

Evaluation of diagnostic criteria and *cut-off* points to predict underweight among adolescents from the Brazilian semiarid region

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Abstract

Objectives: to evaluate diagnostic criteria and to propose arm and calf circumference cutoff points to predict underweight in adolescents aged 13-19 years in two Brazilian municipalities of the semiarid region.

Methods: underweight was defined as a Body Mass Index (BMI) of less than two z-scores, according to World Health Organization criteria (2007). Measurements of arm and calf circumferences were compared to BMI, and the diagnostic criteria for low-weight prediction were evaluated with the area under the Receiver Operating Characteristic (ROC) curve, coefficients of sensitivity, specificity, predictive values, kappa and diagnostic odds ratios.

Results: the prevalence of underweight was 4.2% (CI95%= 3.3-5.0). The cutoff points for arm circumference were 22.1 cm (adolescents of both genders aged 13-15 years), and 25.1 cm and 24.0 cm, respectively, for males and females aged 16-19 years. The cutoff points for calf circumference were 30.0 cm in the first group and 31.8 cm and 31.0 cm, respectively, in the second age group.

Conclusions: both anthropometric indicators analyzed evidenced a reasonable to excellent diagnostic capacity to predict underweight among adolescents.

Key words Nutritional status, Body mass index, ROC curve, Adolescent, Anthropometry



Introduction

Literature indicates that the prevalence of underweight in adolescents has been decreasing, while overweight prevalence has increased.¹ However, it is noteworthy that around 4% of Brazilian children and adolescents aged 0-19 years have a weight deficit or suffer from malnutrition.² This may be related to the influence of poor health and socioeconomic conditions to which a considerable part of the population, especially in the North and Northeast regions of the country, is exposed.³

Malnutrition denotes a pathological condition, due to lack of energy and protein, in varied proportions, and may be aggravated by repeated infections.⁴ Malnutrition may be acute or chronic. Chronic malnutrition is defined as short height for age and differs from acute malnutrition, defined as low weight for height. It is emphasized that the latter can appear at any stage of life and can be reversed.⁵

Weight deficit in childhood and adolescence is attributable to a variety of factors closely related to conditions of life and satisfaction of bare necessities and can potentially delay growth and sexual maturation in this age group. Furthermore, it is related to the greater probability of showing low cognitive development, suffering neurological damage and less resistance to diseases.⁶ In adulthood, this weight deficit can have repercussions on social capital and is related to lower schooling and low income. It may also be reflected in increased susceptibility to cardiovascular diseases in adults.⁷

For the diagnosis of childhood malnutrition, clinical exams, biochemical tests and anthropometry are indicated methods.⁸ The most widely used anthropometric indicator for adolescents is assessing the nutritional status via body mass index (BMI).³ In some communities, however, scales and stadiometers, or even qualified personnel to operate them in order to achieve accurate measurement for weight and height⁹ are not always available. Associated to this, knowledge and access to the reference criteria to conduct the investigation of the nutritional status classification are required.

The use of arm circumference (AC) measurement for detection of underweight in children and adolescents has been recommended in other countries, in situations where, for various reasons, classic anthropometric indicators based on weight and height knowledge cannot be used.^{9,10} Compared to these indicators, the AC measurement tool has the advantage of being a simple device (tape measure), fast, with results easily interpreted and low cost.⁹

Regarding calf circumference (CC) measure-

ment, no study using this type of measurement to predict underweight in adolescents was found. However, this measure has been applied to evaluate malnutrition and underweight in the elderly, showing good diagnostic capacity, besides being easily measured.¹¹

This study aimed to test diagnostic criteria and to propose cutoff points for AC and CC for the prediction of underweight in adolescents of two municipalities in the Brazilian semi-arid region.

