number of false-negatives, especially among females (increase sensitivity), while maintaining the high levels of specificity already seen for the different criteria, in addition to ensuring that these levels are associated to health hazard.[7]

Since our measurements were carried out independently by two researchers, and considering that both were blinded as to the hypotheses of the present study, we believe the possibility of observer bias may be discarded. Furthermore, reproducibility of anthropometric measurements was high (ICC >0.95).

Although the refusal rate for the different anthropometric measurements was relatively low (≈12%), we cannot discard the possibility of selection bias, given that we were unable to compare these characteristics between participants and non-participants.

Another limitation to be considered when interpreting the present results is the use of %F determined based on skinfold thickness measurements. This procedure is expected to underestimate the amount of fat in leaner adolescents while overestimating this amount in fatter ones.

We conclude that the BMI classification criteria analyzed in the present study provide similar estimates of prevalence of excess weight, with the exception of the criteria proposed by Conde & Monteiro,[3] which result in higher prevalence among males.

Sensitivity of the criteria evaluated was high for males and low for females; specificity was high for adolescents of both sexes. Thus, the cutoff points of these criteria allowed for accurate classification of almost all adolescents without excess body fat, with very few false-positives. On the other hand, these criteria resulted in a high number of false-negatives among female adolescents.

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