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Accuracy of obesity diagnosis in Brazilian adolescents: comparison of Cole et al and Must et al criteria with DXA percentage of fat mass

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Abstract

Objectives: to assess the accuracy of the two most used anthropometric criteria: Must and Cole to diagnose obesity in adolescence comparing with percentage of fat mass determined by DXA.

Methodology: cross-sectional study with 418 adolescents (52.4% males) attending a private school in São Paulo/Brazil. Anthropometric measures of height and weight were taken and BMI was calculated. Analysis of body composition was performed using the DXA to detect percentage of fat mass. Using the method proposed by Ellis & Wong (ERM) two sex-specific linear regression models of fat percentage for age in years were fitted. The comparison between the methods was carried out through the analyses of specificity and sensitivity with two residual percentiles as cutoff points (ERM85[th] and ERM95th) as standards. A logistic model was fitted to estimate the probability curves of obesity classification.

Results: the comparison of the two classic criteria for the diagnosis of obesity with the ERM85[th] and ERM 95th, yields for females the same sensitivities of 0.50 and 0.20 for both criteria. For males sensitivities for ERM 85th were 0.61(Must) and 0.49 (Cole); while for ERM95[th] the sensitivities were 0.81 (Must) and 0.64 (Cole). Therefore, there are high probabilities that those criteria diagnose adolescents as obese, when actually they are not.

Conclusion: the Must and Cole criteria were similar and present flaws for the diagnosis of obesity. In clinical practice and field studies anthropometric criteria should be evaluated as to the diagnostic accuracy along with ot-

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PRECISIÓN DEL DIAGNÓSTICO DE OBESIDAD EN ADOLESCENTES BRASILEÑOS: COMPARACIÓN DE LOS CRITERIOS DE COLE Y COLS. Y DE MUST Y COLS. CON EL PORCENTAJE DXA SOBRE MASA GRASA

Resumen

Objetivos: valorar la precisión de dos de los criterios antropométricos más utilizados, los de Must y los de Cole, para diagnosticar la obesidad en adolescentes comparando el porcentaje de masa grasa determinada por DXA.

Metodología: estudio transversal sobre 418 adolescentes (52,4% varones) de un colegio privado de Sao Paulo (Brasil). Se tomaron las medidas antropométricas peso y talla, y se calculó el IMC. Se realizó el análisis de la composición corporal utilizando DXA para detectar el porcentaje de masa grasa. Utilizando el método propuesto por Ellis y Wong (ERM), se crearon dos modelos de regresión lineal específicos para el sexo para el porcentaje de grasa en relación con la edad (años). Se realizó la comparación entre ambos métodos mediante el análisis de especificidad y sensibilidad con dos percentiles residuales (Percentil 85 del ERM (ERM85) y percentil 95 del ERM (ERM95)) como puntos de corte estándar. Se ajustó un modelo logístico para estimar las curvas de probabilidad de la clasificación de la obesidad.

Resultados: la comparación de los dos criterios clásicos del diagnóstico de la obesidad con el ERM85 y el ERM95 muestra, para las mujeres, las mismas sensibilidades, de 0,50 y 0,20, para ambos criterios. Para los hombres, las sensibilidades del ERM85 fueron 0,61 (Must) y 0,49 (Cole), mientras que las del ERM95 fueron 0,81 (Must) y 0,64 (Cole). Por lo tanto, la probabilidad de que estos dos criterios diagnostiquen la obesidad en adolescentes es elevada cuando realmente no lo son.

Conclusión: los criterios de Must y los de Cole fueron similares y presentan fallos en el diagnóstico de la obesidad. En la práctica clínica y los estudios de campo, los criterios antropométricos deberían evaluarse en relación con la precisión diagnóstica junto con otros parámetros clíni-

her clinical parameters and, when feasible, the analysis of fatness percentage. However, the anthropometric criteria evaluated are efficient in the identification of non-obese adolescent in the two cutoff points considered.

cos y, cuando sea posible, el análisis del porcentaje de adiposidad. Sin embargo, los criterios antropométricos evaluados son eficaces para la identificación de los adolescentes no obesos con los dos puntos de corte considerados.

Introduction

Obesity may be defined as a multifactor syndrome that consists of physiological, biochemical, metabolic, anatomical, psychological and social alterations. Moreover, refers to an increase in body weight above an arbitrary standard defined in relation to height, characterized by abnormally high proportion of body fat[1].

