A comparison of distribution curves of body mass index from Brazil and the United States for assessing overweight and obesity in Brazilian adolescents

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ABSTRACT

Objective.   *To assess the validity of recommendations for use of the 85th and 95th percentiles of body mass index (BMI) of the population in the United States of America as a screening tool to assess overweight/obesity in adolescents.*

Methods.   *We investigated the relation between BMI and percent body fat in 1 540 adolescents (717 males and 823 females) aged 10 to 17.9 years old from a private high school in Niterói, a city in the state of Rio de Janeiro, Brazil. We used bioelectric impedance, with the appropriate equations for adolescents, to estimate percent body fat, which served as the gold standard (30% for girls and 25% for boys) to calculate the sensitivity and specificity of the 85th and 95th percentiles of the United States and Brazilian distribution curves of BMI.*

Results.   *Sensitivity and specificity were high (above 80%) for the Niterói boys, except for the 85th percentile of the Brazilian curve (specificity = 61.8%) and for the 95th percentile of the United States curve (sensitivity = 55.4%). For the Niterói girls, the 85th- and 95th-percentile BMI cutoff points, from both the United States and Brazilian curves, showed low sensitivity, and that sensitivity decreased with age. Specificity was high for the girls, and much higher than it was for the boys.*

Conclusions.   *These data suggest that using BMI to screen for overweight/obesity in adolescents can generate a high percentage of false-positives for Niterói boys and an even higher percentage of false-negatives for Niterói girls. A more universal approach to using anthropometric measures to screen for overweight/obesity should be developed, preferably linked to stages of maturation.*

Key words   Health of adolescents, obesity, Brazil, body mass index.

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The prevalence of obesity is increasing in both developed and developing countries (1). In Brazil, for example, a comparison of national nutrition surveys conducted in 1975 and in 1989 showed that the prevalence of obesity rose from 2.4% to 4.9% among men and from 6.9% to 11.7% among women (2).

When obesity occurs during adolescence, it tends to persist into adulthood (3), and it is associated with risk factors for later cardiovascular diseases (4, 5). These facts reinforce the importance of diagnosing obesity early so that preventive actions can be taken.

In epidemiological studies, body mass index (BMI) has been used to assess obesity in adults due to that index's high correlation with body mass and body fatness and low correla-

tion with stature as well as its ability to predict morbidity and mortality (6, 7). In the United States of America the Expert Committee on Clinical Guidelines for Overweight in Adolescent Preventive Services suggested, for several reasons, that specific BMI values for age and sex be used as the criterion to screen for overweight in adolescents. These reasons included the BMI's correlation with subcutaneous and body fatness, the ease with which the information on weight and stature can be obtained for use in computing BMI, and the possibility of continuing to use this criterion into adulthood (8). The World Health Organization (WHO) has made a similar recommendation concerning using anthropometry to assess the risk of overweight among adolescents (9).

In spite of these two recommendations, there are difficulties with using BMI to assess adolescents. BMI does not reflect the changes in body composition that occur during that life stage (6), and BMI is also undesirably correlated with adolescents' stature (6, 10, 11). The Expert Committee in the United States recommended the use of the 85th and the 95th percentiles of the BMI curves of the United States population (12) as the cutoff points for risk of overweight and for overweight (8). The choice of these values was based purely on statistics, in contrast to the rationale for the cutoff points established for adults, which are based on studies of morbidity and mortality. Even the WHO has acknowledged that the recommended United States BMI values seem extremely high in comparison to the values of other developed countries, which may reduce the United States values' usefulness in other countries (9). In the developing world, where a good proportion of youngsters are stunted from childhood (13), the use of BMI values from a United States population whose youths have grown to their full potential may cause errors in nutritional assessment (14).