Methods

This study is part of a larger project that aimed to evaluate basic health indicators and issues related to drug use and adolescent pregnancy in the municipalities of Caracol and Anísio de Abreu, in the state of Piauí, Brazil. This is a cross-sectional, population-based study with all adolescents aged 13-19 years living in urban and rural areas of these municipalities between January and February 2011. Further methodological details are available in other publications.^{12,13}

These municipalities are located in the south of Piauí, approximately 600 km from Teresina, the capital. At the time of collection, the population of Caracol and Anísio de Abreu was 10,212 and 9,098 inhabitants, respectively. The Human Development Index (HDI) of the municipality of Caracol was 0.552, and 0.635 for Anísio de Abreu.¹⁴

Information was collected from the adolescents through a standardized questionnaire for the purposes of this study, applied at home, containing socioeconomic, demographic and behavioral issues. Weight, height, AC and CC measures were also collected. Weight was measured with a portable digital scale with 100g precision and capacity for up to 150 kilograms. Height was measured with anthropometer "Alturaexata"[®] with an accuracy of one millimeter. Circumferences were measured with a flexible and inelastic measuring tape according to a standard technique.¹⁴ CB was measured at the midpoint between acromion and olecranon, and CC was measured at the upper portion of the calf in order to take the largest circumference.

Data were collected by eight interviewers, undergraduate students from the Campus of São Raimundo Nonato, State University of Piauí (UESPI), trained for four days. On the fifth day, the pilot study was also carried out in the city of São Raimundo Nonato (PI). Quality control was performed with the review of questionnaires and partial repetition of 5% of interviews to compare responses obtained and confirm their achievement.

All questionnaires were coded, revised and double entered in reverse order by different typists using the Epi-Info® 6.0 program.

Underweight was identified from the BMI (kg/m^2), according to World Health Organization criteria,¹⁵ which define underweight as BMI below minus two z-scores for age and gender. AC and CC measurements were compared with BMI and their diagnostic criteria were tested and evaluated for underweight prediction. Data were analyzed with program Stata®, version 11.2.¹⁶ Continuous variables were described by mean and standard deviation (SD). The normality of these variables was tested and confirmed by visual analysis of the histogram. Pearson correlation (r) was used to analyze the linear relationship between anthropometric indicators. The coefficient of determination (R^2) was also calculated.

The Receiver Operating Characteristic (ROC) curve technique was employed to predict the cutoff points for each of the two indicators analyzed. The area under the curve (AUC) ROC was used to estimate the overall performance of the indicators analyzed in the prediction of underweight. The AUC-ROC value of 1.00 is a perfect test; values from 0.90 to 0.99 indicate excellent test; values from 0.80 to 0.89 show a good test; values from 0.70 to 0.79 suggest that the test is reasonable; values from 0.60 to 0.69, poor; and values from 0.50 to 0.59 indicate a useless test.¹⁷

The performance of indicators used to predict underweight was measured by the criteria of sensitivity, specificity, positive predictive values (PPV) and negative predictive values (NPV), positive and negative likelihood ratio (LR) and diagnostic odds ratio (DOR). DOR consists of ratio between LR^+ and LR^- and shows the practical utility of the test, expressing the odds of a correctly positive diagnosis between sick individuals versus the same diagnosis among non-sick individuals. DOR values above 1.00 are directly associated with greater discriminatory power of the test analyzed.¹⁸

The corresponding percentile was verified for each cutoff point obtained, at the break point of the ROC curve, that is, at the highest values of sensitivity and specificity simultaneously. The overall concordance and kappa coefficient were calculated from these cut-off points. Confidence intervals of 95% (95% CI) for AUC, DOR and kappa coefficient were shown. Analyses described above were stratified by gender (male / female) and by age group (13-15 years and 16-19 years).

The study design was approved by the Research Ethics Committee of the Faculty of Medicine, in

Federal University of Pelotas (CEPAS / UFPel).

Results

Forty-nine losses were accounted for of the 2,154 eligible adolescents. We excluded 17 individuals with extreme values for anthropometric measurements (AC less than 14 cm, AC greater than 50 cm or CC greater than 50 cm). Thus, the N of the study was 2,088, with a response rate of 96.9%. Mean age was 15.7 years ($\text{SD}=1.9$) and mean BMI was $19.9 \text{ kg}/\text{m}^2$ ($\text{SD}=3.1$) (Table 1). An underweight prevalence of 4.2% ($\text{CI}95\%= 3.3\text{-}5.0$) was found for the whole sample, with 4.9% ($\text{CI}95\%= 3.5\text{-}6.2$) for males and 3.6% ($\text{CI}95\%= 2.5\text{-}4.7$) for females.

