Original article

Diagnostic properties and cutoff points for overweight prediction through anthropometric indicators in adolescents from Caracol, Piauí, Brazil, 2011

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Abstract

Objective: to assess the diagnostic criteria and propose cutoff points for waist circumference (WC), arm circumference (AC), leg circumference (LC) and waist/height ratio (WHR) for overweight prediction in adolescents. **Methods**: a census with all individuals aged 13-19 years old (N=1,075) from the municipality of Caracol-PI, Brazil was carried out; overweight was defined as body mass index (BMI) above one z-score, according to the criterion of the World Health Organization. **Results**: the cutoff points (in centimeters) of WC, AC, LC and WHR for overweight prediction were, respectively, 76.4, 26.4, 34.0 and 0.460 in males, and 74.6, 27.0, 34.5 and 0.475 in females; the area under the ROC curve was above 0.70 (males) and 0.90 (females). **Conclusion**: the anthropometric indicators assessed reached satisfactory diagnostic values for overweight prediction in adolescents from the Brazilian semi-arid region.

Keywords: Nutritional Status; Body Mass Index; ROC Curve; Anthropometry; Cross-Sectional Studies.

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Introduction

Excessive body weight is characterized by the presence of overweight or obesity and is considered an important issue of Public Health throughout the world.[1] In addition to increasing the risk of death and reduce the quality of life, excess weight is a risk factor for almost all chronic non-communicable diseases (NCDs), which can manifest in adolescence, and if worse in adulthood.[2] There is, in literature, sufficient evidence of the link between excess weight in adolescents and morbidity of cardiovascular and metabolic origin in adulthood.[3]

Several methods have been employed to detect the occurrence of excess weight. Among them, it is worth mentioning the dual energy X-ray absorptiometry (DEXA), hydrostatic weighing, plesthmography and anthropometry the most indicated to evaluate body fat. However, the fact that those methods are extremely costly and complex hampers their use in large scale.[4] The anthropometric methods, such as the body mass index (BMI) and the measurement of body circumferences, simple and low cost, are the most commonly used in population-based studies or with a greater number of individuals.[5]

> *Excess weight is a risk factor for almost all chronic non-communicable diseases.*

The BMI is the indicator most often used in all age groups, to determine overweight and obesity.[5] In spite of not evaluating the distribution of body fat,[5,6] the BMI is good to infer excess weight in young individuals.[6] Other anthropometric indicator that has been widely employed in this age range, in place of the BMI or complementary form to this, is the waist circumference (WC). The WC is also a simple and low-cost, capable of achieving good results in the measurement of body composition, since the accumulation of abdominal fat, alone, it is significantly associated with the risk factors for health.[7]

Other parameters have also been used for assessment of body composition, such as the waist/height (WHR)[8,9] and arm circumference (AC).[10,11] However, these indicators are still poorly applied to predict the excess weight in children and adolescents, because for these critical values are not well established in the literature.[7]

Therefore, the present study is justified by the lack of publications about the accuracy of anthropometric indicators to predict excess weight, as well as the cutting points to be used to in this condition.

The purpose of this study was to assess the diagnostic properties and suggest cutoff points for WC, WHR, AC and leg circumference (LC), to predict overweight in adolescents aged 13 to 19 years old from the Brazilian semi-arid region.

Methods

This is a cross-sectional study and is part of a larger project, whose focus was to study pregnancy incidence and issues regarding drug use among adolescents from the municipality of Caracol, south of state of Piauí. Data collection occurred between January and February 2011. Caracol is located approximately 600km from the capital Teresina and has about 10 thousand inhabitants, being 60% residing in the rural area. The Human Development Index (HDI), in 2014, was 0.552 vs. 0.646 in the state of Piauí and 0.727 in Brazil. Since the per capita gross domestic product (GDP) was R$3,371.04 vs. R$7,140.67 (Piauí) and R$20,371.64 (Brazil). In half of the households, the destination of waste is being burned in his own residence. The index of development of basic education is below the target hall. In relation to the rest of the country, the economy of Caracol offers a higher predominance of agricultural activities.[12]

