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Body mass index for predicting hyperglycemia and serum lipid changes in Brazilian adolescents

Índice de massa corporal para predizer hiperglicemia e alterações lipídicas em adolescentes brasileiros

ABSTRACT

OBJECTIVE: To determine the best cut-offs of body mass index for identifying alterations of blood lipids and glucose in adolescents.

METHODS: A probabilistic sample including 577 adolescent students aged 12-19 years in 2003 (210 males and 367 females) from state public schools in the city of Niterói, Southeastern Brazil, was studied. The Receiver Operating Characteristic curve was used to identify the best age-adjusted BMI cut-off for predicting high levels of serum total cholesterol (≥150mg/dL), LDL-C (≥ 100mg/dL), serum triglycerides (≥100mg/dL), plasma glucose (>100mg/dL) and low levels of HDL-C (< 45mg/dL). Four references were used to calculate sensitivity and specificity of BMI cut-offs: one Brazilian, one international and two American.

RESULTS: The most prevalent metabolic alterations (>50%) were: high total cholesterol and low HDL-C. BMI predicted high levels of triglycerides in males, high LDL-C in females, and high total cholesterol and the occurrence of three or more metabolic alterations in both males and females (areas under the curve range: 0.59 to 0.67), with low sensitivity (57%–66%) and low specificity (58%–66%). The best BMI cut-offs for this sample (20.3 kg/m² to 21.0 kg/m²) were lower than those proposed in the references studied.

CONCLUSIONS: Although BMI values lower than the International cut-offs were better predictor of some metabolic abnormalities in Brazilian adolescents, overall BMI is not a good predictor of these abnormalities in this population.

DESCRIPTORS: Adolescent. Body Mass Index. Risk Factors. Sensitivity and Specificity. Hyperglycemia. Hyperlipidemias. Diagnostic Techniques and Procedures.

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RESUMO

OBJETIVO: Determinar os melhores pontos de corte do índice de massa corporal (IMC) para identificar alterações no perfil lipêmico e glicêmico em adolescentes.

MÉTODOS: Foram avaliados 577 adolescentes de 12 a 19 anos (210 meninos e 367 meninas) em uma amostra probabilística de estudantes de escolas estaduais da cidade de Niterói (RJ), em 2003. Foi utilizada a curva *Receiver Operating Characteristic* para identificar o melhor ponto de corte, ajustado para idade, para predizer valores elevados de colesterol total sérico (≥150mg/dL), LDL-C (≥100mg/dL), triglicérides (≥100mg/dL), glicose plasmática (>100mg/dL) e baixos valores de HDL-C (<45mg/dL). Quatro referências foram utilizadas para verificar a sensibilidade e especificidade dos pontos de corte: uma nacional, uma internacional e duas americanas.

RESULTADOS: As alterações metabólicas de maior prevalência (>50%) foram: colesterol total elevado e HDL-C baixa. O IMC foi capaz de predizer valores elevados de triglicérides nos meninos, LDL-C nas meninas e colesterol total e presença de três ou mais alterações metabólicas em ambos os sexos (área sob a curva: 0,59 a 0,67), embora com baixa sensibilidade (57% a 66%) e especificidade (58% a 66%). Os melhores pontos de corte na amostra estudada (20,3 kg/m² a 21,0 kg/m²) foram inferiores aos propostos pelas outras referências.

CONCLUSÕES: Embora valores de IMC menores do que os das referências internacionais tenham sido preditores de algumas alterações metabólicas em adolescentes brasileiros, o IMC não foi um bom índice para identificar estas anormalidades na amostra estudada.

DESCRITORES: Adolescente. Índice de Massa Corporal. Sensibilidade e Especificidade. Fatores de Risco. Hiperglicemia. Hiperlipidemias. Técnicas de Diagnóstico e Procedimentos.

