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Research Article

Percentiles of Body Circumferences and Cutoff Points Regarding the Obesity of Adolescents from São Paulo – Brazil

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Abstract

Purpose: To describe the distribution of Waist Circumference (WC) percentiles and cutoff points for obesity in Brazilian adolescents.

Methods: Study including adolescents aged ≥10 and <16 years conducted. Anthropometric measurements (weight, height and WC) were taken and data of WC were divided into percentiles derived from LMS regression. The Receiver Operating Characteristic (ROC) curve was used to determine the cutoff points for obesity (BMI ≥ 97th).

Results: The study included 8.020 adolescents, 54.5% were female. The mean WC was higher in males (70.23 vs. 68.55) and increased according to the stages of sexual maturation in girls: M1 and M5 = 63.26 = 74.53 and boys: 67.86 = G1 and G5 = 73.08. The cutoff points of WC showed high sensitivity (89.3 - 100 and 100 - 94.7) and specificity (87.3 - 87.9 and 88.4 - 95), both female and male, respectively. According to the cutoff points proposed, central obesity was identified in 18.57% girls and 20.96% boys. The values of WC above the P75 showed significant association with adiposity in adolescents 10-15 years.

Conclusion: The WC was significantly associated with body adiposity, and its age-specific percentiles and cutoff points may be used as surrogate markers of central obesity and its comorbidities.

ABBREVIATIONS

BMI: Body Mass Index; LMS: (L) Curve (M) Mean and (S) Coefficient of variation; ROC: Receiver Operating Characteristic; SAS: Statistical Analysis System; WC: Waist Circumference; WHO: World Health Organization

INTRODUCTION

Currently abdominal obesity have shown greater growth than overall obesity among adolescents [1,2]. The anatomical distribution of body fat is closely related to the effects of obesity on health. Both in adults and in children, the body fat located in the upper part of the body, or visceral fat, can be a better indicator of endocrinological imbalance, environmental stress or genetic factors than the fat per se [3-5].

Since the measurement of the waist circumference is associated with total body fat and has been considered a powerful marker of abdominal fat accumulation and visceral adiposity tissue in young people [6,7], their assessment is of great importance in the pediatric population [8].

Although several countries [9-11] already published specific cutoff points for its population, there is no international standardization to abdominal adiposity in adolescents, according to sex and age.

It is known that the value of waist circumference may have a large variation (3.8% to 33.2%) from one country to another, possibly due in part to population differences, how to measure, and the cutoff points [12].

In Brazil there is no population studies with specific waist circumference of teenagers who could assist in the diagnosis of abdominal obesity cutoffs. According to Santana *et al.* (2012), the simple assessment of BMI and waist circumference may have significant utility in predicting the development of cardiovascular and metabolic risk factors in adulthood [13].

Therefore, the objective of this work was to assess, in a representative sample of adolescents aged 10 to 15, the distribution of the circumference of the waist in percentiles and values that would represent higher sensitivity and specificity in relation to obesity, identified by the body mass index at the 95th percentile for age and gender, establishing suitable for use in adolescents cutoffs.

MATERIALS AND METHODS

Study design and sampling

The study population was drawn from the "The nutritional profile of adolescents at public and private schools in São Paulo" study. It is a segmented population-based cross-sectional with collection of anthropometric data and other information using questionnaires. The selection of schools was based on the 2002 School Census, which included all schools in the city of São Paulo, divided into four areas: North, Midwest, East, and South.

Local offices were contacted and asked to provide information of schools with students 10 to 15 years attending morning and afternoon classes, their location and number of students enrolled. The total number of schools by area was ascertained and the proportional relationship between public and private schools was calculated taking into account the number of schools by area, i.e., areas with more schools would have a larger number of schools assessed. The following exclusion criteria were applied for school selection: schools with students aged 10 to 16 attending night classes only; schools of difficult access and/or located in violent areas; and schools with a small number of students (less than 200). The remaining schools were then randomly selected; in case of refusal, another school in the same area was drawn. All principals of the participating schools signed consent for the study.

