

Performance of references based on body mass index for detecting excess body fatness in schoolchildren aged 7 to 10 years

Desempenho de referências baseadas no índice de massa corporal para a detecção do excesso de gordura corporal em escolares de 7 a 10 anos de idade

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ABSTRACT: *Objective:* To compare the sensitivity and specificity of body mass index (BMI)-based classification systems and to determine the optimal cut-offs for predicting excess body fatness in schoolchildren. *Methods:* 2795 schoolchildren aged 7–10 years were examined. Excess body fatness was defined as the standardized residuals of the sum of three skinfold thickness ranking at or above the 90th percentile. The international BMI-based system recommended by the World Health Organization (WHO-2007) was evaluated on the basis of its sensitivity and specificity for detecting excess body fatness and compared with a national BMI reference (Brazil-2006). Likelihood ratios analysis was used to select the optimal cut-offs in each curve. *Results:* The two classification systems presented high sensitivity (92.5–98.6%) and moderate specificity (75.9–85.0%) for both sexes. The optimal BMI cut-offs improved specificity with no marked loss of sensitivity. Using the proposed BMI cut-offs, the post-test probability of predicting excess body fatness for children classified as non-overweight decreased from 10 (pre-test probability) to 1.4% in girls and to 1.1% in boys. For overweight children, this probability increased to more than 46.0%. *Conclusion:* The results showed that both the WHO-2007 and Brazil-2006 classification systems can be used as screening instruments for excess body fatness, and that one of the limitations of using the BMI-for-age references could be improved by refining the existing cut-offs.

Keywords: Body Mass Index. Adiposity. Children. Sensitivity. Specificity. Likelihood ratio analysis.

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RESUMO: *Objetivo:* Comparar a sensibilidade e especificidade de sistemas de classificação baseados no índice de massa corporal (IMC) e determinar os melhores pontos de corte na predição do excesso de gordura corporal em escolares. *Métodos:* 2795 escolares com idade entre 7 a 10 anos foram examinados. O excesso de gordura corporal foi definido como os resíduos padronizados do somatório de três dobras cutâneas iguais ou superiores ao percentil 90. O sistema internacional baseado no IMC, recomendado pela Organização Mundial de Saúde (OMS-2007), foi avaliado com base em sua sensibilidade e especificidade para detecção do excesso de gordura corporal e comparado com uma referência do IMC nacional (Brasil-2006). A análise da razão de verossimilhança foi usada para selecionar os melhores pontos de corte em cada curva. *Resultados:* Os dois sistemas de classificação apresentaram alta sensibilidade (92,5 – 98,6%) e moderada especificidade (75,9 – 85,0%) para ambos os sexos. Os ótimos pontos de corte melhoraram a especificidade sem perda acentuada da sensibilidade. Usando os pontos de corte propostos, a probabilidade pós-teste de predizer o excesso de gordura corporal para crianças classificadas sem excesso de peso diminuiu de 10% (probabilidade pré-teste) para 1,4% em meninas e para 1,1% em meninos. Para crianças classificadas com excesso de peso, essa probabilidade aumentou para mais de 46,0%, em ambos os sexos. *Conclusão:* Os resultados mostraram que ambos os sistemas de classificação, OMS-2007 e Brasil-2006, podem ser usados como instrumentos de rastreamento do excesso de gordura corporal. As limitações do uso de referências do IMC-para-idade podem ser melhoradas pelo refinamento dos pontos de corte existentes.

Palavras-chave: Índice de Massa Corporal. Adiposidade. Criança. Sensibilidade. Especificidade. Análise da razão de verossimilhança.

INTRODUCTION

Over the last decade there has been a steady increase in the number of studies on the diagnostic accuracy of age- and sex-specific body mass index (BMI) references for children and adolescents¹. Most of these studies have used the International Obesity Task Force (IOTF)² approach vs. national reference data to identify children and adolescents with excess body fatness³⁻⁸. The recently updated World Health Organization (WHO-2007) BMI reference⁹ for children and adolescents aged 5 to 19 years has been recommended as an international reference and is being adopted by countries concerned with the growing problem of childhood obesity. However, only a few studies have evaluated its performance in detecting excess body fatness^{7,10}.