INTRODUCTION

In Brazil, overweight prevalence in adolescents tripled over a period of 20 years[23] with increased risk for cardiovascular diseases resulting from metabolic abnormalities.[19] Since obese adolescents tend to remain obese in adulthood,[13] early identification of youths at risk is of most interest to public health policies as they have a higher risk for mortality and morbidity.[7,11]

Body mass index (BMI) is used to evaluate overweight and obesity. It is correlated with body fat, it is easily measured and can be used for both adolescent and adult evaluation.[14,25] The cut-offs used for definition of overweight and obesity, generally in the 85th and 95th percentiles of the distribution based on American population data,[17,20] were statistically defined, and they are not associated to morbidity or mortality.

BMI accuracy for predicting body fat in adolescents has been widely investigated and it has shown better specificity than sensitivity.[4,24] However, BMI validation depends on its ability of predicting body fat and mostly future risks to health, associated with metabolic changes, such as hyperglycemia, and dyslipidemias.

Recently the International Obesity Task Force (IOTF[5] 2000) established BMI cut-offs for children and adolescents, corresponding to 25 kg/m^2 for overweight and 30 kg/m^2 for obesity, based on BMI data collected in six different regions.[5] This criterion is known as "international reference" although two studies have evaluated its association with morbidity in adolescents.[3,16]

The present study aimed to determine the best cut-offs of body mass index for identifying alterations of blood lipids and glucose in adolescents.

METHODS

A probabilistic sample including adolescent students aged 12–19 years, from 5th grade of public elementary school to 3rd grade of high school, in the city of Niterói, Southeastern Brazil, was studied. In 2001, the base year for the sample estimate, 25,102 students aged 12–19 years were enrolled in 33 public schools in the city of Niterói.

The sample size was based on a 25% prevalence of hypercholesterolemia,[10] at 95% confidence level, with 5% precision. Due to cluster sampling by random class selection, the sample size was increased by 20%, making a total of 600 students.[18] As 30% non-response was anticipated according to a pilot study, the total sample should comprise 780 adolescents (26 classes with 30 students each). Twenty-eight classes were sampled, because 13 out of the 33 schools had classes with less than 30 students.

This sample can adequately evaluate sensitivity and specificity, according to the sample size formula for diagnostic tests,[1] N = Z x Z (P(1-P))/(D*D), applying the highest sensitivity (P=83.7%), described in Katzmarzyk et al's study[15] (2004), and the semi-amplitude for 95% confidence interval (D=5%), with Z=1.96. In the selected classes, 757 students met the eligibility criteria; i.e., not having physical disability that might prevent the anthropometric evaluation, not being pregnant, or breastfeeding. Anthropometric data was obtained from 610 adolescents (43 did not have their parents' consent; 85 refused to participate; and 19 were no-show). Also, 33 adolescents did not give blood samples, remaining 577 adolescents (23.8% non-response rate).

Data was collected by a trained team composed by three nutritionists and eight college nutrition students, under the supervision of the project's main investigator, from June to December 2003.

Weight was measured using an electronic scale with maximum capacity of 150 kg and precision of 50 g. Height was measured in duplicate using a portable anthropometer with 0.1 cm precision (0.5 cm maximum variation was allowed between the two measures, and then a mean value was calculated). The adolescents were barefoot, wore light clothes, and remained in the orthostatic position.[12]

Overweight and obese adolescents were those who were above the specific BMI cut-offs for age and gender, according to IOTF criterion.[5] In the analyses, the categories of overweight and obesity were combined due to the low prevalence of obesity (2.7%).

Blood samples were taken from adolescents who had fasted for 12 hours to measure serum glucose, total cholesterol, high-density lipoprotein cholesterol (HDL-C) and triglycerides. Blood sample were analyzed using the automated Express Plus enzymatic method in a clinical analysis laboratory certified by the Brazilian Society of Clinical Pathology. Low-density lipoprotein cholesterol (LDL-C) was calculated.[9]

The cut-offs for metabolic abnormalities were: total cholesterol ≥150 mg/dL, LDL-C ≥100 mg/dL, HDL-C <45 mg/dL, triglycerides >100 mg/dL,[22] and glucose ≥100 mg/dL.[8] Risk for cardiovascular disease was evaluated using two approaches. First, it was categorized

Table 1. Weighted means and prevalences (95% confidence interval) of anthropometric, body composition and biochemical variables in adolescents, by gender. Niterói, Southeastern Brazil, 2003.