There were studied 43 schools in the city of São Paulo, of which 32 public and 11 private. They were located in the four major areas of the city as follows: 17% in the North; 17% Midwest; 37% East and 29% South. The largest number of public schools were in the Eastern area of the city (n=11; 34.4%) and the largest number of private schools were in the South (n=6; 54.5%). Their original distribution was preserved. Data were collected between September 2004 and June 2005. Adolescents were excluded if they met any of the following criteria: pregnancy; younger or older than the age range; and having a physical condition that would prevent routine anthropometric assessment. No formula was used to estimate the sample size. A probabilistic approach was followed and all schools selected that agreed to be part in the study were asked to hand in the students a free informed consent form to be signed by their parents or guardians agreeing to their children's participation. Only students who handed back a signed consent form were included in the study sample.

All ethical principles of Resolution 196 of the National Brazilian Health Council were followed, and the study was approved by the Research Ethics Committee of Federal University of São Paulo (No. 0977/03).

Study protocol

The anthropometric assessment was led by a team comprising four researchers, three nutritionists and a physical educator. All of them graduate students properly trained in the required techniques and standard procedures. This same team conducted a pilot study with more than 2,000 adolescents, and calculated intra- and inter-observer reliability to minimize errors.

Information on demographic and anthropometric variables and pubertal stage was obtained. Demographic information (age and gender) was collected through a pre-tested questionnaire administered in a face-to-face interview. A self-assessment method was used to determine sexual maturation using Tanner's pubertal staging for breast development (B1, B2, B3, B4, B5) in girls and genitalia (G1, G2, G3, G4, G5) in boys [14]. We validated this approach using the method proposed by Matsudo and Matsudo [15].The adolescents were instructed on the self-assessment following the WHO recommendations [16].

The anthropometric assessment included weight, height and waist circumference (WC) measures following the proposed measurement techniques [16]. Weight was measured using a digital portable scale (Seca®) with capacity of 150 kg and height was measured using a wall-mounted digital stadiometer (Seca®). BMI (kg/m^2) was calculated using these data. WHO-proposed criteria [17] were used to assess nutritional status. WC measures were taken preferably at midpoint between the costal margin and iliac crest [16,18] using an inelastic metric tape (Seca®).

All anthropometric measures were taken during science and physical education classes. Adolescent self-assessment of sexual maturation was performed in a separate room at school. The very school administration would establish a schedule for evaluation days so as it would not interfere with daily school routines. School teachers helped dealing with the students during assessments.

Statistical methods

Transformation of the anthropometric data into percentiles: Construction of the centile curves was performed with the LMS Chart Maker Pro version 2.3 software program (The Institute of Child Health, London), which fits smooth centile curves to reference data [19,20].

References for WC for age were constructed with the LMS method and presented as SD lines. This method summarises the distribution of the data by three spline curves, the L, M, and S, that vary in time: the Box-Cox transformation power that converts data to normality and minimises the skewness of the dataset (L), the median (M), and the coefficient of variation (S) [21].

A descriptive analysis of the study variables was carried out as well as the Mann-Whitney test to compare WC between two groups and the Kruskal-Wallis test for comparison between percentiles (three or more groups) in non-normal distribution.

The analysis of the distribution of the circumference values obtained in the sample studied, we previously ordinated the data, considering from the lowest value (minimum) to the highest value (maximum). Then we subdivided the data into 100 parts of equivalent sizes called percentiles, and adopted the values correspondent to 5th, 10th, 15th, 25th, 50th, 75th, 85th, 90th and 95th, according to gender and age group. We calculated the respective curves from the percentile values of the circumferences.

We carried out the analysis of the ROC curve [22] for all the circumferences, using the 97th percentile of the BMI as the reference, according to the parameters of the WHO [17].

The ROC curves were used to identify the circumference values, according to age and gender, that predict the highest association with the BMI ≥ 97th. The ROC curve calculates the sensitivity (probability of correctly detecting the true-positive results) and the specificity (probability of correctly detect the true-negative results), selecting the value that maximizes the sensitivity and the specificity simultaneously. The ROC curve shows the relation between the values of sensitivity and specificity for each cutoff point, forming a graph in the shape of an inverted "L". The closer to the left upper corner the curve is, and the closer to 1.0 the area under the ROC curve is, the higher the accuracy of the new measure will be in discriminating the subjects, based on the values of the gold standard method.