In the absence of a “gold standard” to measure body fat content, such as the multi-component models, studies have typically used an indirect method (e.g. bioimpedance, skinfolds), and defined a proportion of participants as excessively fat on the basis of these measurements¹. Subsequently, estimation is made of the extent to which the optimal cut-off points in the BMI-for-age distribution classified such children correctly.

Previous studies on diagnostic accuracy of BMI used summary statistics, such as sensitivity and specificity, area under the curve^{3,5-8,10-12}, and likelihood ratio (LR) analysis^{5,10,13}.

In the majority of the studies a significantly higher sensitivity was reported using national reference data than when using the IOTF^{3,7} or the WHO-2007 approach⁷, and the reverse for specificity^{3,6,7}. Other studies reported similar values of specificity between the IOTF and national BMI reference data^{4,5}.

In light of the recommendations made in recent guidelines for using BMI national reference data on the management of obesity in youth^{14,15}, this study evaluates the performance of the last age- and sex-specific BMI reference values proposed for Brazilian children and adolescents (Brazil-2006)¹⁶, against excess body fatness in a representative sample of schoolchildren from Florianópolis. In addition to the comparison of sensitivity and specificity of the Brazil-2006 with that of the WHO-2007, a LR analysis was performed to select the optimal cut-offs for classifying children as overweight (including obesity) according to WHO-2007 and Brazil-2006 BMI reference curves, allowing the calculation of the post-test probabilities of excess body fatness.

METHODOLOGY

SUBJECTS

Data were extracted from the database of a cross-sectional epidemiological study¹⁷ which reported the prevalence of overweight and obesity in Florianópolis' schoolchildren in 2002. Florianópolis is the capital of the province of Santa Catarina, in the south of Brazil. The city has a total area of 433 km²; its demographic density is 760 hab/km². At the time this study was conducted, the population was 369,102 inhabitants (urban 94.1%), life expectancy at birth was 72.8 years, and infant mortality rate was 18.5/1000 live births^{18,19}.

Sample size was calculated considering 10% overweight prevalence²⁰ and 95% confidence limits. The sampling error was 2.0 and the design effect 2%. The reference population consisted of students enrolled in public and private elementary schools. The study population was selected using a stratified cluster sampling design. The study was conducted from September to November 2002. Public and private elementary schools were first stratified by geographic area and then randomly selected from a list of schools within each area, with probability weight proportional to the size of the school. Of 122 schools (44 private and 78 public), 16 were selected (nine public and seven private). In each school selected, all classes were included and all the children attending the first four grades were invited to participate, but only 7 to 10-year-old children were included in this study. Elementary school is obligatory in Florianópolis and nearly all 7 to 10-year-old children attend the first four years of school.

Post hoc analysis to estimate power for diagnostic accuracy parameters was calculated using the lowest overweight prevalence of 22.7% according to WHO-2007 BMI reference (Table 1), an expected value of 90% for sensitivity/specificity as the mid-point of their range between 85 and 95% in Brazil-2006 BMI reference (Table 2), and 5% error for minimal acceptable lower confidence limit²¹. This method estimated 474 and 1614 children with and without overweight, respectively, producing the total sample size of 2088.

Table 1. Anthropometric measurements and frequencies of overweight using two body mass index definitions among 2795 schoolchildren in Florianópolis, 2002.

Variables	Girls (n = 1341) Mean (95%CI)	Boys (n = 1454) Mean (95%CI)	p-value
Age (years)	8.51 (8.45 – 8.57)	8.54 (8.48 – 8.60)	0.426*
Weight (kg)	30.3 (29.9 – 30.7)	31.3 (30.9 – 31.7)	< 0.001*
Height (cm)	133.2 (132.7 – 133.7)	134.0 (133.6 – 134.5)	0.010**
BMI (kg/m ²)	16.9 (16.8 – 17.0)	17.2 (17.1 – 17.4)	< 0.001*
Sum of skinfolds (mm)	31.5 (30.9 – 32.1)	27.6 (27.0 – 28.3)	< 0.001*
Overweight (including obesity)	% (95%CI)		p-value
WHO-2007	22.7 (20.5 – 25.0)	31.6 (29.2 – 34.0)	< 0.001***
Brazil-2006	25.7 (23.3 – 28.0)	23.6 (21.4 – 25.8)	0.218***

BMI: body mass index; WHO: World Health Organization; *Student's *t*-test for equal variances; **Student's *t*-test for unequal variances; *** χ^2 test.