Variable	Male (n = 210)	Female (n = 367)
Age (years)		
Mean	17 (16.4;17.5)	16.4 (16.0;17.2)
Weight (kg)		
Mean	64.4* (62.5;66.7)	54.9 (53.6;56.3)
Height (cm)		
Mean	174.1* (172.6;175.6)	161.4 (160.0;162.7)
BMI (kg/m^2)		
Mean	21.2 (20.7;21.8)	21.1 (20.5;21.6)
Overweight – n (%)	36 (18.7)	58 (14.9)
95% CI	(13.3;24.0)	(9.5;20.4)
Total cholesterol (mg/dL)		
Mean	150.6 (142.2;159.0)	160.2 (153.1;167.4)
≥150 mg/dL – n (%)	111 (52.3)	223 (58.2)
95% CI	(41.8;62.8)	(48.5;67.9)
LDL-C (mg/dL)		
Mean	87.5 (81.2;93.8)	98.3 (91.6;105.0)
≥100 mg/dL – n (%)	74 (36.5)	170 (43.7)
95% CI	(26.6;46.4)	(33.7;53.8)
HDL-C (mg/dL)		
Mean	46.4 (43.1;49.6)	46.5 (43.5;49.5)
<45 mg/dL – n (%)	109 (55.9)	194 (56.7)
95% CI	(42.1;69.7)	(41.8;71.5)
Triglycerides (mg/dL)		
Mean	84.4 (78.7;90.1)	79.0 (73.1;84.9)
>100 mg/dL – n (%)	52 (24.8)	71 (17.9)
95% CI	(18.1;31.4)	(11.9;23.9)
Glucose (mg/dL)		
Mean	91.1 (87.5;94.7)	90.0 (86.8;93.2)
≥100 mg/dL – n (%)	55 (29.2)	58 (19.4)
95% CI	(16.8;41.5)	(8.9;29.9)
Metabolic abnormalities (%)		
None	8.4 (2.7;13.9)	7.6 (2.5;12.7)
One	33.3 (26.2;40.4)	32.7 (25.4;39.9)
Two	24.1 (18.3;29.9)	22.7 (16.8;28.8)
Three or more	34.2 (24.4;44.1)	37.0 (27.7;46.3)

* When 95% confidence interval does not intersect while comparing female and male adolescents.
BMI = Body mass index

as no abnormality, one abnormality, two abnormalities, and cluster of three or more abnormalities. Second, it was considered a dichotomous variable: at least one abnormality and no abnormalities.

Weighted mean values, prevalence and their respective 95% CI were calculated taking into account the effect of the cluster study design using “Proc Surveymeans” of the SAS 8.2 (Institute Inc, Cary, NC, USA).

The Receiver Operating Characteristic (ROC) curve was used for identifying the best BMI cut-offs (which maximize sensitivity and specificity), stratified by gender, to predict metabolic abnormalities. The SPSS 11.0 (Chicago, IL, USA) was used in this analysis. Due to the importance of age in BMI variation, BMI values were age-adjusted by residual analysis (BMI variation independent of the linear age effect).

Areas under the ROC curve (AUC) and their 95% CI were calculated. For those statistically significant the best BMI cut-offs were identified and their sensitivity and specificity for weight classification were estimated based on four different references,[2,5,17,20] adjusted for age. To estimate the sensitivity, specificity and AUC as for international criterion,[5] as we conducted the analysis adjusted for age, the mean values of BMI for those aged 12-19 years were calculated, corresponding to a BMI of 25 kg/m² for 18 years old. For the American curves and for Brazilian reference,[17,20] the mean BMI values in the 85th percentile was calculated.

Table 2. Weighted means and prevalences (95% confidence interval) of anthropometric and biochemical variables in adolescents, by gender and nutritional status. Niterói, Southeastern Brazil, 2003.

