

Neck circumference: cutoff points for Brazilian children

Circunferência do pescoço: proposta de pontos de corte para crianças brasileiras

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ABSTRACT

Objective

The objective of the present study was to propose cutoff points of neck circumference for predicting overweight in Brazilian children.

Method

We conducted a cross-sectional study with 875 children from public schools in Brazil. Weight, height, and neck circumference were measured. Nutritional status and the risk of complications were assessed based on the values of body mass index and neck circumference. Receiver operating characteristic curve analysis was used to verify the cutoff points.

Results

The median age was eight years, and the majority of the children had normal weights by body mass index and had no risk of metabolic complications by neck circumference. There was a correlation between neck circumference and body mass index ($k=0.689$; $p<0.005$). The mean values proposed for overweight were 29.2 cm for girls and 29.1 cm for boys.

Conclusion

Neck circumference had a good correlation with body mass index, and the cutoff points proposed can identify overweight in Brazilian children.

Keywords: Anthropometry. Child development. Nutritional status.

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RESUMO

Objetivo

O objetivo do presente estudo foi propor pontos de corte para circunferência do pescoço para predição de excesso de peso em crianças brasileiras.

Método

Estudo transversal realizado com 875 crianças. Foram mensurados peso, estatura e circunferência do pescoço. O diagnóstico do estado nutricional e risco de complicações foi realizado com base nos valores de índice de massa corporal e circunferência de pescoço. Para verificar os pontos de corte foi utilizada a curva Característica de Operação do Receptor.

Resultados

A mediana de idade foi de oito anos e a maioria das crianças apresentou eutrofia pelo índice de massa corporal e nenhum risco de complicações metabólicas. Observou-se correlação substancial entre a circunferência do pescoço com o índice de massa corporal ($k=0,689$; $p<0,005$). Os valores médios de circunferência de pescoço propostos para excesso de peso foi 29,2 cm para meninas e 29,1 cm para meninos.

Conclusão

A circunferência do pescoço possui boa correlação com o índice de massa corporal e os pontos de corte aqui propostos possuem força para identificar crianças brasileiras com excesso de peso.

Palavras-chave: Antropometria. Desenvolvimento infantil. Estado nutricional.

INTRODUCTION

Computed tomography and Dual-Energy X-ray Absorptiometry are considered as reference techniques for total body fat measurement; however, as they are expensive, they are used only in scientific research and in specific cases [1]. In pediatrics, doubly indirect methods constituting anthropometry, or more specifically, weight and height measurements to calculate the Body Mass Index (BMI), are primarily used to predict the nutritional status of children [2,3]. Other techniques are also used, such as skinfold measurement and Waist Circumference (WC); however, due to technical limitations, other measurements to assess risks related to excess body fat are being studied, for example, Neck Circumference (NC) [4,-6].

According to Preis *et al.* [7], NC measures the risk of metabolic complications more accurately than other commonly used methods, such as WC and BMI. It is an easy-to-perform and economical technique that presents a good correlation with BMI and WC, and using NC is as practical as using WC; additionally, it is not influenced by respiratory movements, abdominal distension, and differences in measurement protocols at different locations [5,6,8,9].

As it is a relatively new anthropometric assessment technique, few studies use NC as an indicator of adiposity in children, and very few cutoff points have been proposed in the literature for children. Magalhães *et al.* [10] state that the cutoff points currently used were formulated with children from China, the United States, and Turkey and, despite the low number of studies, the existing results indicate that NC is a useful technique to identify overweight, obesity, and the risk of high adiposity; additionally, it is an important predictor of the risk of cardiovascular disease, especially when the cutoffs are adjusted for sex and age [11,12].

Considering the above, the objective of this study was to propose cutoff points for predicting metabolic risk using the NC of Brazilian children.

METHODS

This cross-sectional study included children from municipal schools in *Volta Redonda* (RJ), Brazil. The city had 39 municipal schools at the end of 2017 and, to minimize bias, schools and groups that had

children eligible to participate in the research were randomly selected till the sample size for statistical representativeness was achieved.