Table 2. Sensitivity and specificity for excess body fatness according to body mass index-based references.

WHO-2007		Brazil-2006	
Sen (95%CI)	Spe (95%CI)	Sen (95%CI)	Spe (95%CI)
Girls			
92.5 (88.1 – 97.0)	85.0 (83.0 – 87.0)	94.8 (91.0 – 98.5)	82.0 (79.9 – 84.2)
Boys			
98.6 (96.7 – 100.0)	75.9 (73.5 – 78.2)	94.5 (90.8 – 98.2)	84.3 (82.3 – 86.2)

WHO: World Health Organization; Sen: sensitivity; Spe: specificity.

Prior to the data collection the informed consent form was delivered to the school, along with a letter addressed to parents with information about the survey, data to be collected, and assurance that it would not present any risks. Information included anthropometric data (height, weight, skinfolds and arm, waist and hip circumferences) and sociodemographic status of the family. This study addresses the children's measurements of height, weight, and thickness of three skinfolds (triceps, subscapular, and the median calf).

Children who were absent on the days of data collection or who returned the sociodemographic questionnaire with missing information were contacted at the end of the research by phone and by their school teacher putting reminders in the child's notebook, trying to schedule a new date to collect the information. Of the 3522 children attending the first four grades of elementary school, 209 were excluded because they were not in

the age range of the protocol (< 7.0 or > 10.0 years old), and 377 because of missing data (170 children absent or ill; 207 parents or children refused to participate).

Parents gave a written consent for their child's participation in this study, which received approval from the Committee on Human Studies of the Federal University of Santa Catarina (Protocol n° 037/02).

Anthropometric measurement

The administrative department of each school provided information on the children's age and gender. The BMI and the sum of three skinfold thickness (SFT) measurements were selected to assess the nutritional status of the participants. Anthropometry was performed in each school by two trained physical education teachers. Theoretical and practical workshops on measurement technique were held in order to standardize the anthropometric measurements. Measurements of the weight, height, and SFT of participants were taken, following the standard techniques recommended by Lohman et al.²². Anthropometric measurements were taken in lightly-dressed children, without shoes. Weight was measured with a digital-solar 180 kg scale (Marte[®], model PP) and height was measured using a metric tape fixed to a wall without a baseboard. The BMI was computed as weight in kilograms divided by height in meters squared.

SFTs were measured at three regional body sites: triceps, subscapular, and the median calf using a skinfold caliper (Cescor[®], scientific sports equipment, Porto Alegre, RS, Brazil) over the right side of the body. The measurements were done in duplicate and a third measurement was performed if the duplicates differed by more than 1 mm. The average of two readings at each site or of the two nearest readings was used for analysis.

Statistical analysis

The subjects were classified as overweight (including obesity) according to two BMI-based classification systems: WHO-2007 and Brazil-2006. Both references have summarized the weight/height ratio, constructed as BMI, in three independent parameters: L (power in the Box Cox transformation), M (median), and S (coefficient of variation)²³. Using the equation:

$$C = M[1+(LSZ)]^{1/L}$$

it is possible to estimate any centile of a reference distribution^{9,16}. The BMI-for-age Z-scores were calculated based on the following equation:

$$Z = [(BMI/M)^L - 1]/(LS)$$

In both curves the BMI critical values for classifying nutritional status as overweight were expressed as centiles and Z-scores equivalent to 25 kg/m² in adults. Using Brazil-2006 curves, those values corresponded to + 1.2 Z for girls and + 1.32 Z for boys. Using the WHO-2007, those values corresponded to + 1 Z.