The prevalence of obesity in developed and developing countries has increased in all age groups, including childhood and adolescence[2,3]. The complex etiology involving genetic and environmental factors, associated to the clinic and metabolic complications that determine the increase of morbid mortality in adulthood, establish the early diagnosis and the prevention as public health priorities[4-6].

The growth speed —adolescence spur— is a characteristic of this period. It happens during the sexual maturation phase and has no precise relation with the chronological age[7] The adolescent's maturation, influenced by the production of sexual hormones, modifies the body composition, determining the distribution of fatness characteristic of each sex[8]. Ethnic factors and physical activity also influence the anthropometric measures and the percentage of fatness in adolescents[9,10].

The diagnosis of obesity in adolescents is made through anthropometric measures based on the body mass index [BMI= Body Weight (Kg)/Height^2 (m^2)] and the percentage of body fatness[11,12].

Anthropometric risk condition for obesity is defined by the BMI value above a certain cutoff point of the reference curve used.[8] The cutoff points most frequently used are those proposed by Must et al.[13], who consider BMI percentiles distribution according to race, age and sex from the NHANES I Curves, and Cole et al.[14] recently presented new cutoff points and reference curves for the BMI as an instrument for the early detection of obesity in childhood and adolescence[14].

Studies were carried out in order to evaluate the body mass index as a risk indicator of obesity in adolescents[11,15,16]. When the BMI was compared to the percentage of fatness determined by the triceps skinfold thickness, it was concluded that, even though it is difficult to diagnose obesity in this age group, the BMI is a simple method: data is easily obtained, it has a low cost and high specificity (86

to 99% for overweight and 96 to 100% for obesity) and low sensitivity (4% to 75% for overweight and 14% to 60% for obesity)[12].

Dual energy X-ray absorptiometry (DXA) method, a more precise measure of the percentage of body fatness, yields accuracy comparable to that of hydrodensitometry, with an in vivo precision of 2 to 4%[17]. Regional studies performed measurements of fat mass in children by means of skin fold thickness and/or DXA, resulting in the median values of the sample studied according to sex, age and state of sexual maturation[18]. However, an international reference standard for the normality of fatness in childhood and adolescence has not yet been proposed[11,19].

This study aims at comparing the agreement between the two anthropometric procedures most used to diagnose obesity in adolescence, Must et al.[13] and Cole et al.[14], with a standard defined as the body fat mass percentage determined by DXA in order to contribute to understand such a challenging and complex clinical procedure.

Methodology

The study was carried out in a private school of São Paulo city (Brazil), attended by 2787 adolescents from well-off families. Adolescents with acute or chronic diseases were excluded. The study sample comprised 454 adolescents randomly selected, 36(8.6%) selected students did not get parental approval, and the final sample comprised 418 adolescents. Adolescents' parents signed the informed consent. The study protocol was submitted to and approved by São Paulo Hospital Ethics Committee.

The adolescent's pubertal stages were classified according to Tanner criteria[20] by two trained pediatricians during a clinical examination. Priority was given to the breast development in females and genitals development in males. The Tanner stages 4 and 5 were aggregated in one category and labeled as T4. Three nutritionists collected the students' anthropometric parameters. Height was measured to the nearest millimeter with a wall-mounted stadiometer, and weight was measured on electronic scale to the nearest 0.1 kg with subjects wearing light clothing and no shoes[21]. Their BMI was calculated from their anthropometry[22]. The body mass percentage was estimated with the use of DXA (Hologic QDR-4500A, Fan

Beam x-ray Bone Densimeter, Inc. Massachusetts), equipped with pediatric (5 to 16 years of age) and adult (>16 years of age) software. One fully trained operator following manufacturer's recommendation of subjects position and results analysis completed all DXA on the same scanner with the same software. The scanner determines total fat mass, bone-free lean tissue mass, bone mineral content (g), and area bone density (g/cm²). Percentage fat mass determined by DXA is calculated as [fat mass / (fat mass + bone free lean tissue mass + bone mineral content) X 100].