In the study were included all adolescents aged 13 to 19 years, living in urban and rural areas of the municipality. This age range was defined by reason of the study-pilot of the original project have concluded that approximately 90% of adolescents aged 10 to 12 years were not able to read, understand or respond to the self-administered questionnaire. The individuals who were institutionalized or who presented some important cognitive limitation were not included in the study. The pregnant adolescents (n=24) during the period of data collection were also excluded from the analysis.

A standardized questionnaire and developed specifically for the study was applied to the domicile of the participant to investigate demographic issues, socioeconomic and behavioral factors. Anthropometric measurements were collected: height weight; and circumferences of the arm, waist and leg. The weight

was collected by means of a portable digital scale with 100 g precision and a capacity of up to 150 kilos. The height was measured by exact height anthropometer, with an accuracy of one centimeter (1 cm). The circumferences were measured in centimeters, with a metric tape flexible and inelastic in accordance with standardized technique.[13]

WC was measured above the line of the navel; the AC, at the midpoint between the acromion and the elbow; and the LC, in the upper portion of the calf. Adolescents were excluded from the analysis with (i) AC greater than 50cm (n=2) and less than 14cm (n=3), (ii) LC increased with 50cm (n=2) and (iii) WC less than 50cm (n=4); besides these, two were excluded individuals with more than one measurement is incorrect or missing data.

For data collection, participated in eight interviewers, undergraduate students of the Campus of São Raimundo Nonato, Universidade Estadual do Piauí (UESPI). They were trained during four days for the application of the questionnaire and collection of anthropometric measures; the pilot study was carried out on the following day, the fifth day of training, in São Raimundo Nonato. Quality control was performed with the revision of the questionnaires and partial repetition of 5% of interviews, for confirmation and comparison of the responses obtained. All questionnaires were coded and reviewed by the interviewers, and doubly entered in reverse order, by different typists, using the Epi Info program® 6.0.

Excess weight was defined as BMI, calculated by the ratio between the weight (kg) and height squared (m^2). We used the criteria of the World Health Organization (WHO), which defines overweight as a BMI above a z-score for age and sex.14 The measures of WC, AC, LC and WHR were compared with BMI, and their diagnostic criteria tested and evaluated for prediction of excess weight.

For data analysis, we used the Stata® version 11.2. Continuous variables were described by mean and standard deviation (SD). In the normality of variables was tested and confirmed by visual analysis of the histogram. The analysis of the linear relationship among the anthropometric variables, we used the Pearson correlation. It is also calculated the coefficient of determination R^2 with the purpose to evaluate the explanatory capacity of each anthropometric indicator on the BMI.

To predict the cutoff points for each indicator analyzed, it was used the technique of receiver operating characteristic (ROC) curve. The area under the ROC curve (AUC) was used to estimate the overall performance of the indicators analyzed in the prediction of excess weight. The AUC that presents value of 1.00 means perfect test, values of 0.90 to 0.99 indicate excellent test of 0.80 to 0.89 reflect test good, from 0.70 to 0.79, test reasonable from 0.60 to 0.69, bad test, and from 0.50 to 0.59, test useless.[15]

The performance of anthropometric measures employed to predict excess weight was measured by the following properties: Sensitivity; Specificity; positive predictive values (PPV) and negative (NPV); positive and negative likelihood ratio (LR) and diagnostic odds ratio DOR. The DOR is the ratio between LR positive and negative LR and describes the practical usefulness of the test, expressing the chance of a positive diagnosis correctly between sick individuals versus the same diagnosis between individuals not sick. So, DOR values higher than 1.00 are directly associated to higher discriminatory capacity of the test analyzed.[16]

For each cutoff point of obtained link point of breakage of the ROC curve, that is, the greater the sensitivity and specificity values simultaneously, it was found that the corresponding percentile. From these values of the cutoff point, we calculated the overall concordance and Kappa coefficient. Were described the confidence intervals of 95% (95%CI) to the AUC, DOR and Kappa coefficient. All analyzes were stratified by sex and age, in years: 13 to 15; and 16 to 19.

