Neck circumference as a complementary measure to identify excess body weight in children aged 13-24 months

Circunferência do pescoço como medida complementar para identificar excesso de peso corporal em crianças de 13-24 meses de idade

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Abstract

Objectives: to analyze the accuracy of neck circumference (NC) as a measure for assessing excess body weight in children aged 13-24 months of life, according to gender.

Methods: this is a cross-sectional study comparing the neck circumferences in relation to body mass index (BMI) and other anthropometric measures. The best cut-off point for identifying excess body weight was determined using the Receiver Operating Characteristics curve (ROC curve), according to gender and age groups 13-15 months, 16-19 months and 20-24 months.

Results: NC was positively correlated (p<0.001) with body weight and BMI in both genders, and length in girls (p<0.001). Positive correlations were found between NC and BMI in the three age groups (13-15, 16-19 and 20-24 months) in both boys and girls. The NC cut-off points for boys were 23.6, 23.9 and 24.0 cm, and 23.4, 23.5 and 23.6 cm for girls, for the 13-15, 16-19 and 20-24 age groups respectively.

Conclusions: NC can be used to screen for excess body weight in children aged 13-24 months. However, further studies with a larger sample will be required in order to complement these results.

Key words *Overweight, Pediatric obesity, ROC curve, Neck*

Resumo

Objetivos: analisar a correlação da circunferência do pescoço (CP) com medidas antropométricas em crianças de 13-24 meses de vida, de acordo com o sexo.

Métodos: estudo de corte seccional comparando as medidas de circunferência do pescoço em relação ao índice de massa corporal (IMC) e outras medidas antropométricas. Construiu-se a curva Receiver-Operating Characteristic (ROC) de forma a avaliar o melhor ponto de corte para identificar excesso de peso corporal segundo o sexo e os grupos etários 13-15, 16-19 e 20-24 meses.

Resultados: a CP foi positivamente correlacionada ao peso corporal e ao IMC em ambos os sexos (p<0,001), e ao comprimento no sexo feminino (p<0,001). O IMC foi positivamente correlacionado (p<0,05) com a CP nos três grupos etários (13-15, 16-19 e 20-24 meses) investigados e em ambos os sexos. Os valores dos pontos de corte da CP para os meninos foram 23,6; 23,9 e 24,0 cm, e para as meninas 23,4; 23,5 e 23,6 cm, respectivamente para os grupos etários 13-15, 16-19 e 20-24 meses.

Conclusões: a CP pode ser utilizada para identificar excesso de peso em crianças de 13 a 24 meses de idade. Contudo, são necessários mais estudos com amostras maiores para complementar nossos resultados.

Palavras-chave *Sobrepeso, Obesidade infantil, Curva ROC, Pescoço*

Introduction

The prevalence of overweight and obesity has increased substantially in children and adolescents over the past three decades, with variations from country to country.[1] Between 1990 and 2010, the worldwide prevalence of early childhood overweight and obesity increased by 21% over the first decade and 31% over the second decade, and is projected to continue to increase by 36% over the next decade (2010-2020).[2] In Brazil, childhood obesity has also increased at an alarming rate. Amongst children aged 5-9 years, the rate of childhood obesity has risen from 2.4% in 1975 to 14.2% in 2009,[3] generating a great economic burden for the Brazilian Health System.[4]

A more rapid increase in weight-for-length during the first six months of life has been shown to be significantly associated with an increased risk of obesity at three years of age.[5] Furthermore, weight alterations during infancy may have a greater influence on later risk of obesity than birth weight.[5] Therefore, the identification and prevention of modifiable risk factors are fundamental for control of excess body weight.[6]

Anthropometric indices are the most commonly used tools for identifying obesity for reason their practicability, low cost, and strong correlation with body fat.[7] The anthropometric index most commonly used is the Body Mass Index (BMI).[7] However, BMI cannot provide precise information about body fat distribution.[7] Measures of waist circumference (WC) have been used to diagnose excess body weight and body fat accumulation.[8,9] More recently, neck circumference (NC) has been proposed by a number of authors as an effective, inexpensive and easily applied measure for evaluating upper body fat distribution[7,9-15] and thereby identifying children at risk of developing conditions related to central obesity.[16] An additional advantage of using NC as a proxy for upper body fat distribution is that it shows no variation in size throughout the day.[7,12]

Although several studies have been published that have examined NC as a measure for identifying excess body weight,[7,9,12,13,15-21] to our knowledge, no study has been conducted with children under two years of age. The purpose of the present study was thus to evaluate the accuracy of NC as a measure for assessing excess body weight in children aged 13-24 and to provide NC data to help establish guidelines that can be used to identify excess body weight in children under two years of age.