RESULTS

A total of 8,020 adolescents participated in the study, of which 54.5% (4,372) were female, with mean age of 13.04 (1.27) years. The sample comprised 2.23% of 360,000 middle school students enrolled in public and private schools in the city of São Paulo.

With regard to nutritional status, 69.5% of the adolescents studied were normal weight, 17.2% overweight, 10.3% obese and 0.65% extremely obese. Excess weight was more prevalent in adolescent males than females (31.6% vs. 25.4%) and among private compared to public school students (36.6% vs. 25.3%). There was no statistical difference in nutritional disorders by city area (North, South, East and Midwest) (p = 0.097) with the lowest prevalence of excess weight in the East (27.4%) and the highest prevalence in the South (28.6%).

The characteristics of the studied population are presented in Table 1. We can verify that the mean age is similar between boys and girls and a statistically significant difference between all other variables shown in Table 1. Values of weight, height and waist circumference girls are smaller than the values boys.

The Table 2 show the means and standard deviations for waist circumference according to age and gender. In both sexes, we can see an increase in waist circumference with advancing age. Moreover, in all ages, girls have lower values than boys.

Table 3 presents the mean and standard deviations for waist circumference according sexual maturation (Tanner) and gender. In both sexes, we can see an increase in waist circumference with advancing sexual maturation (Tanner stages). Moreover, stages 1, 2 and 3 of Tanner girls have lower values than boys (Table 3).

Table 4 shows the values of the waist circumference in percentiles, according to age and gender. The girls had higher waist circumference at 13 years old, in the percentiles 90, 95 and 97, ie, even with advancing age, the girls reached the highest values of waist circumference to 13 years (90th, 95th and 97th. Already boys have higher values of waist circumference at 15 years for all percentiles, ie, waist circumference boys increased with advancing age (Table 4).

Table 5 presents the cutoff points obtained in the ROC curves of the waist circumference, showing the best point of the curve in which most of the adolescents studied, according to age and gender, would be correctly classified, and a minority would be incorrectly classified as regards obesity.

DISCUSSION

This study assessed the distribution of WC percentiles and

Table 1: Characteristics of the population studied according to gender.

	Female		Male		
	Mean (s.d.)	**Range**	**Mean (s.d.)**	**Range**	**p-valor**
Age (years)	13.03 (1.26)	10.0 – 15.92	13.06 (1.29)	10.0 – 15.92	0.27
Weight (kg)	49.48 (10.91)	24.80 – 106.2	50.55 (13.44)*	22.0 – 110.6	<.001
Height (cm)	155.77 (7.87)	124.5 – 186.8	157.75 (11.39)*	125.83 – 189.3	<.001
BMI (kg/m^2)	20.26 (3.59)	10.74 – 40.29	20.07 (3.8)*	11.75 – 54.80	<.001
WC(cm)	68.5 (9.1)	45 – 119	70.2 (10.0)*	36 – 115	<.001

BMI: Body Mass Index; WC: Waist Circumference; *p<0.05 differences between gender

Table 2: Sample sizes and means and standard deviations (mean (s.d.)) for WC in Brazilian youth 10–15 y of age.

	Females		Males	
Age (y)	**Sample Size**	**WC (cm)**	**Sample Size**	**WC (cm)**
10	180	63.55 (8.24)	134	66.11 (9.05)
11	891	65.86 (8.64)	765	67.65 (9.94)
12	999	67.86 (9.33)	816	68.85 (10.02)
13	1106	69.47 (8.73)	904	71.34 (10.38)
14	961	71.06 (8.93)	787	72.66 (9.03)
15	234	70.95 (7.96)	242	73.23 (9.67)

WC: Waist circumference.

Table 3: Mean and standard deviations (s.d.) for WC, stratified by sexual maturation (Tanner) and gender.

	Females		Males	
Tanner	**Sample Size**	**WC (cm)**	**Sample Size**	**WC (cm)**
1	148	63.26 (9.40)	144	67.85 (10.26)
2	1057	65.69 (8.32)	1080	68.36 (10.31)
3	1807	68.63 (8.51)	1343	70.16 (9.65)
4	818	72.71 (9.3)	669	72.55 (9.86)
5	132	74.52 (9.48)	28	73.08 (10.0)

WC: Waist circumference.