	Male		Female	
Variable	Overweight (n = 36)	No Overweight (n = 174)	Overweight (n = 58)	No Overweight (n = 309)
Age (years)				
Mean	17.0 (16.3;17.7)	16.9 (16.4;17.5)	16.5 (15.6;17.4)	16.7 (16.1;17.3)
Weight (kg)				
Mean	81.7*(77.0;86.4)	60.7 (58.9;62.5)	70.1*(66.6;73.7)	52.3 (51.2;53.3)
Height (cm)				
Mean	175.7(173.1;178.3)	173.8(172.1;175.5)	160.5(159.0;161.9)	161.5(160.0;163.1)
BMI (kg/m²)				
Mean	26.4*(25.4;27.3)	20.1 (19.6;20.5)	27.2*(26.1;28.3)	20.0 (19.7;20.3)
Cholesterol (mg/dL)				
Mean	151.5(140.1;162.8)	150.4(141.8;158.9)	175.0(158.5;191.5)	157.6(150.5;164.8)
≥150 mg/dL–%	54.4(36.2;72.5)	51.9(40.6;63.1)	78.1(63.0;93.2)	54.8(44.0;65.5)
LDL-C (mg/dL)				
Mean	86.8 (75.5;98.0)	87.6 (81.6;93.7)	109.8(98.1;121.6)	96.2 (89.1;103.4)
≥100 mg/dL–%	34.6(17.6;51.6)	36.9(26.6;47.3)	57.6(39.5;75.7)	41.3(30.0;52.6)
HDL-C (mg/dL)				
Mean	45.1(41.5;48.6)	46.7(43.1;50.2)	46.8(41.5;52.1)	46.4(43.4;49.4)
<45 mg/dL–%	61.1(43.0;79.3)	54.7(39.2;70.3)	53.6(31.4;75.7)	57.2(42.0;72.4)
Triglycerides (mg/dL)				
Mean	97.7(82.9;112.6)	81.3(75.9;86.7)	92.7(80.8; 104.7)	76.6(70.2;83.0)
>100 mg/dL–%	45.0*(28.0;62.0)	20.1(13.3;27.0)	33.1(16.0;50.1)	15.3(9.8;20.7)
Glucose (mg/dL)				
Mean	89.9(85.2;94.5)	91.4(87.4;95.2)	90.5(86.6;94.4)	89.9(86.5;93.4)
≥100 mg/dL–%	20.3(2.3;38.4)	31.2(16.9;45.6)	21.3(9.7;32.8)	19.1(7.0;31.2)
Metabolic abnormalities (%)				
None	4.1(0.0;10.5)	9.3(3.2;15.3)	3.5(0.0;7.4)	8.3(2.3;14.3)
One	34.6(13.6;55.6)	33.0(24.3;41.7)	12.7(2.6;22.9)	36.1(27.9;44.4)*
Two	25.2(5.4;44.9)	23.9(17.5;30.3)	27.3(11.4;43.2)	22.0(16.1;27.9)
Three or more	36.1(16.4;55.9)	33.8(23.9;43.7)	56.5(40.0;73.0)	33.6(23.2;43.9)

* When 95% confidence interval does not intersect while comparing adolescents with or without overweight.

The study protocol was approved by the Research Ethics Committee of "Clementino Fraga Filho Hospital" at Universidade Federal do Rio de Janeiro. Consent forms were signed by adolescents over 18 or their parents or guardians.

RESULTS

Adolescents who did not participate in the study (n=180; 23.8%) did not differ from those participating as for the prevalence of overweight according to the IOTF criterion (16.3% and 13.7%, respectively; $\chi^2 = 0.43$ p=0.51) and gender (36.4% and 41.1% males, respectively; χ^2=1.30, p=0.25). But the proportion of older adolescents (15–18.9 years) was higher (χ^2=8.62, p=0.003) among non-participants (38.9% and 27.4%, respectively).

Except for weight and height, which were greater among boys, there were no statistically significant differences for metabolic abnormalities between males and females. In both, overweight prevalence was less than 20% and prevalence of high total cholesterol (≥150 mg/dL) and low HDL-C (<45 mg/dL) was greater than 50% (Table 1).