Methods

This cross-sectional study is part of a larger research program examining the determinants and related health outcomes of being large for gestational age (LGA) in childhood. Details of the recruitment process have been previously described.[22] Briefly, all 435 mothers and child pairs previously enrolled in the larger research program in Joinville, Santa Catarina, Brazil, were invited to participate in this new investigation. Mothers had been previously informed regarding the purpose and logistics of the study and signed an informed consent form. After exclusions and losses, a total of 279 children participated in the present study. Details of the recruitment of the study participants are presented in Figure 1.

Trained researchers took anthropometric measurements of the children and collected demographic data at the homes of the participants between March 2013 and March 2014. The body weight of the children was measured using a portable digital Beurer brand scale, model BY20, with a capacity of up to 20 kg and increments of 10 g. Length was obtained using a pediatric anthropometric ruler with a capacity of up to 100 cm and increments of 1 mm. Body weight and length data were used to calculate BMI (body weight [kg]/length [m²]). The NC was measured using a flexible tape with a capacity of up to 150 cm and increments of 1 mm. At the time of the NC measurement, the children were in the standing position and the measurement was obtained at the level of the thyroid cartilage, with the tape not compressing the skin.
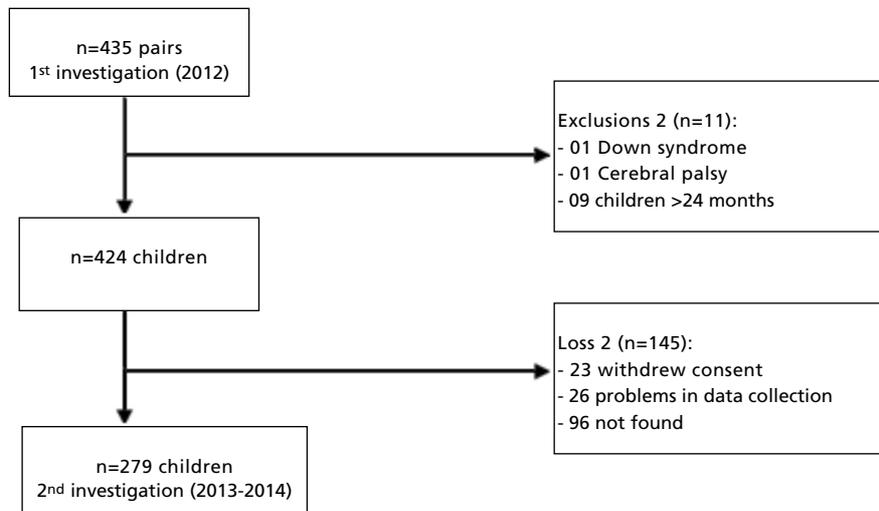
All anthropometric measurements were performed in duplicate and the mean of the two measurements used for analysis. The body weight of each child was classified according to the 2006 WHO Child Growth Standards, BMI for age and gender, which considers the risk of excess body weight (overweight/obese) for children to be a BMI $\geq$ 85th percentile.[23]

Statistical analysis was conducted using the SPSS statistical software (SPSS Inc., version 17.0, Chicago, IL). Distributions of the anthropometric measurements were assessed using the Kolmogorov-Smirnov test. Median and interquartile range were used to analyze the continuous variables. Spearman's correlation coefficient was used to explore the relationship between NC and age, body weight, length and BMI of the children.

The best NC cutoffs for identifying children with overweight/obesity (excess body weight) were determined using the *Receiver Operating Characteristic curve* (ROC curve), according to gender and three

Figure 1

Flow chart of study participant recruitment. Joinville, Brazil.

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┌─────────────────────────────┐
│        n=435 pairs          │
│ 1st investigation (2012)    │
└─────────────────────────────┘
              │                          ┌──────────────────────────────────┐
              │                          │ Exclusions 2 (n=11):             │
              ├────────────────────────▶ │ - 01 Down syndrome               │
              │                          │ - 01 Cerebral palsy              │
              ▼                          │ - 09 children >24 months         │
┌─────────────────────────────┐         └──────────────────────────────────┘
│       n=424 children        │
└─────────────────────────────┘
              │                          ┌──────────────────────────────────┐
              │                          │ Loss 2 (n=145):                  │
              ├────────────────────────▶ │ - 23 withdrew consent            │
              │                          │ - 26 problems in data collection │
              ▼                          │ - 96 not found                   │
┌─────────────────────────────┐         └──────────────────────────────────┘
│       n=279 children        │
│ 2nd investigation (2013-2014)│
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age groups (13-15 months, 16-19 months and 20-24 months). The areas under the curve and the 95% confidence intervals (CI) were determined.

The ROC curve was used to demonstrate the overall discriminatory power of the diagnostic test and the area under the curve (AUC) was used as a measure of the diagnostic power of the test, which in this case is NC. The greater the AUC, the greater the discriminatory power of NC and the 95% CI should not include 0.50.[24] Subsequently, the sensitivity (probability of an individual classified with excess body weight according to NC by age and gender being classified as having excess body weight based on BMI values; true positives) and specificity (probability of an individual classified without excess body weight according to NC by age and gender, being classified as having excess body weight based on BMI values; false positives) were determined. The 95% CIs of anthropometric measures were also estimated. All tests were considered significant at $p<0.05$.