Due to the importance of age in body fat variation, the sum of SFT values was modeled as a polynomial function of age in linear regression models. Using the model with the highest Pearson coefficient, the standardized residual for each sex was estimated (skinfolds variation independent of the linear age effect). Values exceeding ± 4 standard deviations of the standardized residual values were excluded (50 boys, 91 girls) because they were considered as outliers. The unconventional value ± 4 deviations has been chosen to preserve, as much as possible, the sample heterogeneity. These standardized residuals were then converted into percentiles. In this way, subjects were effectively ranked according to their Z-score. The sum of SFT (standardized residuals) ranking at or above the 90th percentile was adopted as the reference standard for the evaluation of excess body fatness. Currently, no skinfold cut-offs for defining excess body fatness in children have been internationally accepted. In this study the arbitrary cut-off of the sum of skinfolds ranking at or above the 90th percentile, by sex and age group, has been adopted as the definition for excess body fatness. This percentile was chosen as a conventional cut-off in clinical terms to ensure adequate numbers for statistical analysis, and to account for typical high-adiposity individuals maintaining some variability among them, which cannot be reached with the choice of the 95th percentile. The sensitivity and specificity analysis were performed using the 85th, 90th, and 95th percentiles of the sum of SFT as the standard reference and BMI cut-offs as the diagnostic test (data not shown). Although there were no significant differences for both sensitivity and specificity values between the three critical values for excess body fatness, the 90th percentile presented the best compromise between sensitivity and specificity rates for both BMI references. Furthermore, we believe that a child with the sum of SFT greater than or equal to the 90th percentile should be identified as having excess body fatness because even this degree of adiposity was associated with adverse levels of cardiovascular disease risk factors²⁴.

Sensitivity was defined as the percentage of children with excess body fatness (children in the top 10% of the body fatness distribution based on SFT-standardized residuals) classified as overweight by BMI. Specificity was defined as the percentage of children without excess body fatness (children not in the top 10% of the body fatness distribution based on SFT-standardized residuals) classified as non-overweight by BMI.

LR analysis stratified by sex was used to determine the optimal cut-offs of WHO-2007 and Brazil-2006 Z-score curves with the highest accuracy for detection of excess body fatness in each sex. LR states how many times more likely the particular test results are in patients with excess body fatness than in those without excess body fatness. Positive LR_s [sensitivity/(1 – specificity)] above 10 and negative LR_s [(1 – sensitivity)/specificity] below 0.1 have been noted as providing convincing diagnostic evidence, whereas those above 5 and below 0.2 give strong diagnostic evidence²⁵. Thus, in this study the optimal BMI cut-offs were chosen from among those Z-scores showing positive LR_s (LR+) values between 5 and 10 and negative LR_s between 0.1 and 0.2.

The probability of excess body fatness in children identified as non-overweight or overweight (including obesity), according to the WHO-2007 and Brazil-2006 optimal BMI cut-offs, was computed by means of Bayes' theorem, where

post-test odds = pre-test odds \times LR (LR+ and LR-) and
pre-test odds = prevalence / 1 - prevalence.

In clinical practice, it is essential to know how a particular test result predicts the risk of abnormality²⁶. For the calculation of the pre-test odds, the prevalence of excess body fatness based on the 90th percentile of the sum of SFT (standardized residuals) of the sample itself was used. Finally, the post-test odds were converted into probabilities: post-test probability = post-test odds / 1 + post-test results.

The significance level was set at $p < 0.05$. Statistical analyses were performed with SPSS version 10.0 (Statistical Package for Social Sciences, Chicago, IL, USA) and STATA version 10.0 (Stata Corporation, College Station, TX, USA).

RESULTS

The final analytical population consisted of 2795 schoolchildren (48% girls). Table 1 shows the subjects characteristics and the prevalence of overweight (including obesity) according to the WHO-2007 and Brazil-2006 BMI references, stratified by sex. Compared to the girls, the boys were significantly taller, heavier, and presented higher mean BMI. The girls had a significantly higher mean sum of SFT than the boys. According to the WHO-2007 reference, the boys were significantly more likely than their female counterparts to be overweight. No significant differences between the sexes were observed for overweight prevalence according to the Brazil-2006 BMI references.

Table 2 compares the sensitivity and specificity of BMI cut-offs for overweight (including obesity) from WHO-2007 and Brazil-2006 references in detecting excess body fatness in children defined by the sum of SFT (standardized residuals) ranking at or above the 90th percentile as the standard reference. The WHO-2007 classification showed significant statistical differences between genders for specificity values. In contrast, there were no significant differences in either sensitivity and specificity between girls and boys when the Brazil-2006 classification was used. In the case of boys, a significant statistical difference in the specificity rate was found between the WHO-2007 and Brazil-2006 references.