The inclusion criteria were children of both sexes aged 7–10 years, who had informed consent forms signed by their legal guardians. The exclusion criteria were children who were absent on the day of the evaluation or any event that could affect anthropometry, such as the presence of body edema, metallic prostheses, limbs in plaster casts, goiter or other masses in the neck, neck or cervical cervix deformity, genetic disorders, and health problems being treated with medications that could change their body compositions. Information about the presence of disease or use of medication was verified using the school registration form. The Tanner classification was used to minimize selection bias, and girls who self-reported menarche or who rated themselves as \geq PH3 or \geq B3 (PH = pubic hair; B = breast) and boys who classified themselves as $>$ PH1 or $>$ G2 (PH = pubic hair; G = genitalia) were excluded [13]. Finally, children who refused to provide at least one of the necessary anthropometric measurements, despite the consent of their guardians, were excluded.

Weight and height were measured according to the protocol proposed by the Brazilian Ministry of Health [14] using an Avanutri® digital scale with 150 kg capacity and 0.1 g graduation and an Avanutri® portable anthropometer with 2 m length and 0.1 cm graduation. These measurements were used to calculate the BMI. Diagnoses were classified using the BMI cutoff points by age proposed by the World Health Organization (WHO) [15].

The NC was measured at the average height of the neck, according to the protocol proposed by Ben-Noun and Laor [5], with an Avanutri® flexible and inelastic measuring tape with 2 m length that was graduated in centimeters and subdivided in millimeters. The risk of metabolic complications according to NC was diagnosed according to the cutoff points proposed by Lou *et al.* [12].

The WHO AnthroPlus® software and SAS System for Windows (version 9.4) were used for sample description and tabulation. Exploratory data analysis was performed using summary measures (mean, standard deviation, minimum, median, maximum, frequency, and percentage). The sexes were compared using the Mann-Whitney test. The agreement between NC and % fat was evaluated using the Kappa coefficient. The significance level was set at 5%.

The relationship between NC and excess weight by BMI was determined by analyzing the Receiver Operating Characteristic (ROC) curve. Good performance presents a curve sloping toward the upper left corner. The Area Under the Curve (AUC) measures the diagnostic power of a test. A perfect test has an AUC of 1.0, and AUCs $<$ 0.5 indicate that the test is not efficient. Point sensitivity and specificity were checked at all cutoff points to find the optimal cutoff value. The significance level was set at 5%. The study was approved by the National Research Ethics Committee under opinion CAAE n° 46492015.5.0000.5237.

RESULTS

A total of 974 children were included, of which four were excluded for having a plaster cast on the day of the evaluation, 43 for refusing to undergo anthropometric measurements, and 52 for being absent on the day of the evaluation. The final sample totaled 875 participants from schools, including 484 girls and 391 boys. The median age was eight years (CI=8.4–8.5). The skin color declared in school records showed a slight predominance of white students (n=337), followed by Pardo (n=329) and black (n=209).

Table 1 presents the anthropometric characteristics of the group stratified by sex. We did not use confidence intervals as most variables were not normally distributed. Boys had higher weights and

heights, whereas girls had higher BMI values. The median NC was the same in both the groups. Regarding the nutritional status, most children had normal weights by BMI (58.2%), followed by obesity (21.5%), overweight (17.7%), underweight (2.5%), and severe underweight (0.1%), and they showed no risk of metabolic complications by NC (51.3%). However, a significant number of children (almost half) did not present adequate nutritional status. BMI and NC showed a substantial correlation ($k=0.689$; $p<0.001$); additionally, when adjusted for sex, the correlation between the variables was positive ($r=0.688$ for girls and $r=0.690$ for boys; $p<0.001$).

Table 1 – Anthropometric data of the children stratified by sex. *Volta Redonda* (RJ), Brazil, 2018.

Variable	General (n=875)	Girls (n=484)	Boys (n=391)	p-value
	Median (minimum–maximum)	Median (minimum–maximum)	Median (minimum–maximum)	
Weight (kg)	31.2 (14.4–85.6)	31.2 (16.7–85.6)	31.2 (14.4–74.0)	0.8066
Height (m)	1.35 (1.05–1.71)	1.34 (1.11–1.71)	1.35 (1.05–1.67)	0.2613
BMI (kg/m ²)	17.1 (11.8–37.5)	17.2 (12.3–37.5)	17.1 (11.8–33.6)	0.5775
BMI (Z score)	0.62 (-3.8–7.3)	0.64 (-2.57–7.1)	0.59 (-3.82–7.4)	0.9705
NC (cm)	28.3 (15.9–39)	28.3 (20–39)	28.3 (15.9–37.7)	0.8471

Note: BMI: Body Mass Index; NC: Neck Circumference.