Data Analysis

Subjects were classified as obese according to the two classical anthropometrical criteria based on the BMI. The criterion of Must et al.[13] detects obesity when the BMI is above the 95th percentile for race, age and sex from combined NHANES and NCHS curves[13]. The proposal of Cole et al.[14] is based on international cutoff points derived from 6 databases of different countries (including Brazil), each with more than 10,000 individuals. Sex-specific BMI percentile curves were constructed for each country by LMS method[23], and combined by averaging them with the constraint that at the age of 18 the cutoffs must be the stated BMI 25 and 30 for Kg/m² the 85th and 95th percentiles respectively[14].

In the absence of an international reference for cutoff points of the fatness percentage indicative of obesity, we adopted the methodology proposed by Ellis & Wong[24]. Two sex-specific linear regression models of fat percentage for age in years were fitted. In the next step, studentized residuals were obtained and ranked. Individuals were classified in two cutoffs: above the 85th and the 95th residuals percentiles. For simplicity, these classifications will be referred as the Ellis Regression Method (ERM) followed by the respective percentile (e.g. ERM 95th) when it is necessary.

Simple regression models and Pearson correlation coefficient were used to describe the linear trends between fat percentage and BMI in both sexes.

Logistic models were used to estimate the probabilities or risk of obesity classification given the BMI [P (Obesity | BMI)] taking the four (Cole, Must, ERM 85th and ERM 95th) classifications previously mentioned as dependent variables[25].

The ERM classifications were taken as standards for comparison purposes. The comparison with the anthropometric methods was carried out through the analyses of specificity; sensitivity and ROC curve analysis including the comparison of the areas under the curve. The hypotheses of equality between the areas were tested by Bonferroni test[26].

Statistical significance was considered for p-values less than 0.05. The software Stata 7.0[27] was used for the statistical procedures.

Results

Table I presents the descriptive statistics of the main studied variables: Tanner pubertal stage, age, weight, height, BMI and DXA percentage of whole-body fatness.

As expected, it can be observed that all variables increase in the later phases of sexual maturation, which happens earlier for girls. Weight and height show higher absolute values for boys, and the differences between sexes grow deeper in the later stages of age and sexual maturation. Moreover, the percentage of whole-body fatness increases for girls and decreases for boys in the later ages and pubertal stages.

Figure 1 shows that even though there is strong evidence of a correlation between BMI and the DXA percentage of whole-body fatness, such correlation is far from being perfect, especially among males (Male: R= 0.56; Female: R= 0.78) which makes difficult the anthropometric evaluation in adolescence.

Table II shows the probability of a diagnosis of obesity according to the BMI and sex for the criteria of Must et al.[13], Cole et al.[14], ERM 85th and ERM95th[24]. When the procedures of Cole et al.[14] and those of Must et al.[13] are compared for both sexes, it can be observed that the probability to diagnose

Table I
Descriptive statistics-Adolescent classified by gender, age and predominant Tanner pubertal stage. Mean and Standard deviations of height, weight, BMI and DXA percentage of whole-body fatness