Gender-specific comparisons of the performance of the optimal BMI cut-offs derived from the LR analysis and the existing BMI Z-values for diagnosis of overweight from the WHO-2007 and Brazil-2006 references are further illustrated in Table 3. For WHO-2007 references, the optimal cut-offs were equivalent to the 87th (girls) and 95th (boys) percentiles; for Brazil-2006 references, these cut-offs were equivalent to the 90th (girls) and 95th (boys)

Table 3. Performance of the reference values and the proposed cut-offs for body mass index-based criteria to screen for excess body fatness.*

	Z-score	LR+	LR-	Sen (%)	Spe (%)	P
	Girls					
WHO-2007	1.00	6.21	0.09	92.5	85.1	84
WHO-2007 optimal BMI cut-off [†]	1.12	7.87	0.13	88.1	88.8	87
Brazil-2006	1.02	5.25	0.06	94.8	81.9	85
Brazil-2006 optimal BMI cut-off [†]	1.28	7.99	0.13	88.1	89.0	90
	Boys					
WHO-2007	1.00	4.09	0.02	98.6	75.9	84
WHO-2007 optimal BMI cut-off [†]	1.61	10.01	0.10	91.0	90.9	95
Brazil-2006	1.32	5.97	0.07	94.5	84.2	91
Brazil-2006 optimal BMI cut-off [†]	1.60	9.93	0.10	91.0	90.8	95

WHO: World Health Organization; LR: likelihood ratio; Sen: sensitivity; Spe: specificity; P: percentile; *Standardized residuals ranking at/or above the 90th percentile of the sum of skinfolds; [†]The optimal cut-offs for BMI Z-values, derived by likelihood ratio analysis.

percentiles. For both sexes, the optimal BMI cut-offs were higher than both the WHO-2007 and Brazil-2006 BMI Z-values for overweight. For example, with the use of the optimal BMI cut-off, a girl with excess body fatness would be 7.87 times (using WHO-2007 BMI curves) or 7.99 times (using Brazil-2006 BMI curves) as likely as a girl without excess body fatness to be classified as overweight. On the other hand, a girl without excess body fatness would be only 0.13 times (using both, WHO-2007 or Brazil-2006 BMI curves) as likely to be classified as overweight. Using the optimal BMI cut-offs, a boy with excess body fatness would be 10.01 times (using WHO-2007 BMI curves) or 9.93 times (using Brazil-2006 BMI curves) as likely as a boy without excess body fatness to be classified as overweight, whereas a boy without excess body fatness would be only 0.10 times (using WHO-2007 or Brazil-2006 BMI curves) as likely to be classified as overweight.

Table 4 presents the post-test probability of excess body fatness estimated using the optimal BMI cut-offs and the existing BMI Z-values for diagnosis of overweight from the WHO-2007 and Brazil-2006 references. After the classification as non-overweight by the WHO-2007 and Brazil-2006 optimal BMI cut-offs, the child's probability of having excess body fatness decreased from 10.0 (pre-test probability of excess body fatness) to 1.4% in girls and to 1.1% in boys. When the test result is positive (i.e. children classified as overweight by the WHO-2007 or

Table 4. Post-test probability of excess body fatness in 2795 schoolchildren diagnosed as non-overweight or overweight according to the reference values and WHO-2007 and Brazil-2006 optimal cut-offs.

	Post-test probability of excess body fatness*	
	Negative (%)	Positive (%)
	Girls	
WHO-2007	1.0	40.6
WHO-2007 optimal cut-off [†]	1.4	46.4
Brazil-2006	0.7	36.6
Brazil-2006 optimal cut-off [†]	1.4	46.8
	Boys	
WHO-2007	0.2	31.0
WHO-2007 optimal cut-off [†]	1.1	52.4
Brazil-2006	0.8	39.6
Brazil-2006 optimal cut-off [†]	1.1	52.2

WHO: World Health Organization; *Negative post-test probability: probability of excess body fatness with diagnosis of non-overweight by BMI; Positive post-test probability: probability of excess body fatness with diagnosis of overweight by BMI; †The optimal cut-offs for BMI Z-values, derived by likelihood ratio analysis.

Brazil-2006 optimal BMI cut-offs), the child's probability of having excess body fatness increased to 50.0% for boys and 46.0% for girls. The negative and positive post-test probabilities of excess body fatness in schoolchildren diagnosed as non-overweight or overweight according to the existing BMI Z-values from the WHO-2007 and Brazil-2006 references were lower than using the optimal BMI cut-offs. When data from non-overweight children were assessed, both BMI reference values produced similar results to the optimal BMI cut-offs for the negative post-test probability of excess body fatness. On the other hand, in the detection of positive cases the changes obtained with the use of optimal BMI cut-offs were significant. For girls, the positive post-test probability of excess body fatness using the WHO-2007 and Brazil-2006 optimal BMI cut-offs increased 1.14 and 1.27 times, respectively, compared to BMI reference values. For boys, the refinement of the WHO-2007 optimal BMI cut-off was higher than the Brazil-2006 optimal BMI cut-off (1.69 versus 1.31 times).