The individuals older than 18 years signed the Informed Consent Form (ICF). For the rest, the document was signed by their legal guardian. The project of the study was approved by the Research Ethics Committee of the Federal University of Pelotas (strains/UFPel), under the number 001/08.

Results

Among the 1,109 adolescents eligible for the study, there were 21 losses and other 13 individuals with absent or improbable values. Therefore, the final number of participants in the study was 1,075, with the proportion of 96.9% response. The mean age was 15.7 years (SD=1.9) and the mean BMI was 19.8 kg/m^2 (SD=3.1) (Table 1). It was found prevalence of excess weight of 10.1% (95%CI

8.3;12.0): 9.2% for males (95%CI 6.7;11.7) and 11.0% (95%CI 8.4;13.6) for females.

The values of Pearson correlation coefficients are presented in Table 2. It was found that, for the male sex, the variable with higher correlation with BMI was the LC (r=0.73); and for the female sex, the WHR (r=0.85) and WC (r=0.84). The anthropometric indicators showed higher values of R^2 for the explanation of the variability of BMI in females. The measures of WC, WHR, AC, LC showed 69% of R^2, 72%, 66% and 66%, respectively, for the females. For males, the same indicators had R^2 for 42%, 37%, 41%, 53%, respectively.

In Table 3, are presented anthropometric indicators as predictors of excess weight in adolescents, for both genders: AUC-ROC, sensitivity; specificity; PPV; NVP and ROD. Among the boys, the AUC values ranged from 0.67 (95%CI 0.53;0.81) for AC in ages of 16 to 19 years to 0.85 (95%CI 0.77;0.94) to WHR in ages of 13 to 15 years. For girls, the AUC ranged from 0.92 (95%CI 0.89;0.96) for LC in ages of 16 to 19 years to 0.99 (95%CI 0.98;1.00) to WHR in ages of 13 to 15 years.

The AUC of each anthropometric indicator in predicting overweight in adolescents are presented in Figure 1. It has been observed that the AUC was higher

Table 1 – Description of the age and anthropometric data of adolescents in the municipality of Caracol, Piauí, 2011

Variables	Total (N=1,075)	Males (N=512)	Females (N=563)
	Mean (SD[a])	Mean (SD[a])	Mean (SD[a])
Age (in years)	15.7 (1.9)	15.7 (1.9)	15.7 (1.9)
Weight (kg)	52.3 (9.9)	54.7 (10.4)	50.2 (9.0)
Height (cm)	162.2 (8.9)	166.4 (9.3)	158.3 (6.4)
BMI[b] (kg/m²)	19.8 (3.1)	19.6 (2.8)	20.0 (3.3)
Waist circumference (cm)	71.7 (7.2)	74.0 (6.7)	69.6 (7.1)
Waist/height ratio	0.44 (0.04)	0.45 (0.04)	0.44 (0.04)
Arm circumference (cm)	25.3 (3.0)	25.2 (3.2)	24.9 (2.8)
Leg circumference (cm)	32.5 (2.9)	32.7 (3.0)	32.4 (2.8)

A) SD: standard deviation.
B) BMI: body mass index.