Figures 1 and 2 present the best cutoff points for NC by sex according to the AUC from the ROC curve for BMI.

The values found were 29.3 cm for boys (specificity, 85.9%; sensitivity, 66.7%) and 29.1 cm for girls (specificity, 87.6%; sensitivity, 70.5%). The proposed values by age group and stratified by sex are shown in Tables 2 and 3.

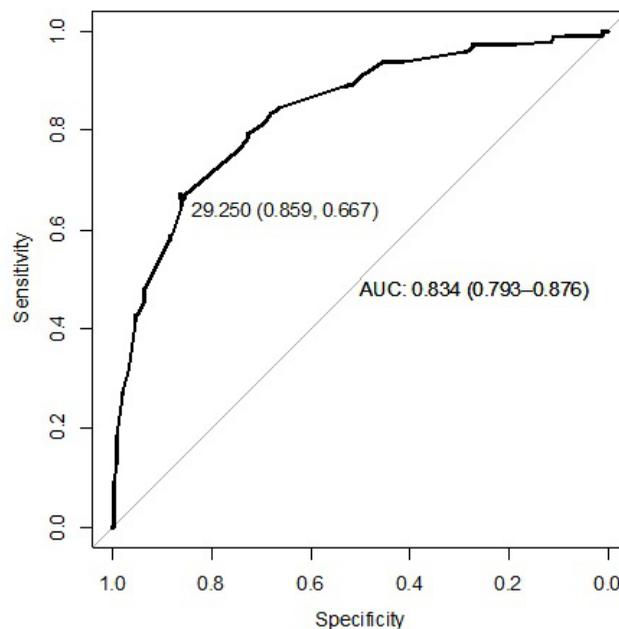


Figure 1 – ROC curve of the cutoff point proposed for neck circumference in Brazilian male children. *Volta Redonda* (RJ), Brazil, 2018.

Note: AUC: Area Under the ROC curve.

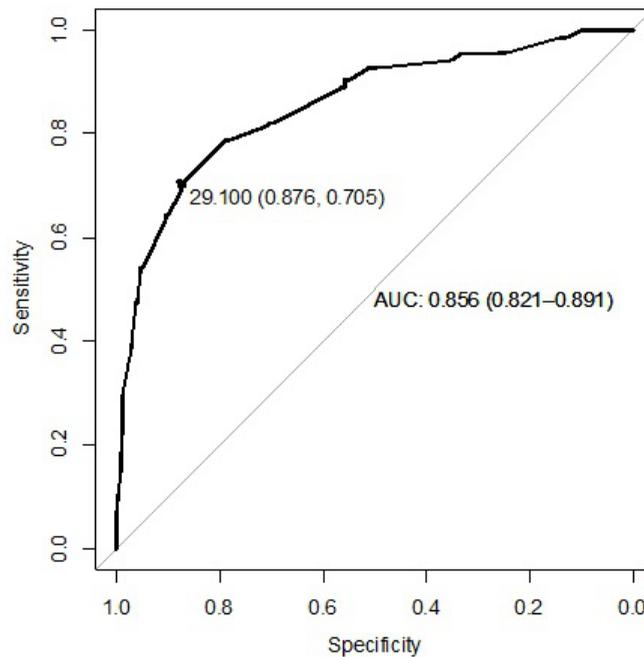


Figure 2 – ROC curve of the proposed cutoff point for neck circumference in Brazilian female children. *Volta Redonda* (RJ), Brazil, 2018.
 Note: AUC: Area Under the ROC curve.

Table 2 – Area under the curve, optimal cutoff values, sensitivities, and specificities for neck circumference associated with overweight/obesity in boys. *Volta Redonda* (RJ), Brazil, 2018.