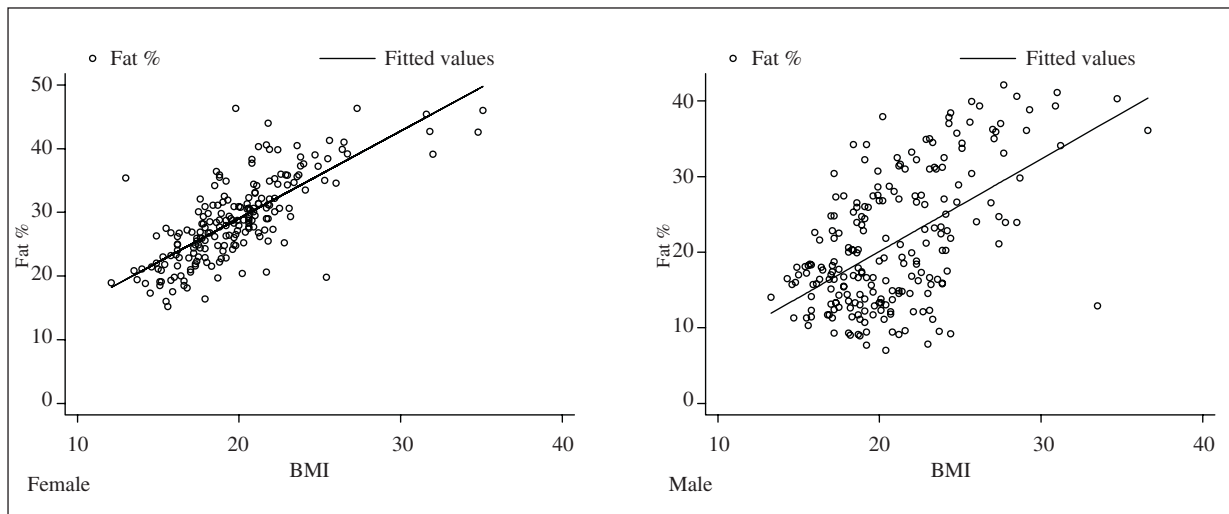| Agender	Age years	Tanner	Height (m)	Weight (kg)	BMi (kg/m²)	DXA Whole-body Fatness (%)
Females	9-11 (n=88)	58% T2	147.0 (7.3)	39.9 (9.0)	18.4 (3.2)	27.3 (6.6)
	12-14 (n=54)	48.2% T3	156.8 (6.2)	51.1 (10.5)	20.7 (3.7)	30.3 (7.0)
	15-18(n=57)	94.7%T4	162.0 (5.5)	55.1 (10.0)	21.0 (3.6)	29.5 (5.8)
Males	9-11 (n=69)	63.8% T1	145.6 (7.5)	41.7 (10.9)	19.6 (3.9)	25.7 (7.9)
	12-14 (n=86)	53.5% T3	162.2 (9.2)	54.2 (11.2)	20.5 (3.8)	20.5 (9.0)
	15-18(n=64)	78.1% T4	173.3 (7.2)	67.4 (12.1)	22.6 (3.9)	17.0 (6.9)

Fig. 1.—Correlation of DXA percentage of whole-body fatness and BMI by gender. The straight lines equations and Pearson's correlation coefficients are: Female - % whole-body fatness = 1.6 + 1.4 (BMI), R = 0.78; Male - % whole-body fatness = 4.3 + 1.2 (BMI), R = 0.56.

Table II
Estimated probabilities of obesity diagnosis for the different methods by BMI and gender

	Females Percentage %					Males Percentage %			
BMI	*ERM 95th	**ERM 85th	MUST	COLE		*ERM 95th	**ERM 85th	MUST	COLE
20	1.1	9.0	0.2	0.0		0.6	4.6	0.5	0.0
21	1.8	13.9	0.7	0.0		1.0	7.2	1.3	0.1
22	3.0	20.9	3.0	0.0		1.6	11.1	3.0	0.3
23	4.9	30.2	11.2	0.2		2.6	16.8	7.1	1.1
24	7.9	41.3	34.2	1.3		4.2	24.5	15.8	3.5
25	12.7	53.5	68.1	8.2		6.7	34.3	31.4	10.6
26	19.6	65.2	89.8	36.9		10.5	45.6	52.8	28.3
27	29.1	75.4	97.3	79.4		16.2	57.4	73.3	56.6
28	40.9	83.3	99.3	96.2		24.1	68.4	87.0	81.2
29	53.7	89.1	99.3	99.4		34.3	77.7	94.2	93.5
30	66.2	93.0	100.0	99.9		46.3	84.9	97.6	9 7.9

* The smaller values of DXA fat mass percentage for girls and boys classified as obese with ERM 95th were 33,5 % and 36,1 % respectively.

** The smaller values of DXA fat mass percentage for girls and boys classified as obese with ERM 85th were 31,4 % and 23,9 % respectively.

obesity in a given BMI is higher for the criteria proposed by Must et al.[13] Table II footnote shows the smaller values of DXA fat mass percentage for girls and boys classified as obese in ERM 95th (33.5% and 36.1%) and ERM 85th (31.4% and 23.9%), respectively. It can also be observed in this table that the probabilities of Must and Cole criteria for diagnosing obesity are quite different from probabilities of such diagnosis utilizing ERM in either of the two adopted cutoff points.

Table III shows the sensitivity (ST), the specificity (SF), the accuracy (A) and the area under the ROC curve. It also shows the significance of Bonferroni's[25] x2 (P) for the anthropometric procedures of Must et al. and Cole et al., according to two cutoff points (ERM85[th] and ERM95[th]) for the studentized residual percentiles of the percentage of total fatness for both sexes.