Table 4: LMS percentiles values of WC in 8019 Brazilian adolescents aged 10-15 years.

Gender	Age	n	3th	5th	10th	15th	25th	50th	75th	85th	90th	95th	97th
Female	10	180	53.29	54.26	55.89	57.09	59.04	63.40	69.14	73.08	76.25	81.98	86.63
	11	891	53.36	54.55	56.51	57.94	60.21	65.12	71.15	75.00	77.92	82.81	86.43
	12	999	55.34	56.51	58.45	59.87	62.16	67.17	73.51	77.69	80.93	86.53	90.80
	13	1.106	57.31	58.47	60.40	61.80	64.08	69.05	75.37	79.55	82.80	88.42	92.73
	14	961	58.35	59.58	61.59	63.04	65.35	70.28	76.23	79.98	82.79	87.44	90.82
	15	234	58.56	59.80	61.82	63.27	65.56	70.34	75.97	79.41	81.95	86.06	88.98
Male	10	134	56.02	57.00	58.65	59.88	61.90	66.55	73.02	77.77	81.81	89.78	90.07
	11	765	54.14	55.37	57.40	58.90	61.31	66.63	73.46	78.01	81.57	87.77	92.57
	12	816	54.44	55.81	58.08	59.74	62.39	68.16	75.31	79.93	83.45	89.38	93.79
	13	904	57.15	58.46	60.63	62.22	64.77	70.33	77.29	81.83	85.32	91.25	95.72
	14	787	60.79	61.92	63.81	65.19	67.43	72.34	78.64	82.84	86.14	91.91	96.41
	15	242	62.34	63.40	65.17	66.48	68.61	73.41	79.84	84.34	88.02	94.85	100.59

WC: Waist circumference.

Table 5: Cutoff points of the WC according to age and gender of the adolescents that presented the highest sensitivity and specificity as regards adiposity.

			Age					
Variables		**Gender**	**10**	**11**	**12**	**13**	**14**	**15**
WC	Area	F	0.916	0.897	0.941	0.931	0.945	0.966
		M	0.968	0.919	0.944	0.945	0.971	0.946
	95% CI	F	0.841-0.991	0.853-0.941	0.916-0.967	0.900-0.962	0.916-0.973	0.939-0.992
		M	0.941-0.994	0.885-0.952	0.919-0.970	0.914-0.976	0.945-0.998	0.861-1.000
	Spec	F	87.3	86.9	83.0	81.8	82.4	87.9
		M	88.4	86.7	90.3	89.3	91.3	95.1
	Sens	F	89.3	82.6	94.3	91.7	94.7	100.0
		M	100.0	88.8	89.2	92.5	97.2	94.7
	Cutoff	F	≥69.20	≥72.40	≥73.30	≥74.95	≥76.90	≥78.95
		M	≥71.15	≥73.40	≥76.90	≥78.85	≥79.95	≥84.75

WC: Waist circumference: Spec: Specificity; Sens: Sensitivity.

cutoffs in adolescents 10–15 years in the city of São Paulo that would more likely identify adiposity.

In Brazil, recent data has revealed that malnutrition in young population coexists with alarming high prevalences of overweight and obesity, which has an impact on the national health care system and other cultural, social, and economic effects. Data from the POF (Pesquisa de Orçamentos Familiares) - Brasilian National Data of Budget Familial Research (2008–2009) (provided by the Brazilian Institute of Geography and Statistics) showed that 21.7% of male and 19.4% of female adolescents are overweight [23].

In the present study it was found that approximately 28% of adolescents are overweight reviews, and according to sex, the prevalence of overweight was higher than that found in studies of POF. This result demonstrates the importance of making an early diagnosis of obesity in this population and especially to verify the presence of risk factors associated with it.

The pattern of regional distribution of body fat is concerning because there is an intrinsic relationship between fat body accumulation and development of metabolic disorders such as insulin resistance, dyslipidemia and diabetes and other noncommunicable diseases [7,24,25].

Although it is pertinent discussion on the use of waist circumference, BMI, or a combination of these indices as markers of cardiovascular risk, was observed in most investigations that high values of waist circumference are associated with a higher risk hypertension [26,27].