Table 2 – Pearson correlation coefficients for data of anthropometric measures of adolescents (N=1,075) the municipality of Caracol, Piauí, 2011

Sex	Variables	BMI[a]	WC[b]	WHR[c]	AC[d]	LC[e]
Male (N=512)	BMI[b] (kg/m²)	1.00				
	WC[b] (cm)	0.65	1.00			
	WHR[c]	0.61	0.79	1.00		
	AC[d] (cm)	0.64	0.76	0.48	1.00	
	LC[e] (cm)	0.73	0.73	0.46	0.77	1.00
Female (N=563)	BMI[a] (kg/m²)	1.00				
	WC[b] (cm)	0.84	1.00			
	WHR[c]	0.85	0.92	1.00		
	AC[d] (cm)	0.81	0.76	0.70	1.00	
	LC[e] (cm)	0.81	0.74	0.65	0.77	1.00

a) BMI: body mass index.
b) WC: waist circumference.
c) WHR: waist/height.
d) AC: arm circumference.
e) LC: circumference of the leg.

for females and all anthropometric indicators showed predictive ability of reasonable to excellent. The values of the cut-off point, percentile, concordance and Kappa of anthropometric indicators, according to sex and age range, are shown in Table 4. It appeared that the percentiles equivalent to the cutoff points for the prediction of excess weight ranged from 55.1 to AC in males from 16 to 19 years to 86.0 for WHR in females from 13 to 15 years; the overall concordance ranged from 57.0% (Kappa= 0.05) to 93.8% (Kappa= 0.70) for these same groups of sex-age.