The correlation coefficients of AC and CC with BMI varied from 0.74 (AC males) to 0.81 (AC females). The anthropometric indicators showed higher values of R^2 for the explanation of BMI's variability in females. AC and CC measurements had an R^2 of 66% and 64%, respectively, in females; for males, the same indicators had an R^2 of 55% and 58%.

The AUC-ROC of the anthropometric indicators for underweight prediction is shown in Figure 1. We observed that AUC was higher for females, and is "good" (0.85 for AC and 0.87 for CC). In males, AUC was "reasonable" for AC ($\text{AUC}=0.76$) and "good" for CP ($\text{AUC}=0.82$).

The diagnostic criteria (AUC-ROC, sensitivity, specificity, PPV, NPV and DOR) of the anthropometric indicators as predictors of underweight, according to gender and age range are shown in Table 2. AUC ranged from 0.78 (0.70-0.87) for AC in males aged 13-15 years to 0.88 (0.82-0.93) for CC in the same age group. In females, AUC values ranged from 0.85 (0.74-0.96) for CC among those aged 13-15 years to 0.91 (0.86-0.95) for CC in those aged 16-19 years.

Table 3 shows the cutoff values, percentile, concordance, kappa coefficient of the anthropometric indicators, according to gender and age group. The *cut-off* point for underweight, in the age group of 13-15 years was 22.1 cm for AC and 30.0 cm for CC, for both genders. For the age group 16-19 years, AC *cut-off* point was 24.0 cm (females) and 25.1 cm (males), and 31.0 cm (females) and 31.8 cm (males) for CC. We found that percentiles equivalent to *cut-off* points for underweight prediction ranged from 19.0 cm (CC for females aged 16-19 years) to 29.1 cm for AC in males aged 13-15 years. The overall concordance ranged from 84.3% ($\text{kappa}=0.27$) to 72.6% ($\text{kappa}=0.10$) for the same groups above.

Table 1

Description of age and anthropometric data of adolescents from the city of Caracol and Anísio de Abreu (PI), Brazil, 2011.

Variable	All (N=2.088)	Males (N=970)	Females (N=1.118)
	$\bar{X} \pm SD$	$\bar{X} \pm SD$	$\bar{X} \pm SD$
Age (years)	15.7 ± 1.9	15.7 ± 1.9	15.7 ± 1.9
Weight (kg)	52.4 ± 10.0	54.6 ± 10.9	50.4 ± 8.8
Height (cm)	161.9 ± 8.7	166.4 ± 8.9	158.0 ± 6.3
BMI (kg/m ²)	19.9 ± 3.1	19.6 ± 2.9	20.2 ± 3.2
Arm circumference (cm)	25.2 ± 3.1	25.5 ± 3.3	25.0 ± 2.9
Calf circumference (cm)	32.6 ± 3.0	32.7 ± 3.1	32.6 ± 2.9

Table 2

Diagnostic properties of anthropometric indicators for the prediction of underweight in adolescents according to gender and age group. Caracol and Anísio de Abreu (PI), Brazil, 2011 (N = 2,088).