For girls, Cole and Must procedures yielded similar results in this accuracy analysis when we consider any of the two cutoff points. The results for boys showed that in the ERM 95th cutoff point, the Must criteria is more accurate than Cole criteria.

	Females Percentage (%)					Males Percentage (%)				
ERM 95th	ST	SF	A	ROC	p*	ST	SF	A	ROC	p*
MUST	50.0	96.8	94.5	0.734		81.2	90.9	90.4	0.863	
COLE	50.0	97.9	95.5	0.739	.156	63.6	93.8	92.2	0.787	.212
ERM 85th										
MUST	20.0	97.0	85.4	0.585		60.6	95.7	90.4	0.782	
COLE	20.0	98.2	86.4	0.591	.156	48.5	97.9	90.4	0.732	.089

*p-value of Bonferroni test [26] for the null hypothesis of equal ROC areas for Must and Cole methods.

Nevertheless, the statistical significance test showed no evidence of differences for the two procedures when the ROC curve areas are compared.

Discussion and Conclusion

This cross-sectional study involves the diagnosis of obesity among adolescents of a private school, in a middle class district of São Paulo, Brazil.

Sexual phenotypic changes that take place in adolescence cause body composition and weight/height modifications[7,8]. Our results show increase of fat mass among girls in the higher stages of sexual maturation and the increase of the lean mass among boys in the same stages. A great variety of age groups found in this study that fit into each Tanner's different pubertal stage, reflects one of the main peculiarities of adolescence which make the diagnosis of obesity based on anthropometry less accurate.

These results are in accordance with the literature[9,10], that is, the body fat distribution has a direct relation with sex and pubertal stage. Other genetic and environmental factors, such as ethnic group, eating habits, lifestyle, physical activity, socio-economical situation and nutritional state influence the body composition of the adolescent as well[9,10,18]. The action of hormones such as leptin, which have higher serological levels in female adolescents, contributes to the increase of fatty mass, while the testosterone increases the lean mass among boys. The growth hormone is a powerful inhibitor of the lipoprotein lipase, increasing the free fatty acids and reducing the fatty mass[10]. So, the percentage of body fatness is influenced by genetic and environmental factors, which have a direct relation with the deposit of fat in the adipose tissue[28].

DXA is considered a non-invasive methodology that provides gold standard parameters to determine body composition, including the amount of fatness[17,29]. In general, the data obtained in this study have mean values of fatness percentage and body mass index by age and sexual maturity that are higher than those observed for female Australian[11] adolescents (Tanner 4 female 20.9%) and Dutch adolescents[18]. On the other hand, our results are lower than those reported for pubertal Italian[15] girls and boys, 38.4 and 26.7 %, respectively.

Comparing the present study with the data on the evaluation of Houston (Texas, USA) adolescents, the average fatness percentage distributed according to gender, age and ethnics, presented higher values than those of the white Americans, similar to black Americans and lower than the Latin American females. However, the values for male adolescents aged 9-11 were higher than the white, black and Latin American adolescents. At the ages of 15 to 18 years old, the data obtained were similar to the Latin ethnic group but higher than the American white and black adolescents[24].

Miscegenation constitutes a characteristic of the Brazilian population which compromises the comparison by ethnic groups. We can conclude that the studied well-off Brazilian adolescents have average fat body mass higher than most of the regional studies in the literature.

A correlation between BMI and DXA percentage of whole-body fatness was observed in the studied adolescents (R = 0.78 in girls and e R = 0.56 in boys). A study with Dutch children and adolescents, comparing BMI and percentage of fatness detected by DXA, also found a stronger correlation in females (R = 0.84) when compared to males (R = 0.56)[22]. For the same variables, another study carried out with Italian children and adolescents, reached similar correlation of R = 0.69 and R = 0.63 for girls and boys, respectively[15].

Another study with adolescents aged 12-19 comparing the BMI and the DXA percentage of body composition found correlation coefficient R = 0.85 (0.80-0.89) for girls and R = 0.82 (0.76-0.87) for boys[16]. Therefore, it is confirmed in the literature, the positive correlation of BMI and the DXA percentage of body fat mass in different ethnic groups. Ethnics, age and pubertal stage seem to interfere in this correlation strength.