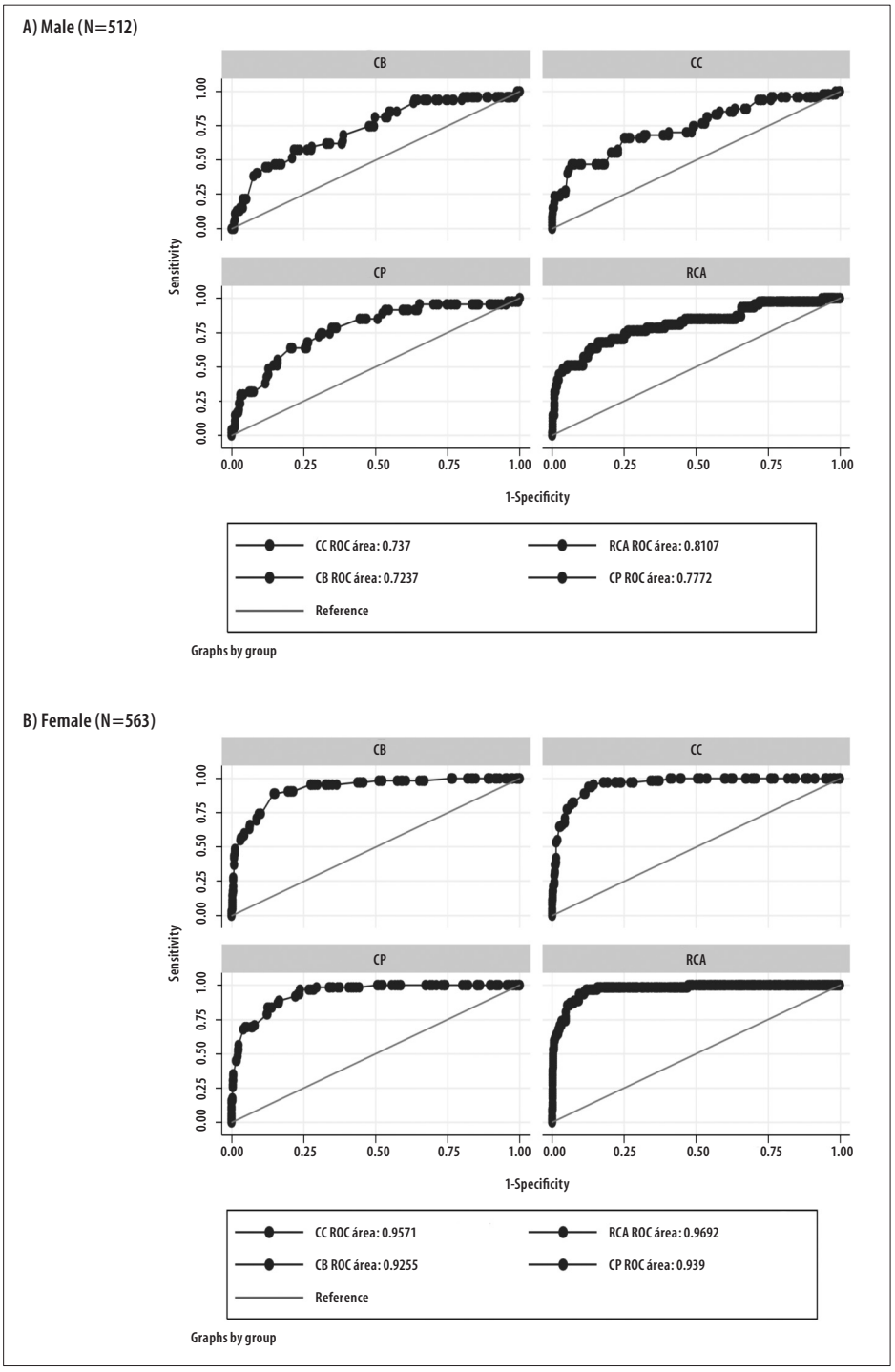
Discussion

The objective of this work was to analyze the diagnostic criteria of some anthropometric indicators for prediction of excess weight in adolescents. Among the main findings, mention the elevated values found for the area under the ROC curve - AUC--ROC - and the DOR, mainly for females. In addition, it should be emphasized that the four indicators analyzed - WC, WHR, AC and LC - presented diagnostic capacity of reasonable to excellent to predict overweight in adolescents.

Table 3 – Diagnostic properties of the anthropometric indicators to detect excess weight in adolescents (N=1,075), according to sex and age, in the municipality of Caracol, Piauí, 2011

Indicator	The AUC-ROC[a] (95%CI[b])	Sensitivity (%)[c]	Specificity (%)[c]	PPV[d] (%)[c]	NVP[e] (%)[c]	DOR[f] (95%CI[b])
Males						
13 to 15 years (n=254)						
WC[g] (cm)	0.80 (0.70;0.91)	71.4	69.8	22.7	95.2	5.8 (2.5;14)
WHR[h]	0.85 (0.77;0.94)	78.6	80.4	33.3	96.8	15 (5.9;38)
AC[i] (cm)	0.80 (0.69;0.90)	71.4	73.0	24.7	95.4	6.8 (2.9;16)
LC[j] (cm)	0.81 (0.71;0.91)	71.4	72.8	23.4	95.7	6.7 (3.1;14)
16 to 19 years (n=258)						
WC[g] (cm)	0.70 (0.56;0.85)	52.6	62.8	10.1	94.3	1.9 (0.8;4.7)
WHR[h]	0.78 (0.64;0.92)	73.7	72.4	17.5	97.2	7.3 (2.6;30)
AC[i] (cm)	0.67 (0.53;0.81)	57.9	56.9	9.7	94.4	1.8 (0.7;4.6)
LC[j] (cm)	0.77 (0.67;0.87)	68.4	68.6	14.8	96.5	4.7 (1.8;12.5)
Females						
13 to 15 years (n=272)						
WC[g] (cm)	0.97 (0.95;1.00)	88.0	92.7	55.0	98.7	93 (27;319)
WHR[h]	0.99 (0.98;1.00)	92.0	93.9	60.5	99.1	178 (42 ; –)
AC[i] (cm)	0.93 (0.88;0.98)	84.0	89.1	43.8	98.2	43 (14;128)
LC[j] (cm)	0.96 (0.92;0.99)	88.0	89.5	45.8	98.7	62 (18;208)
16 to 19 years (n=291)						
WC[g] (cm)	0.95 (0.92;0.97)	86.5	88.2	51.6	97.8	48 (18;128)
WHR[h]	0.95 (0.92;0.99)	86.4	91.3	59.3	97.9	68 (25;185)
AC[i] (cm)	0.93 (0.88;0.97)	75.7	87.8	47.5	96.1	22 (10;51)
LC[j] (cm)	0.92 (0.89;0.96)	78.4	83.1	40.3	96.3	18 (7.7;41)