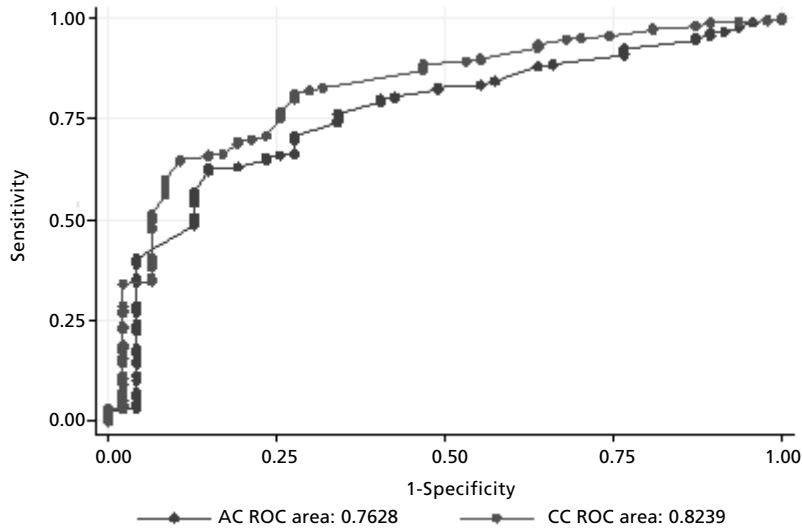
Indicator	AUC-ROC (CI95%)	Sens. %	Spec. %	PPV %	NPV %	DOR (CI95%)
Male 13-15 years (n=482)						
AC (cm)	0.78 (0.70; 0.87)	75.0	72.5	8.6	98.8	7.9 (2.6; 24)
CC (cm)	0.88 (0.82; 0.93)	75.0	77.3	10.2	98.9	10.2 (3.4; 31)
Male 16-19 years (n=488)						
AC (cm)	0.84 (0.76; 0.93)	80.6	78.6	20.3	98.4	15.3 (6.3; 37)
CC (cm)	0.86 (0.79; 0.94)	77.4	80.3	21.1	98.1	14.0 (6.0; 33)
Female 13-15 years (n=559)						
AC (cm)	0.87 (0.75; 0.98)	81.3	80.1	10.7	99.3	17.5 (5.2; 58)
CC (cm)	0.85 (0.74; 0.96)	75.0	81.6	10.7	99.1	13.3 (4.4; 40)
Female 16-19 years (n=559)						
AC (cm)	0.89 (0.84; 0.94)	79.2	79.4	14.7	98.8	14.7 (5.6; 39)
CC (cm)	0.91 (0.86; 0.95)	87.5	84.1	19.8	99.3	37 (11.5; 119)

AUC-ROC:= Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC); Sens.= Sensitivity; Spec.=Specificity; PPV= Positive Predictive Value; NPV= Negative Predictive Value; DOR= Diagnostic Odds Ratio; CI95%= 95% Confidence Interval; AC= Arm Circumference; CC= Calf Circumference.

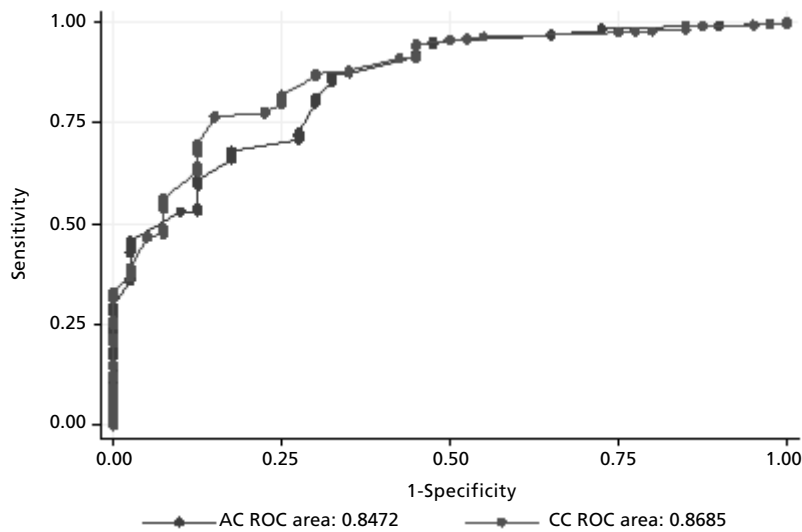
Figure 1

ROC curve of the anthropometric indicators for the diagnosis of underweight in adolescents aged 13 to 19 years from Caracol and Anísio de Abreu (PI), Brazil, 2011.

A) Male (n=970)



A) Female (n=1,118)



AC= Arm Circumference; CC= Calf Circumference; ROC= receiver operating characteristic.

Table 3

Anthropometric indicators for diagnosis of underweight in adolescents, by BMI / WHO, 2007. Caracol and Anísio de Abreu (PI), Brazil, 2011 (N = 2,088).