A comparison of overweight adolescents with all other adolescents (Table 2) showed that overweight males had significantly increased prevalence of high triglycerides (45.0% and 20.1%, respectively). Despite the non-statistically significant difference, the prevalence of this metabolic abnormality was twice as high among overweight females (33.1%) compared to others (15.3%). Among females, AUC predicting metabolic abnormalities ranged between 0.46 and 0.65 and was statistically significant for total cholesterol, LDL-C, and presence of three or more abnormalities. Among males, AUC ranged between 0.44 and 0.67 and was statistically significant for total cholesterol, triglycerides, and the presence of three and more abnormalities (Table 3). Graphic representations of significant AUCs are shown in the Figure.

The best BMI cut-offs for the population studied ranged between 20.3 kg/m² and 21.0 kg/m². These cut-offs were lower but showed higher sensitivity (range: 57% to 66%) and lower specificity (range: 58% to 66%) than cut-offs from the other four references evaluated (Table 4). BMI had better specificity than sensitivity for predicting metabolic abnormalities. For three or more abnormalities the sensitivity was higher than 60% (Table 4).

DISCUSSION

The prevalences of overweight of 18.7% for males and 14.9% for females found in the present study were close to those reported (17.0% in both sexes) in adolescents living in another urban area in Southeastern Brazil.[23]

The magnitude of metabolic abnormalities indicating cardiovascular risk was considerable and greater than those found in other studies with Brazilian adolescents.[19] The new cut-offs used in this study, established by the Brazilian Society of Cardiology as risk indicators for adolescents, are lower than the previous ones, which may in part explain the high prevalence. Prevalence of overweight is rapidly increasing in Brazil[23] and this increase in adolescents may require a more sensitive criterion to identify metabolic abnormalities which have been associated with overweight.

The present study is pioneering in identifying BMI cut-offs associated with cardiovascular risk factors in adolescents, although previous Brazilian studies have shown a correlation between cardiovascular risk factors and BMI.[6,21] We found that BMI predicted high levels of total cholesterol and the presence of three or

Table 3. Area under the ROC curve of BMI adjusted for age for predicting metabolic abnormalities in adolescents. Niterói, Southeastern, 2003.

Variable	Male			Female		
	AUC	95% CI	p-value	AUC	95% CI	p-value
Total cholesterol	0.59	(0.51;0.66)	0.03*	0.61	(0.55;0.67)	<0.001*
LDL-C	0.52	(0.44;0.60)	0.62	0.61	(0.55;0.67)	<0.001*
HDL-C	0.49	(0.41;0.57)	0.86	0.46	(0.41;0.52)	0.31
Triglycerides	0.62	(0.53;0.71)	0.01*	0.53	(0.45;0.61)	0.46
Plasma glucose	0.44	(0.35;0.53)	0.18	0.51	(0.43;0.59)	0.74
Metabolic abnormalities						
One	0.63	(0.48;0.78)	0.10	0.53	(0.41;0.65)	0.61
Two	0.61	(0.46;0.76)	0.16	0.60	(0.48;0.72)	0.10
Three or more	0.67	(0.52;0.81)	0.03*	0.65	(0.53;0.76)	0.02*
At least one	0.64	(0.48;0.77)	0.06	0.59	(0.48;0.71)	0.09

* When 95% confidence interval does not include the 0.50 value
AUC: area under the ROC curve