a) AUC-ROC: area under the ROC curve (ROC: Receiver operating characteristic).
b) 95%CI: 95% confidence interval.
c) The corresponding cutoff points for each measure, sex and age are shown in Table 4.
d) PPV: positive predictive value.
e) VPN: negative predictive value.
f) ROD: ratio odds diagnosis.
g) WC: waist circumference.
h) WHR: waist/height ratio.
i) AC: arm circumference.
j) LC: circumference of the leg.



Legend:
WC: waist circumference.
WHR: waist/height ratio.
AC: arm circumference.
LC: circumference of the leg.
ROC: Receiver operating characteristic.

Figure 1 – ROC curve of anthropometric indicators for diagnosing overweight in adolescents from 13 to 19 years in the municipality of Caracol, Piauí, 2011

Table 4 – Anthropometric indicators for diagnosing excess weight, compared to the BMI[a] (WHO, 2007), among adolescents (N=1,075) in the municipality of Caracol, Piauí, 2011

Indicator	Cut-off point	Percentile	Concordance (%)	Kappa (95%CI[b])
Males				
13 to 15 years (n=254)				
WC[c] (cm)	74.3	65.2	70.0	0.21 (0.10;0.32)
WHR[d]	0.46	73.9	80.2	0.37 (0.24;0.50)
AC[e] (cm)	26.0	68.1	72.8	0.24 (0.13;0.36)
LC[f] (cm)	33.4	68.3	72.7	0.23 (0.13;0.33)
16 to 19 years (n=258)				
WC[c] (cm)	78.1	61.3	62.0	0.05 (0.00;0.13)
WHR[d]	0.46	69.0	72.5	0.19 (0.08;0.29)
AC[e] (cm)	27.1	55.1	57.0	0.05 (0.00;0.12)
LC[f] (cm)	35.0	65.9	68.6	0.14 (0.04;0.24)
Females				
13 to 15 years (n=272)				
WC[c] (cm)	73.2	85.3	92.3	0.64 (0.49;0.78)
WHR[d]	0.47	86.0	93.8	0.70 (0.56;0.83)
AC[e] (cm)	26.5	82.4	88.6	0.52 (0.37;0.61)
LC[f] (cm)	34.5	82.2	89.3	0.55 (0.41;0.69)
16 to 19 years (n=291)				
WC[c] (cm)	75.8	78.7	88.0	0.58 (0.46;0.70)
WHR[d]	0.48	81.4	90.7	0.65 (0.53;0.77)
AC[e] (cm)	27.4	79.7	86.3	0.51 (0.38;0.64)
LC[f] (cm)	34.8	75.3	82.5	0.44 (0.31;0.56)

a) BMI: body mass index.
b) 95%CI: 95% confidence interval.
c) WC: waist circumference.
d) WHR: waist/height.
e) AC: arm circumference.
f) LC: leg circumference.

The average WC found was similar to that presented by studies carried out in Brazil[6] and in other countries of the world,[8] with populations of age matched. Regarding the most appropriate percentile for estimation of excess weight in adolescents, a study conducted in Spain indicated the 70th percentile;[17] another, in New Zealand, pointed out as being more appropriate to the 80th percentile;[18]. Two studies, one located in Norway[19] and another in Mexico,[20] proposed the percentile of 85th percentile as being the best WC cut-off point to predict overweight in adolescents. In the present study, the WC cut-off point for girls from 13 to 15 years corresponded to the 85th percentile, which is equivalent to 1 standard deviation from the mean. Points out that some studies[8,21] recommend the 90th percentile of WC in this age, for both genders, although to estimate the presence of obesity.