There is limited information on the validity of the WHO-proposed cutoff points in assessing the nutritional status of adolescents worldwide. Therefore, we conducted this study to assess the sensitivity and specificity of the proposed BMI cutoff values, using United States and Brazilian distribution curves in identifying overweight and obesity in a group of middle-class Brazilian adolescents.

METHODS

The subjects of the study were students in a private high school in Niterói, which is the second largest city in the state of Rio de Janeiro. Niterói is located approximately 14 km from the state's largest city, Rio de Janeiro. In 1996 Niterói had a total of 450 364 inhabitants.

In Brazil, attending a private school is indicative of middle-class status. Approximately 36% of the students in Niterói attend private high schools, a higher percentage than in the state of Rio de Janeiro (32%) and in the country as a whole (20%). Therefore, the students assessed in this study are likely generally better off than their peers in the rest of the state and Brazil, a factor to take into account when interpreting and generalizing the results from this study.

Out of a total of 2 990 adolescents (10.0 to 17.9 years of age) enrolled in the school in Niterói we decided to study approximately 50% of them, in line with our resources and the time slot that the school's principal made available for the study. Initially, a total of 1 595 adolescents were randomly selected from a list the principal provided of all adolescents of this age group enrolled in the school. Due to operational problems, data on 55 male adolescents were not collected. Therefore, the final sample was made up of 1 540 adolescents, consisting of 717 males and 823 females.

University undergraduate nutrition students trained in making anthropometric measures collected the anthropometric data (body mass and stature) and body composition data (percent body fat) during the Niterói students' physical education classes, from May through December 1996, after authorization was obtained from the parents and the adolescents. Body mass was measured once to the nearest 200 g on a TBF-305 scale (Tanita Corporation of America, Skokie, Illinois, United States of America), with the adolescents wearing no shoes or socks. The weight of the clothes was subtracted from the measured body mass value, using a clothing weight table previously obtained from two department stores. Stature was measured twice, to the nearest 0.1 cm, on a wood stadiometer fixed on a wall, according to Lohman et al. (15). The mean of the two stature measurements was used in the analysis. Body mass index (BMI) was calculated by dividing body mass (kg) by the square of stature (m).

Using the Tanita TBF-305 scale, body composition (percent body fat) was assessed by bioelectric impedance at the same time that body mass was measured. That scale utilizes a leg-to-leg system that is practical for large-scale studies and that has been validated (16, 17). Body density was estimated using age- and sex-specific equations provided by the scale's manufacturer. Percent body fat was estimated from body density using age- and sex-specific equations developed for adolescents by Boileau (18).

For adolescents, there is a lack of a consensus concerning obesity and percent body fat. Given that, in our study we considered obesity to be a percent body fat greater than 25% for boys and greater than 30% for girls (19). We used these values as the gold standard to determine the sensitivity and specificity of the values of BMI ≥ 85th percentile (risk of overweight) and 95th percentile (overweight) of the United States distribution curve (12) and the Brazilian curve, which was obtained from a probabilistic sample of the Brazilian population in a household survey conducted in 1989 (14).

RESULTS

Table 1 shows the results of the measurements of body mass index (BMI) and of body composition (percent body fat) for the adolescents studied.

TABLE 1. Mean and standard deviation (SD) of the body mass index (BMI) and percent body fat of adolescents studied in Niterói, Rio de Janeiro, Brazil, 1996

Age (years)	Boys					Girls				
		BMI (kg/m^2)		Percent body fat			BMI (kg/m^2)		Percent body fat	
	No.	Mean	SD	Mean	SD	No.	Mean	SD	Mean	SD
10–10.9	87	19.5	3.2	17.1	8.6	100	18.1	3.0	21.1	7.4
11–11.9	84	19.7	3.1	17.6	8.0	93	19.0	3.0	22.8	7.1
12–12.9	107	20.2	3.3	16.3	8.5	110	19.6	3.2	22.9	6.6
13–13.9	120	20.4	3.4	16.5	8.6	121	20.4	3.1	26.4	6.5
14–14.9	82	21.1	3.9	15.2	9.1	112	20.2	2.5	25.6	5.5
15–15.9	100	21.4	2.7	13.3	6.3	113	20.8	3.1	27.5	5.5
16–16.9	88	21.6	2.9	14.9	6.2	106	20.9	3.1	27.0	6.2
17–17.9	49	22.6	2.8	16.2	6.0	68	21.0	1.9	28.3	5.3