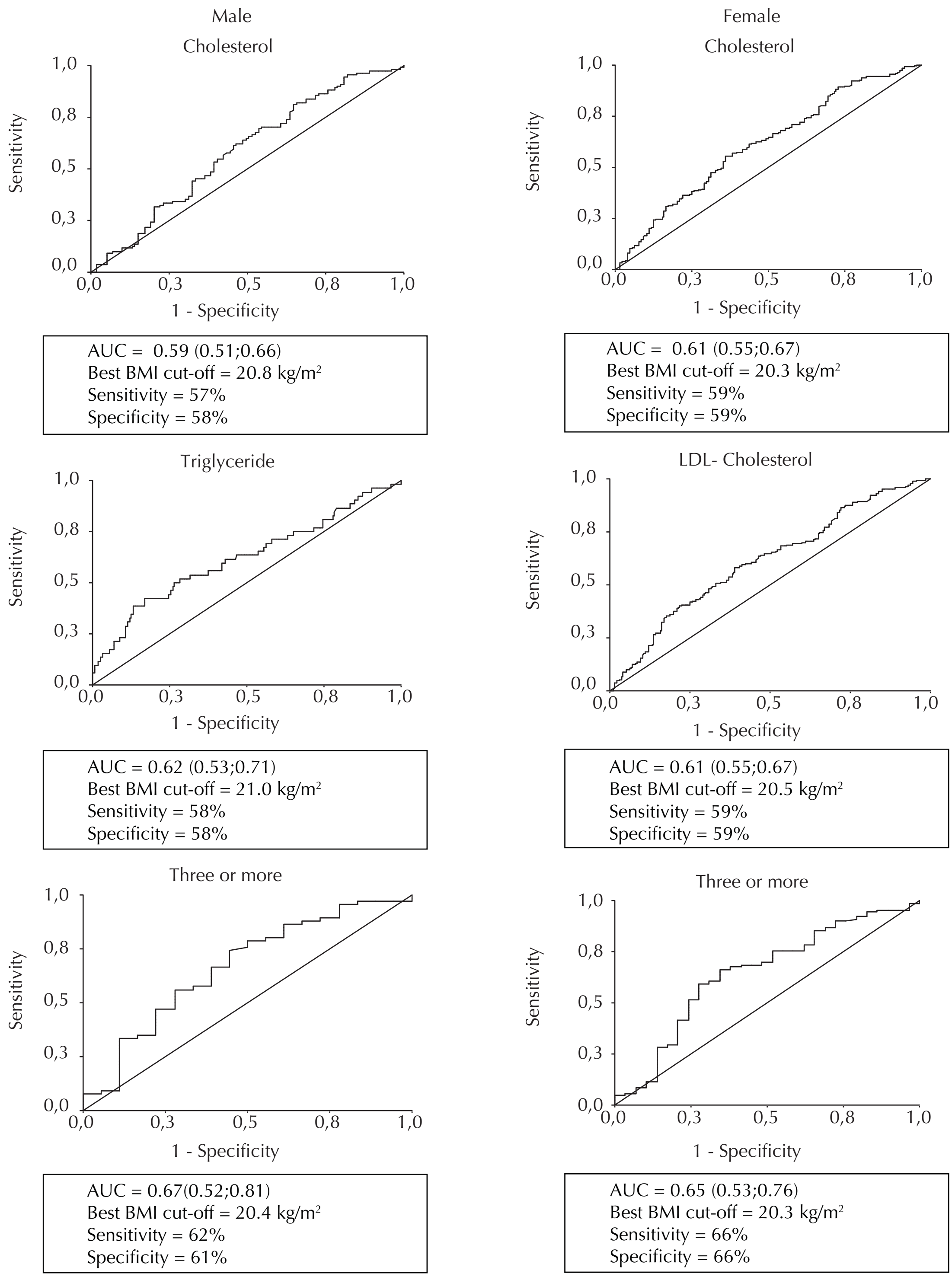

Figure. Area under the ROC curve of BMI adjusted for age for predicting metabolic abnormalities in adolescents. Niterói, Southeastern, 2003.

more metabolic abnormalities in both sexes. In males prediction was greater for increased triglyceride levels, and in females for increased LDL-C levels. The best BMI cut-offs for the population studied ranged between 20.3 kg/m^2 and 21.0 kg/m^2 and identified approximately 60% of adolescents who had (sensitivity) and who did not have (specificity) metabolic abnormalities. These proportions were relatively low as well as the AUC (≈0.60) indicating poor performance of BMI for predicting metabolic abnormalities.

Table 4. Sensitivity and specifi city of the best BMI cut-offs of adolescents, adjusted for age, and of the mean cut-offs based on Brazilian and international references for predicting metabolic abnormalities. Niterói, Southeastern Brazil, 2003.