In relation to its easy of measurement, the waist circumference appropriate for epidemiological studies in children, in addition to being an important tool to verify overweight and obesity in children, thus identifying those who are at risk for the development of metabolic and cardiovascular complications [28,29].

The waist circumference is a highly sensitive and specific measure of the fat located in the upper part of the body [30,31]. However, researchers still lack information on its clinical usefulness to evaluate obesity-related health risks in adolescents [32,33]. Recently, Burgos *et al.* investigated the association of waist circumference with cardiovascular risk factors in Brazilian children and adolescents [34].

The appearance of secondary sexual characteristics, growth spurt and changes in body composition during adolescence vary greatly between individuals, making it difficult to establish specific criteria for nutritional status classification especially based on chronological age [35].

In our study, the WC differences found are likely to be due to differences in overall adiposity; 31.6% of boys were overweight or obese compared with 25.4% of girls. It is noteworthy the different cutoffs in different stages of sexual maturation, pointing to an interaction with physical changes during adolescence and a need for using different cutoffs. Regardless of height, which showed statistical significance for both females ($p<0.001$) in different pubertal stages: B1 ≠ (B2, B3, B4, B5); B2 ≠ (B3, B4, B5); B3 ≠ (B4, B5) and male ($p <0.001$) ≠ G1 (G2, G3, G4, G5); G2 ≠ (G3, G4, G5); G3 ≠ (G4, G5), shows the importance that sexual maturation has on body composition of adolescents.

As the population of this study was 10-16 incomplete years, there was little variation in age studied. Most students were pubescent. Of the 8,020 adolescents studied, sexual maturation was assessed in 90.1% of the sample (7,226, 54.8% of females) because some schools did not allow the self-assessment of their students. Of the adolescent females and males evaluated, 3.7% and 4.4% were in stage 1, 26.7% and 33.1% in stage 2; 45.6% and 41.1% in stage 3; 20.65% and 20.5% in stage 4; and 3.3% and 0.9% in stage 5, respectively.

It was possible to observe in this study, that the waist circumference also presented a good relation to adiposity. The mean value of the waist circumference of the female adolescents that represented the highest relation to adiposity was 74.28cm, with 0.932 of area under the ROC curve, 92.1% of sensitivity and 84.9% of specificity. The mean value of this circumference in the male adolescents was 77.5cm, with 0.949 of the area under the ROC curve, 93.7% of sensitivity and 90.2% of specificity. Since the cutoff points of waist circumference showed high sensitivity and specificity for both genders, we might assume that very few adolescents would be recommended weight control unnecessarily in case those cutoff points were applied to that population.

In the table of waist circumference distribution in percentiles, the values that presented the highest correlation with adiposity for the female adolescents are at the 75th percentile, except for the 15-year-olds, in which the value found corresponds to the 85th percentile. Regarding male adolescents, these values correspond to the 75th percentile for ages 10 to 13, and to the 85th percentile for ages 14 and 15.

A limitation of this study is that BMI for age and gender was used as the gold standard to test WC cutoffs while the use of body composition measures could provide more effective results. But, in the original study, the sample studied was large and these indicators were not evaluated in the entire population, which prevented further comparisons.

Despite its limitations, the study findings showed that WC was significantly associated with body adiposity. Age-specific WC percentiles and cutoff points may be used as surrogate markers of central obesity and its comorbidities and is therefore an important tool for additional clinical assessment in Brazilian adolescents.

CONCLUSION

The results of this study describe the values of circumference at different percentiles of the adolescent population between 10 and 15. They also present the values that would be predictive of a higher relation with obesity, making it possible for health professionals to early identify adolescents at high risk of a higher body fat build-up.

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The World Health Organization (WHO) asserts that the definition of obesity in children and adolescents should be related to that in adults. Nevertheless, since the diseases in adolescence are not as prevalent as they are in the adult population, it is important to asses how accurately anthropometry, including specific levels of Body Mass Index (BMI), and measurements of circumference can predict risk factors diseases in adulthood, as well as support interventions. The results of this study describe the values of circumference at different percentiles of the adolescent population between 10 and 15 years. The WC was significantly associated with body adiposity. They also present the values that would be predictive of a higher relation with obesity.

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