The method of Must et al.[13] is direct, but the extreme percentiles are poorly estimated, due to the fact that small sample impairs the definition of the tracing[28]. Therefore, the probability of obesity diagnosis according to the criteria of Must et al.[13] becomes low in the BMI between 20 and size in the extreme tail of the studied population distribution. Hence, when they are placed on a graph by points by age, the result can appear an erratic interpolation line, which 25 kg/m^2, reaching values of 89.8% in the BMI 26 kg/m^2 among girls and 73.3% in the BMI of 27 kg/m^2 among boys.

The same is true for the Cole et al.[14] methodology, where the probability to diagnose obesity is 79.4% in the BMI 27 kg/m^2 among girls and 81.2% in the BMI 30 kg/m^2 among boys. The Cole et al.[14] methodology consists of a partially indirect method that can be affected by factors of lower tail BMI[30]. The Cole's choice of the LMS method constrained at the BMI cut off values for 18 years (85th -25 kg/m^2, 95th-30 kg/m^2) for the curves estimation, could be the explanation of those distortions from low BMI's. Consequently, the effect of the choice seems to affect the extreme percentiles, mainly the 95th percentile, related to the diagnosis of obesity.

Regarding female adolescents, all the diagnostic criteria of the procedures proposed by Must et al.[13] and Cole et al.[14] behaved similarly for the two evaluated cutoff points . When the prevalence of obesity in the population of Brazilian school adolescents is fixed in 5% (ERM 95th)[24], the specificity is quite high (96.8 and 97.8% respectively). This is an evidence that the non-obese adolescents identified by these criteria presented a low probability of having excessive fat mass. On the other hand, sensitivity showed that the adolescents identified as obese have a low probability (around 50%) of excessive body fat mass.

This comparison also showed that the procedure proposed by Must et al.[13] is more conservative, providing more strict diagnosis of anthropometric risk for obesity. For example, a BMI of 26 kg/m^2 among girls has a probability of obesity diagnosis of 89.8% when Must et al. criterion is considered and of 36.9% for Cole et al criterion.

When we consider the probability curves shapes for the obesity classification by BMI, the ERM 85th and ERM 95th[24] have a probability trend in a more progressive and smooth way for both sexes than that estimated for Cole et al.[14] and of Must et al.[13] procedures. Among girls, the probabilities of obesity diagnose increases abruptly in BMI 25 kg/m^2 at Must et al.[13] criteria and in BMI 27 kg/m^2 at Cole et al.[14] criteria. This fact shows evidence that the BMI as fat mass predictor for obesity classification leads to an overestimation in prevalence studies, mainly in male population.

Another interesting point is that the probability to diagnose obesity for girls are similar for Must et al.[13], Cole et al.[14] and ERM 85th criteria when we consider BMI of 25 Kg/m^2. The same can be observed for boys when we consider BMI of 27 Kg/m^2.

When the two classic criteria for the diagnosis of obesity were compared with the ERM 85th and ERM 95th, we observed that the sensitivity was low in both procedures. For this reason, there is a higher risk that those methods diagnose an adolescent as obese, when actually he/she is not and such misclassification is higher for girls. Among males, misclassification is higher when Cole et al.[14] criteria is considered. Nevertheless, the different methods did not present any statistical differences in the areas under ROC curves. The fact that positive predictive values are low for the procedures studied could generate misleading information about a given population, which in turn would lead to inappropriate nutritional interventions for obesity[31].

On the other hand, the two studied criteria showed high specificity when compared to the ERM 85th and the ERM 95th showing that the adolescents who are not diagnosed as obese have a small probability of being obese.

In accordance with previous studies, this study showed that the BMI should not be used isolated as an indicator of adiposity in adolescence; it should be analyzed with individual characteristics regarding clinical and nutritional states, as well as information on physical activity and family obesity.

In individual nutritional evaluations, the health staff shall have less difficulties to identify the misclassifications of obesity because in clinical practice other parameters such as physical activity, clinical conditions and percentage of fat mass can be considered in the obesity diagnose.

The optimum association of BMI with another procedures to analyze the body composition is expensive and time consuming to be executed in population studies. In screening programs only anthropometrical measures and indicators are used to diagnose obesity. It is important to consider the percentage of misclassification of obesity when we utilize only indicators based on BMI. Those procedures are good to detect the non-obese adolescents but will identify many false positive cases.

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