Age (years)	n	AUC	95% CI	CP (cm)	Spec (%)	Sens (%)
7<8	82	0.900	0.827–0.973	27.9	82.4	87.1
8<9	105	0.815	0.732–0.897	28.1	73.2	77.6
9<10	102	0.866	0.791–0.941	29.1	88.4	78.8
10<11	102	0.867	0.796–0.937	30.5	90.8	67.6

Note: AUC: Area Under the Curve; CI: Confidence Interval; CP: Cutoff Point; Spec: Specificity; Sens: Sensitivity.

Table 3 – Area under the curve, optimal cutoff values, sensitivity, and specificity for neck circumference associated with overweight/obesity in girls. *Volta Redonda* (RJ), Brazil, 2018.

Age (years)	n	AUC	95% CI	CP (cm)	Spec (%)	Sens (%)
7<8	125	0.836	0.756–0.916	28.3	91.6	64.3
8<9	126	0.917	0.870–0.964	28.9	85.0	87.0
9<10	122	0.825	0.751–0.900	29.1	85.9	69.0
10<11	111	0.869	0.801–0.936	30.8	92.2	70.2

Note: AUC: Area Under the Curve; CI: Confidence Interval; CP: Cutoff Point; Spec: Specificity; Sens: Sensitivity.

DISCUSSION

Most of the children evaluated had normal BMI (58.2%) and no risk of NC-related metabolic complications (51.3%). Current estimates show that approximately 6.4 million Brazilian children are overweight, and 3.1 million children are obese. The prevalence of overweight was 33.5% in children aged 5–9 years and 20.5% in children and adolescents aged 10–19 years [16]. The *Pesquisa Nacional de Saúde do*

Escolar (PeNSE, National School Health Survey) reported a 24.8% prevalence of overweight in the southeast region where *Volta Redonda* is located [17]. Considering this, the prevalence of overweight in the evaluated schoolchildren is worrisome, with values clearly greater than the national and regional averages, which could lead to complications in health and quality of life in these children throughout their development [18,19]. *Volta Redonda* [20] had the third best human development index in the state of Rio de Janeiro (0.815); it was considered high according to the norms of the United Nations Development Program, and it had a household per capita income of approximately R\$ 2,298, which is above the state average (R\$ 1,723.00), according to the *Instituto Brasileiro de Geografia e Estatística* (Brazilian Institute of Geography and Statistics) [21]. This fact may explain this disparity, but further studies are required to confirm the hypothesis.

The NC is an important indicator of cardiovascular risk through body fat accumulation associated with arterial hypertension, atherogenesis, low High-Density Lipoprotein levels, hypercholesterolemia, insulin resistance, obesity, type 2 diabetes, and metabolic syndrome [6,8,11,12]. It is widely used to diagnose obstructive sleep apnea, and it is increasingly being used in studies aimed at assessing nutritional status as it is correlated with other anthropometric methods [9,11,12,22]. However, it is a relatively new measure in which only a few parameters are recommended in pediatrics, and the existing parameters are based on different populations [5,11,12].

The comparison with other commonly used cutoff points showed that our study presented higher NC values in girls, contrary to what was observed in boys. According to Chen and Li [23], NC can be used as an indicator of fat accumulation, therefore, increased NC values are justified in girls since they tend to have increases in body fat more markedly near puberty due to physiological events inherent to sexual development and maturation processes [24]. Another possible explanation for different cutoff values is ethnicity. Roman and Barros Filho [25] reported that ethnicity influences body composition, and Brazil is a country that is home to people from practically all parts of the world, demonstrating a trend toward a higher prevalence of overweight.

A possible limitation of the study is the low sensitivity (below 70%) observed in three age groups. According to Kawamura, specificity is the ability of the method to correctly diagnose healthy individuals, and sensitivity is the ability to correctly diagnose outcomes [26]. In practice, in addition to being simple, low-cost, reproducible, and reliable, the diagnostic method should have high sensitivity and specificity, reducing the occurrence of false positive or negative diagnoses [27].

CONCLUSION

Despite the presence of sensitivity values below 70%, the high specificity and the excellent performance of the test, proven by the AUC in all evaluations, give power to the suggested cutoff points, indicating that NC can be used as a risk parameter for overweight in children.

CONTRIBUTORS

All authors participated in the conception, development, revision and approval of the final version of the article.

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