Indicator	Cut-off point	Percentile	Agreement (%)	Kappa (CI95%)
Male 13-15 years (n=482)				
AC (cm)	22.1	29.1	72.6	0.10 (0.04; 0.16)
CC (cm)	30.0	24.5	77.2	0.13 (0.05; 0.20)
Male 16-19 years (n=488)				
AC (cm)	25.1	25.2	78.7	0.25 (0.16; 0.34)
CC (cm)	31.8	23.4	80.1	0.26 (0.16; 0.35)
Female 13-15 years (n=559)				
AC (cm)	22.1	21.7	80.1	0.15 (0.07; 0.22)
CC (cm)	30.0	20.0	81.4	0.15 (0.06; 0.23)
Female 16-19 years (n=559)				
AC (cm)	24.0	23.1	79.4	0.19 (0.11; 0.27)
CC (cm)	31.0	19.0	84.3	0.27 (0.17; 0.37)

BMI= Body Mass Index; WHO= World Health Organization; CI95%= 95% Confidence Interval; AC= Arm Circumference; CC= Calf Circumference.

Discussion

This study aimed to test the diagnostic criteria of two anthropometric indicators (AC and CC) and propose cutoff points to predict underweight in adolescents. Among the main findings are the high values of AUC-ROC (0.78 to 0.91) and DOR (7.9 to 37.0) for both genders and age groups, which means that the two indicators had acceptable diagnostic capacity.

Underweight prevalence was 4.2%, slightly higher than that found in Brazil by the Family Budgets Survey in 2008-2009, with adolescents aged 10-19 years (3.4%),² In 2004, in a study with children aged 8-14 years in the municipality of Rio Branco (Acre) using the WHO criteria,¹⁵ the authors reported an underweight prevalence of 2.5%.¹⁹ In 2001, another study carried out in the city of Porto Velho (Rondônia) found that 4% of children aged 7-10 years were underweight in relation to height.²⁰ It is worth noting that the prevalence of underweight in children and adolescents increases as family income decreases.²

Two studies, namely, one in India⁹ and another in Cambodia¹⁰ applied AC measurement for underweight prediction. The cutoff points found for AC in prediction of underweight (22.1 cm) for the age group of 13-15 years in both genders are similar to values found in a study in India,⁹ in the same age group. The study conducted in Cambodia¹⁰ with children aged 0-14 years of both genders evidenced CB values for acute malnutrition of 18.2 cm in boys and 17.9 cm in girls. Difference found in values in

this last study may be due to the different age range analyzed.

Sensitivity was approximately 90% in both studies reported previously, with specificity varying from 62%¹⁰ to 71%.⁹ In this study, both sensitivity and specificity returned values close to 80%. The AUC-ROC for AC as a predictor of underweight in the study with children and adolescents in Cambodia reached values very similar to those verified in this study (around 0.80). In the study carried out in India with adolescents, AC had a correlation of 0.82 with BMI ($R^2=68\%$), values slightly higher than those found in this study ($r=0.76$, $R^2=58\%$).

The main limitation of this study is the adoption of BMI as the "gold standard" used in analyses for the diagnosis of underweight. While BMI is not the most accurate method for assessing body composition, it is the widely used method in all age groups to determine nutritional status in epidemiological studies.^{2,5} However, for children and adolescents from a poor municipality such as the location used for this study, it may be impractical to assess weight and height. In addition, there are specific values for gender and age to classify BMI at underweight. All these factors may compromise the assessment of the nutritional status of these individuals with BMI.

Therefore, other anthropometric indicators (AC and CC) were investigated, whose measurement is simple and the tool (tape measure) is low-cost, in order to predict underweight among children and adolescents of these Brazilian semi-arid region cities. Another limitation was that no adjusted

analysis was performed for some possible confounders, such as stage of sexual maturation, skin color and socioeconomic level.

As a strength of this research, it should be emphasized that all adolescents aged 13-19 years from the municipalities of Caracol and Anísio de Abreu (PI), representing a census, were included. Studies on these sites are scarce because regions are very poor and difficult to access. Another advantage of this study is the measurement and analysis of two anthropometric indicators, which are low-cost and easy to collect and can be performed more

commonly and used to predict underweight in adolescents in this region. It is also worth noting that AC is already used by doctors of the Médecins Sans Frontières program in Africa to predict malnutrition, showing that it is a useful tool.²¹

Thus, we believe that the indicators used in this study can be applied not only by other researchers, for comparison purposes, but also by health managers and even by the community living in the Brazilian semi-arid region in an attempt to diagnose more swiftly the occurrence of underweight in apparently healthy adolescents.

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Received on March 17, 2017

Final version presented on October 27, 2017

Approved on December 7, 2017