DISCUSSION

The main findings of this study were that, in terms of both sensitivity and specificity, both BMI-based references performed well in detecting excess body fatness in 7 to 10-year-old

schoolchildren. In addition, once the optimal cut-offs for each BMI reference curve had been selected, the Brazil-2006 reference showed superior performance in the positive post-test probability for girls, and the WHO-2007 reference for boys. The optimal BMI cut-offs were higher than the BMI Z-scores recommended by the WHO-2007 and Brazil-2006 references for the diagnosis of overweight.

In order to define obesity, it is necessary to decide upon both a suitable measure of body fat and a suitable cut-off. Due to its association with body composition and risk factors, as well as to the widespread availability of measurements, the BMI has been largely accepted as a valid indirect measure of adiposity in children. Consequently, grades of nutritional status are commonly assessed by way of a reference population²⁷. Reference curves serve as an “empirical health model”, and can be used to assess the nutritional status of an individual or a population, for both calculation either for comparing to a reference population or for diagnosis in order to identify healthy and unhealthy individuals.

Most studies that evaluated the performance of recommended BMI cut-off values of the reference system based their comparisons on estimates of sensitivity and specificity³⁻¹³. In this study the above-mentioned measures were used to compare the two classification systems, whereas the LR estimation was used to select the optimal cut-offs in each curve, allowing the calculation of the post-test probabilities for each BMI reference. The comparison of the obtained results with those of other studies is limited because of differences in age of the children, methods to measure body fat content, the reference standard and the definition of cut-off values for the evaluation of excess body fatness, as well as the analytical approaches for data analysis.

By way of comparison, we screened the literature to identify studies reporting sensitivity and specificity values of BMI which used the same two references as those used here, and conducted in populations with similar age ranges to our study. In general, the sensitivity obtained for WHO-2007 (98.6% for boys and 92.5% for girls) and Brazil-2006 (94.5% for boys and 94.8% for girls) classifications in this study were higher than those reported in previous studies. In Brazil, the performance of three BMI-based classification systems was analyzed (IOTF, WHO-2007, and Brazil-2006) in 1570 schoolchildren aged 7 to 12 years from the city of Paraíba. The sensitivities and specificities using the percentage of body fatness as reference criteria (estimated from SFT measurements) for WHO-2007 were 64.7 and 97.9% in boys; 47.7 and 97.8% in girls and using the Brazil-2006 classification the values were 90.6 and 92.0% in boys; 97.2 and 84.8% in girls⁷. In a sample of 10 to 19-year-old Brazilian adolescents⁴, the Brazil-2006 classification for overweight showed low sensitivity in girls (44.2% for girls aged ≤ 13 years; 18.9% for girls aged ≥ 14 years), but moderate to high specificity for girls of both ages (97.8 and 100.0%, respectively) using percentage of body fatness (derived from DEXA) as the reference standard. For boys, both sensitivities and specificities were higher than 80%. In another study conducted in Brazil, with a sample of 807 adolescents aged 11 to 17 years, the sensitivities and specificities of

Brazil-2006 classification for overweight using percentage of body fatness (estimated by bioelectric impedance) as the reference standard were 95.2 and 75.6% for boys; 86.8 and 88.0% for girls, respectively⁶. In 6991 Singaporean adolescents aged 12 to 18 years, the sensitivities and specificities of WHO-2007 criteria using the top 5% of body fatness (estimated by four skinfolds measurements) as the reference standard were 69.4 and 95.0% for boys; 53.0 and 98.1% for girls, respectively¹⁰.

The present study found small differences in values of specificities between boys and girls (but only for WHO-2007 reference), whereas the BMI classification systems analyzed by other studies showed, in general, better sensitivity for boys and better specificity for girls^{4-6,10,13}. A systematic review study¹ showed higher values of sensitivity and similar values of specificity for obesity definition when a national reference data was compared to the IOTF approach. In addition the authors pointed out that no statically significant results for sensitivity and specificity were identified between sexes.