For both the boys and the girls, BMI increased with age. However, with body composition there was a different pattern. For girls, percent body fat increased with age, but for boys it generally decreased for ages 10 through 15.9 years, and then increased.

The indicated risk of overweight was greater for both boys and girls when the Brazilian distribution curve of BMI was used than it was when the United States distribution curve was used (Table 2). The prevalence of obesity tended to be higher in the younger boys than among the older ones. The prevalence of overweight for boys in all age groups was greater than that for obesity when the Brazilian curve was used, but it was almost completely the reverse of that for the United States curve.

Among the girls studied, the prevalence of obesity tended to increase with age (Table 2). This was the opposite of the pattern found for risk of overweight and for overweight, using both the United States and Brazilian curves. Overall, there were more obese girls than boys.

The proportion of girls with risk of overweight according to the Brazilian distribution of BMI, 22.1%, was close to the prevalence of obesity, 19.9% (Table 2). On the other hand, for the boys, there was no association between the prevalence of obesity and the proportion of boys with risk of overweight, using either the United States or the Brazilian BMI curves. The best predictor for obesity in boys was the 95th percentile of the United States curve.

Assuming the percent body fat cut-off points as the gold standard criteria, we found that BMI showed low sensitivity for the Niterói girls, especially when the distribution of the United States population was used (Table 3). For the 95th-percentile (overweight) criterion, 86% of the Niterói adolescents would have had false-negative

TABLE 2. Prevalence of risk of overweight, of overweight, and of obesity of the adolescents studied in Niterói, Rio de Janeiro, Brazil, using the 85th and the 95th percentiles of the United States (US) and Brazilian distribution curves of body mass index (BMI), 1996

Sex and age (years)	Risk of overweight (%) (BMI between 85th and 95th percentiles)		Overweight (%) (BMI ≥ 95th percentile)		Obesity (%)
	US curve	Brazilian curve	US curve	Brazilian curve	
Boys					
10–10.9	39.1	57.5	20.7	37.9	2.7
11–11.9	34.5	52.4	11.9	28.6	15.5
12–12.9	33.6	51.4	13.1	24.3	16.8
13–13.9	25.8	45.0	4.2	25.8	13.3
14–14.9	24.4	41.5	9.8	26.8	15.8
15–15.9	19.0	41.0	2.0	16.0	6.0
16–16.9	14.8	38.6	2.3	19.3	6.8
17–17.9	12.2	38.8	4.1	20.4	8.2
Overall	26.2	46.2	8.5	25.0	12.8
Girls					
10–10.9	18.0	40.0	6.0	9.0	9.0
11–11.9	26.9	40.9	1.1	8.6	18.3
12–12.9	20.9	30.0	4.5	12.7	12.7
13–13.9	18.2	22.3	3.3	11.6	24.0
14–14.9	7.1	13.4	1.8	3.6	17.9
15–15.9	8.0	10.6	1.8	3.5	29.2
16–16.9	9.4	12.3	2.8	5.7	20.7
17–17.9	2.9	5.9	0.0	0.0	29.4
Overall	14.2	22.1	2.8	7.2	19.9

TABLE 3. Sensitivity (sens) and specificity (spec) using the 85th and the 95th percentiles of the United States (US) and Brazilian distribution curves of body mass index (BMI) as criteria for obesity in the adolescents studied in Niterói, Rio de Janeiro, Brazil, 1996