Variable	Reference	Cut-off (kg/m²)	Sensitivity	Specificity
Male				
Total cholesterol	Best cut-off	20.8	57	58
	Anjos et al[2]	21.7	44	68
	Cole et al[5]	23.6	29	80
	Kuczmarski et al[17]	23.8	29	80
	Must et al[20]	23.9	24	80
Triglycerides	Best cut-off	21.0	58	58
	Anjos et al[2]	21.7	39	60
	Cole et al[5]	23.6	22	72
	Kuczmarski et al[17]	23.8	22	72
	Must et al[20]	23.9	19	74
Three or more metabolic abnormalities	Best cut-off	20.4	62	61
	Anjos et al[2]	21.7	47	79
	Cole et al[5]	23.6	30	89
	Kuczmarski et al[17]	23.8	30	89
	Must et al[20]	23.9	24	89
Female				
Total cholesterol	Best cut-off	20.3	59	59
	Anjos et al[2]	23.6	24	88
	Cole et al[5]	23.9	23	88
	Kuczmarski et al[17]	24.2	21	88
	Must et al[20]	24.4	18	89
LDL-C	Best cut-off	20.5	59	59
	Anjos et al[2]	23.6	26	89
	Cole et al[5]	23.9	25	86
	Kuczmarski et al[17]	24.2	22	86
	Must et al[20]	24.4	19	86
Three or more metabolic abnormalities	Best cut-off	20.3	66	66
	Anjos et al[2]	23.6	27	86
	Cole et al[5]	23.9	26	86
	Kuczmarski et al[17]	24.2	23	86
	Must et al[20]	24.4	19	86

Similar results were reported in a Chilean study,[3] which did not found an association between the magnitude of obesity and risk of dyslipidemia in obese children and adolescents, when testing BMI cut-offs for obesity based on the international reference[5] and on values above the 95th percentile of the CDC reference.

On the other hand, our findings differ from those found in young Americans in the Bogalusa Heart Study.[15] They found BMI had good accuracy for identifying adolescents with three or more metabolic risks, AUC values were between 0.73 and 0.82, the best BMI cut-offs ranged between 19.1 and 24.1 kg/m^2 and sensitivity and specificity were between 67% and 75%.

The BMI cut-offs for classification of overweight of the four references studied had low sensitivity and high specificity. The Brazilian reference showed better sensitivity than the American and the international ones. Similar results were found in American adolescents,[15] although the proportion of false negatives were much higher in our study, nearly 82% in females compared to about 35% in the American study.

The best BMI cut-offs for the population studied were lower than those found in the American and the international references, and consequently more sensitive. The choice of cut-offs with higher sensitivity or specificity has some important implications. If the goal is to prevent body fat gain and its consequences to health, using more sensitive, lower BMI cut-offs, as found in our study, would be more effective at identifying those youths at risk. However, the low specificity of these cut-offs requires additional health care actions for controlling metabolic abnormalities. This emphasis on excess weight might make many adolescents unnecessarily seek care as they do not have any health risks and place a significant burden on health services.

The study sample size did not allow to test and define specific cut-offs for each age, which would be ideal, due to greater BMI variation with growth. Yet we minimized this limitation by adjusting BMI for age. This procedure may also reduce the probability of bias that the higher proportion of missing between older adolescents could introduce in the study. The study findings indicate that BMI cut-off can detect adolescents with three or more metabolic abnormalities – a more advanced risk status, besides predicting isolated alterations in total cholesterol and triglycerides in males, and total cholesterol and LDL in females. Nonetheless, even for these alterations, approximately 40% of them may still be misclassified (false negatives or false positives), suggesting that BMI is not a good predictor for these abnormalities. The international criterion proved to be less sensitive for detecting adolescents with metabolic abnormalities than the national cut-offs.

Investigating new anthropometric measures and criteria that can better predict body fat and cardiovascular risk factors in adolescents from different countries will contribute to better prevention and reduction of the magnitude of non-transmissible chronic diseases associated with obesity.

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