As regards the extent of the WHR, studies indicate that this is a good indicator of excess weight.[22-24] A study compared the WHR with WC and waist/hip ratio, coming to the conclusion that, the WHR was the best predictor of central obesity for both sexes.[25] In this study, the WHR also showed the best diagnostic values. The average values of WHR found here are similar to what was described in another study with adolescents from 10 to 15 years, carried out in the city of São Paulo.[22] The cut-off point to prediction of excess weight was also very similar to the values indicated by other researches,[22,24] ranging from 0.46 to 0.48.

Regarding the use of the measure of AC to predict excess weight were found two studies in Brazil;[11,26] however, these studies were conducted with children from 6 to 10 years, which makes it difficult to comparability of cutoff points. A study done with adolescents from 10 to 14 years of South Africa[10] verified cutoff points for AC of 22,8cm and 23,6cm for boys and girls, respectively. These values are a little below those found in the present study, dedicated to the age range from 13 to 15 years.

With respect to the measurement of LC, was not found any study that has employed this circumference for prediction of excess weight in adolescents. However, it showed good diagnostic capacity, in addition to easy measurement, which may be used in other studies. It is noteworthy that this measure has been applied to assess the nutritional status of the elderly.[27]

As the main limitation of the study in question, cites the use of BMI as the 'gold standard' in the analysis for the diagnosis of excess weight. It is widely known that the BMI is not an accurate method to diagnose high body fat, in virtue of not distinguish lean mass from fat mass, although it is the most widely used method in all age groups, to determine overweight and obesity in epidemiological studies.[5] However, for children of a poor municipality as the place where the present study was performed, it may be infeasible carry a balance and a stadiometer for measuring weight and height. Besides that there are specific values for age and sex, if the objective is to classify a child or adolescent as being above your ideal weight. All these factors can compromise the evaluation of nutritional status of these individuals by BMI. Thus, were investigated other anthropometric indicators (WC, AC and LC), whose measure is easily measurable and the instrument (tape measure), low cost and easy businesses, to predict the excess weight among adolescents the municipality of Piauí state, Brazil.

Another limitation of the study was not having assessed the state of sexual maturation of adolescents. It is expected that, in the age range studied (13 to 19 years), female adolescents have a sexual maturation stage of more advanced than the male.[28] This can, at least in part, explain the greater predictive ability of anthropometric indicators of girls in relation to boys. It is noted that, the low prevalence of excess weight in the investigated population (10.1%), which has repercussions on the low values of PPV found.

As strengths of this study, it is noteworthy that included all adolescents from 13 to 19 years in the municipality of Caracol, configuring a census. It is a very poor place, a region of difficult access and little studied: we found only one study previous to this, conducted with adolescents from 12 to 18 years of interior of Piauí (City of peaks), which evaluated the WC and BMI.[29] It emphasizes, moreover, as an advantage of this research, measurement and analysis of four anthropometric indicators, low cost and easy collection, which can be used to predict overweight in adolescents in this region. It reinforces that was not found study in Brazil, in other countries, who has used the circumference of the leg - LC - for the diagnosis of excess weight in the age range analyzed.

We should make mention of the external validity of this study. Considering the sociodemographic characteristics of adolescents residing in the Brazilian semiarid, it is posible to think that the values of the cutoff point found may be valid not only to other municipalities in the state of Piauí, but also for the Brazilian semiarid region as a whole. The data produced here have the potential not only for comparison purposes, being also possible its use by local health managers with the purpose of estimating the occurrence of excess weight among adolescents residing in this region.

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Authors' Contributions

Dumith SC conceived the study, carried out data interpretation and analysis and supervised the writing of the study. Muraro MFR, Monteiro, Machado KP, Dias M and Oliz MM contributed with the interpretation of the data and wrote the study. César JA coordinated data collection and critically reviewed the study. All authors approved the manuscript´s final version and are responsible for all the aspects of the study, as to ensure that any issues regarding the accuracy or the integrity of any part of the study are properly investigated and addressed.

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