Sex and age (years)	Risk of overweight (BMI between 85th and 95th percentiles)				Overweight (BMI ≥ 95th percentile)			
	US curve		Brazilian curve		US curve		Brazilian curve	
	Sens	Spec	Sens	Spec	Sens	Spec	Sens	Spec
Boys								
10–10.9	100.0	74.6	100.0	52.1	93.7	95.8	100.0	76.1
11–11.9	100.0	77.5	100.0	56.3	76.9	100.0	100.0	84.5
12–12.9	94.4	78.6	100.0	58.4	50.0	94.3	83.3	87.6
13–13.9	93.7	84.6	100.0	63.4	31.2	100.0	93.7	84.6
14–14.9	92.3	88.4	100.0	69.6	61.5	100.0	92.3	85.5
15–15.9	66.7	84.4	100.0	62.8	33.3	100.0	50.0	86.2
16–16.9	66.7	89.0	100.0	65.8	16.7	98.8	66.7	84.1
17–17.9	75.0	93.3	100.0	66.8	25.0	97.8	100	86.7
Overall	91.3	83.4	100.0	61.8	55.4	98.4	89.1	84.5
Girls								
10–10.9	100.0	90.1	100.0	65.9	66.7	100.0	88.9	98.9
11–11.9	82.3	85.5	100.0	72.4	5.9	100.0	29.4	96.0
12–12.9	92.9	89.6	100.0	80.2	35.7	100.0	78.6	96.9
13–13.9	65.5	96.7	79.3	95.6	13.8	100.0	44.8	98.9
14–14.9	25.0	96.7	50.0	94.6	10.0	100.0	15.0	98.9
15–15.9	27.3	100.0	33.3	98.7	6.1	100.0	12.1	100.0
16–16.9	45.5	100.0	59.1	100.0	13.6	100.0	27.3	100.0
17–17.9	10.0	100.0	15.0	97.9	0.0	100.0	0.0	100.0
Overall	49.4	94.5	61.0	87.6	14.0	100.0	30.5	98.6

values using the United States curves, and 70% would have had false-negative values using the Brazilian curves. The sensitivity of BMI decreased with age, and its value was null for the oldest girls. On the other hand, the specificity—using either the 85th or 95th percentiles of either curve—was generally very high.

For the Niterói boys, the criterion for the diagnosis of risk of overweight (85th percentile) generally showed high sensitivity for both the Brazilian and United States curves. The specificity of this 85th-percentile cutoff point, however, was lower, especially when the Brazilian distribution was used. The criterion for overweight (95th percentile) showed low sensitivity and high specificity when the United States curve was used. When the Brazilian curve was used, the sensitivity rose noticeably, while the specificity decreased somewhat.

DISCUSSION

Establishing an anthropometric criterion to assess obesity is much more complex and difficult among adolescents than among other age groups, due to the large variations among individuals and populations during puberty. A universal criterion to define overweight and obesity in adolescents from populations of different parts of the world has yet to be developed (20, 21).

Using BMI is very attractive because of the ease in obtaining the data for its calculation and its good correlation with other measures of adiposity (22, 23). Nevertheless, one must be careful when using BMI during adolescence, for many reasons. First, the index may not be a dependable estimate of body fatness, particularly at different maturational stages (24). Throughout adolescence, body composition changes rapidly, and it changes differently in

boys and girls. That means that the same value of BMI, depending on gender and maturational stage, will indicate a different body composition profile (25). This fact is evident in our analysis of BMI of the adolescents from Niterói. The mean values of BMI for the two sexes were very similar across all age groups, but the values of percent body fat were substantially different for the males and females. While mean BMI increased with age for both sexes, the tendency for the percent body fat was different, increasing in girls and decreasing in boys.