The optimal BMI cut-offs to correctly classify children according to their excess body fatness found in the present study were higher than those recommended by the WHO-2007 and Brazil-2006 references for the diagnosis of overweight. They were chosen firstly as a result of the strong relationship between true-positive vs false-positive cases (tests with high LR+ values give very strong evidence for the diagnosis when positive) and secondly, due to a low frequency of false-negative cases (tests with low LR- values are best for ruling out disease). Since the essence of this work is screening, i.e. ruling out disease, LR- values are very important. However, the optimal cut-offs showed both LR+ and LR- values with moderate diagnostic evidence, which would be considered adequate for public health interventions. Thus, the performance of derived cut-offs justifies the loss in sensitivity imposed by the higher cut-off.

Previous studies used LR analysis to compare the performance of the recommended BMI cut-off values^{5,10,13}. However, if a test is intrinsically dichotomous, the results may be reported in terms of either sensitivity and specificity, or LR+ and LR-, because there are no important advantages of LR in this case²⁸. When test results are measured on a continuous scale (e.g. BMI Z-scores) LR can be estimated for a series of test result intervals. In this study the use of the LR analysis allowed us to make use of the information contained in the test and achieve a fine-tuning of optimal BMI cut-offs for the diagnosis of overweight in each curve.

LRs are also particularly well suited for describing the overall odds of disease when a series of diagnostic tests is used. In this study, the proposed optimal BMI cut-offs for classifying children as overweight using WHO-2007 and Brazil-2006 reference curves, showed that the child's probability of having excess body fatness increased to more than 46.0%. However, before starting any treatment or simply informing a patient about a diagnosis, we would want to be more than 90% certain. When a series of tests is used, an overall probability can be calculated using the LR for each test result. Once we have LRs for the various diagnostic tests, we can calculate the final post-test odds using the following formula: $\text{post-test odds} = \text{pre-test odds} \times \text{LR}_1 \times \text{LR}_2 \times \text{LR}_3 \dots \times \text{LR}_n$.

Computing post-test odds after a series of diagnostic tests is much easier than using the sensitivity/specificity method²⁹. It is an alternative method that could be used for additional information beyond the BMI criteria; for example, if we have LR values for other diagnostic tests, such as cardiovascular risk markers.

Among the relevant aspects of this study, the large sample size and the use of the LR and post-test probability analysis should be highlighted, both of which go beyond sensitivity and specificity. It should also be mentioned that there was no use of any sophisticated measurement reference for body fatness due to the fact that this is a population-based study. The absolute measurement of SFT, despite the low reproducibility reported by other studies, is not based on reference models used to estimate the body fat percentage through predictive equations, as these are susceptible to errors^{30,31}. Furthermore, the use of standardized residuals of the SFT rendered the variable independent of the linear effect of age in the variation of body fat. The measurement of SFT has been used in other studies of the BMI diagnostic performance as the reference measure^{7,10,12}. A limitation of this study relates to the lack of assessment of the technical error of measurement by the anthropometrists in the original project, as the reliability of the SFT measurement can be affected by inter- and intra-observer variabilities. Information about technical error of measurement could more effectively assess the reliability of anthropometric measures taken. However, the rigorous elimination of outliers values, was specifically aimed at preventing such problems.

The results of this study refer to children from Florianópolis aged 7 to 10 years. Further studies of this nature could be conducted in other Brazilian states to refine the debate on the use of national and international references based on BMI to classify children according to nutritional status. It is also suggested that these studies should be conducted with the purpose of stimulating review of the critical BMI values in the reference Brazil-2006.

Based on the results of the present study, in terms of clinical practice and public health programs, both the WHO-2007 and the Brazil-2006 BMI classification systems can be used as screening instruments. When the general data presented by this study are analyzed, we cannot indicate the superiority of a determined BMI reference, because the performances of the curves to correctly identify children with or without excess body fatness were similar. At the national level, given the probable population differences in relative risks at certain BMI values, the Brazilian BMI-based reference is likely to be more suitable. One of the limitations of using the age- and sex-specific BMI references for classifying children as overweight can be minimized by choosing the appropriate cut-offs (chosen for increased accuracy in detecting excess body fatness).

Ideally, overweight and obesity should be defined on both, increase in excessive body fatness and adverse effect on health. Further studies based on excess body fatness anchored with combined biological, biochemical, and metabolic endpoints are recommended.

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