A major problem involves the suggested cutoff points for the definition of overweight and the chosen reference curves. The World Health Organization (9) recommended the 85th percentiles of the United States curves (12) to define risk of overweight. In addition, to classify an adolescent as obese, the WHO suggested using the same

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85th-percentile cutoff point, along with the 90th percentile of both the subscapular and triceps skinfolds of the United States population. The United States Expert Committee had recommended that the criterion for overweight be the 95th percentile of BMI of the United States curves. However, Anjos et al. (14) have shown that the 95th-percentile values of BMI of the Brazilian curve are much lower than those in the United States, a pattern that has been demonstrated in other countries as well (26, 27). The same is true for the 85th percentile from the United States, which has been found to be similar to the 97th percentile of French boys (9). Therefore, the use of the United States reference values to estimate overweight in specific groups of the Brazilian population, such as the one we studied in Niterói, will cause the prevalences to be lower than when the Brazilian BMI distribution curves are used. If the higher values of BMI of the United States population represent greater fatness (28), the use of the United States reference values would underestimate the magnitude of the problem in the Brazilian population. In that case, preventive measures would only be taken if there were an increment in mean values of BMI in the Brazilian population.

The question is whether a high BMI (overweight) really represents high body fatness (obesity). In our study, there were large discrepancies in the indicated prevalences of overweight and of obesity in both sexes, and for both of the reference curves used. These inconsistencies may be due to differences in the maturational, cultural, and behavioral characteristics of adolescents from different parts of the world.

The validation of BMI as an indicator of obesity in adolescents is primarily done by underwater weighing (23, 29, 30) as the gold standard method of assessing body composition. That is true even though there may be an overestimation of fat mass and an underestimation of lean body mass if appropriate corrections for the hydration of the fat-free mass of growing chil-dren are not taken into consideration (18). Underwater weighing is a laboratory-based method that cannot be used in field settings such as this study. In our study, we estimated body composition with the bioelectric impedance method, which has been validated in children (31). In addition, we used equations for the estimation of body density provided by the manufacturer as well as appropriate conversion equations to estimate percent body fat for children (18). Given all that, we are confident of the values we found for body composition in our study.

In the Niterói girls, the prevalence of obesity was higher than the prevalence of overweight, particularly after 13 years of age. This pattern supports the view that BMI does not reflect the changes in body composition that occur as girls mature.

In the Niterói boys, the prevalence of both obesity and of overweight tended to fall as the boys grew older. However, the prevalence of obesity was systematically lower than the prevalence of overweight, except when the cutoff value of the 95th percentile of the United States reference curve was used.

The low sensitivity of BMI that we found for assessing obesity in girls indicates that many adolescents assessed in our study, even though being obese (that is, percent body fat > 30%), are not indicated as being overweight using the 95th percentile. The 85th-percentile cutoff point of the Brazilian distribution curve increased the sensitivity to 61%, with the specificity at around 87%.

In the Niterói boys as a whole, using the BMI resulted in higher sensitivity and lower specificity than with the girls, except for the 95th percentile of the United States population, thus yielding more false-positives and overestimating obesity. The 95th-percentile cutoff point of the Brazilian curve resulted in a sensitivity of 89% and a specificity of 85%. That would make it a better criterion to be used because of its lower estimation of false-negatives and false-positives.

With a group of Canadian adolescents, in comparison to the 90th percentile of percent body fat (used as the gold standard), Himes and Bouchard (23) found low sensitivity for the 85th percentile of BMI for girls and for boys but very high specificity. The same pattern was found by Johnston (32) when using the relative weight greater than 120% as an indicator of obesity in comparison to percent body fat as determined by underwater weighing. More recently, Malina and Katzmarzyk (24) reported on sensitivity and specificity for adolescents of different ethnic origins, using the triceps skinfold and percent body fat (underwater weighing) as criteria for adiposity; BMI had high specificity and low sensitivity. Taken together, these other researchers' results are somewhat similar to what we found in our study for the 95th percentile, particularly in girls.

According to Himes and Dietz (8), in screening adolescents for overweight, it may be more important to have a higher specificity than sensitivity. In that way, fewer adolescents would be incorrectly considered obese. Therefore, based on the results of our study, we believe that BMI is a more appropriate tool to assess risk of overweight in girls than boys, given that BMI has a higher specificity in girls than in boys. Nevertheless, the high number of false-negatives seen in girls could result in fewer of the needed interventions taking place.

The use of the United States BMI reference values seems inappropriate. Even though the Brazilian adolescents did not reach the 95th percentile of BMI of the United States reference, the Brazilian youths already had an undesirably high body fat level.

It is also worth noting that using a fixed cutoff point of percent body fat (> 25% for boys and > 30% for girls) may not have the same meaning for the different maturational stages of adolescence (24). Fixed cutoff points have been suggested for adults, and we used them in our study because of the lack of recommendations for adolescents.

Based on the results of our study, we conclude that WHO's current rec-

ommendation to screen for the risk of obesity in adolescents based on BMI cutoff values from the United States curves will yield substantially fewer cases than would a Brazilian curve. Our data suggest that using BMI to screen for overweight/obesity in adolescents can generate a high percentage of false-positives for boys as well as an even higher percentage of false-negatives for girls than would be true in comparison to using percent body fat as a criterion.

A more universal approach should be developed to using anthropometric methods to screen for overweight/ obesity. Further, this approach should take into consideration the stages of maturation. It is also evident that more data are needed to elucidate the association that high BMI and a high percent body fat in adolescents have with present and future morbidity.

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RESUMEN

Comparación de las curvas de distribución del índice de masa corporal en Brasil y Estados Unidos para evaluar el sobrepeso y la obesidad en adolescentes brasileños

Objetivos. Investigar la validez del empleo de los percentiles 85 y 95 del índice de masa corporal (IMC) de la población de los Estados Unidos de América (EE. UU.) para detectar el sobrepeso y la obesidad en adolescentes.

Métodos. Se investigó la relación entre el IMC y el porcentaje de grasa corporal en 1 540 adolescentes (717 del sexo masculino y 823 del sexo femenino) de 10 a 17,9 años de una escuela secundaria privada de Niterói, una ciudad del estado de Rio de Janeiro, Brasil. Como referencia para calcular la sensibilidad y especificidad de los percentiles 85 y 95 de las curvas de distribución del IMC en los EE. UU. y Brasil se utilizó el porcentaje de grasa corporal, determinado mediante impedancia bioeléctrica, con ecuaciones ajustadas para los adolescentes. Se consideró como obesidad un porcentaje de grasa corporal del 30% en el sexo femenino y del 25% en el sexo masculino.

Resultados. La sensibilidad y la especificidad fueron elevadas (> 80%) para los adolescentes del sexo masculino de Niterói, exceptuando el percentil 85 de la curva de Brasil (especificidad del 61,8%) y el percentil 95 de la curva de EE. UU. (sensibilidad del 55,4%). Para las adolescentes del sexo femenino, los percentiles 85 y 95 de las curvas de ambos países presentaron una baja sensibilidad, que disminuía con la edad; la especificidad, en cambio, fue elevada, y mucho mayor que en el sexo masculino.

Conclusiones. Estos datos indican que el uso del IMC para identificar el sobrepeso y la obesidad en adolescentes de Niterói puede generar un alto porcentaje de resultados positivos falsos en los del sexo masculino y un porcentaje todavía mayor de resultados negativos falsos en las del sexo femenino. Para detectar el sobrepeso y la obesidad sería necesario un método más universal que las medidas antropométricas, de preferencia relacionado con los estadios de maduración.

6th World Conference on Injury Prevention and Control

Dates: 12–15 May 2002
Location: Montreal Convention Centre
Montreal, Quebec, Canada

The 6th World Conference on Injury Prevention and Control is a major global platform to exchange knowledge among professionals committed to reducing the unacceptable burden of injuries, suicide, and interpersonal violence.

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