The research ethics committee of the University of Joinville Region approved this study under authorization Nº 107/2011.

Results

The general characteristics of the children according to gender are described in Table 1. Among the 279 children in our study, 50.8% were male.

Table 2 shows the correlation between NC and age, body weight, length and BMI by gender. There was a positive correlation between NC and body weight and BMI for boys, and between NC and body weight, length and BMI for girls.

The correlation between NC and BMI by age group and gender are presented in Table 3. Positive correlations were found between NC and BMI in the three age groups examined in both boys and girls. However, Spearman's correlation coefficient increased with age in boys only.

The AUCs, including optimal cutoff points, sensitivities and specificities for the associations between NC and excess body weight in the three age groups for boys and girls are shown in Table 4. The NC cut-off points increased with increasing age in both boys and girls and the difference in centimeters between the cut-off points did not exceed 0.3 cm in boys and 0.1 cm in girls. However, there was no statistical significance ($p>0.05$, 95%CI) in the 20-24 months age group for boys or in the 16-19 months age group for girls, according to the AUC values.

Specificity values were generally lower than those for sensitivity, and the latter were higher in boys, except in the 20-24 months age group. The NC cut-off points were able to correctly identify 75.0% to 85.0% of children with risk of excess body weight in boys, and 73.1% to 77.0% in girls. False positives ranged from 7.1% to 51.1% in boys and 31.0% to 47.0% in girls (Table 4).

Table 1

General characteristics of the children according to gender. Joinville, Brazil, 2013-2014.

Characteristic	Boys (n=142)	Girls (n=137)	All
	Median (IR)	Median (IR)	Median (IR)
Age (months)	16.0 (5.0)	15.0 (5.0)	15.0 (5.0)
Body weight (kg)	11.1 (2.1)	10.5 (2.5)	10.8 (2.5)
Length (cm)	80.0 (5.6)	78.5 (5.8)	79.2 (5.5)
BMI (kg/m^2)	17.5 (2.5)	16.9 (2.3)	17.1 (2.5)
NC (cm)	24.0 (2.2)	23.5 (1.7)	23.8 (2.0)

IR= Interquartile Range; NC= Neck circumference; BMI= Body mass index.

Table 2

Correlation between neck circumference and age, body weight, length and body mass index by gender. Joinville, Brazil, 2013-2014.

Characteristic	Boys (n=139)		Girls (n=136)	
	Rho	*p*	Rho	*p*
Age (year)	0.024	0.778	0.124	0.151
Body weight (kg)	0.520	<0.001	0.660	<0.001
Length (cm)	0.117	0.172	0.358	<0.001
BMI (kg/m^2)	0.635	<0.001	0.606	<0.001

Rho= Spearman's rho; BMI= Body mass index.

Table 3

Correlation between body mass index and neck circumference by age and gender. Joinville, Brazil, 2013-2014.

Age (months)	N	BMI-NC	
		Rho	*p*
Boys			
13−15	65	0.604	<0.001
16−19	44	0.663	<0.001
20−24	30	0.719	<0.001
Girls			
13−15	73	0.642	<0.001
16−19	30	0.419	0.021
20−24	33	0.604	<0.001

Rho= Spearman's rho; NC= Neck circumference; BMI= Body mass index.

Table 4

Area under the curve (AUC), frequency (N), optimal cutoff points, sensitivities and specificities for neck circumference (NC) associated with excess body weight in three age groups of boys and girls. Joinville-SC, Brazil, 2013-2014.

Age (months)	N	AUC (95%CI)	Cutoff (cm)	Sensitivity (95%CI)	Specificity (95%CI)
Boys					
13−15	65	80.0 (68.3−91.0)	23.6	85.0 (64.0-95.0)	48.9 (35.1-63.0)
16−19	44	88.0 (77.1−98.1)	23.9	81.8 (61.4-93.0)	63.6 (43.4-80.2)
20−24	30	90.2 (0−100.0)	24.0	75.0 (50.1-90.4)	92.9 (69.0-98.0)
Girls					
13−15	73	81.4 (71.0−92.0)	23.4	73.1 (54.0-86.3)	61.7 (47.4-74.4)
16−19	30	70.0 (51.0−89.0)	23.5	77.0 (50.0-92.0)	53.0 (54.1-86.0)
20−24	33	80.0 (64.4−95.0)	23.6	76.5 (53.0-90.4)	69.0 (44.4-86.0)

CI= Confidence interval.

Discussion

To our knowledge, this is the first study to demonstrate the possibility of using NC to identify excess body weight and upper fat distribution in children under two years of age. The results of this study have shown that body weight and BMI have a positive correlation with NC, corroborating other studies conducted with children older than 2 years of age, in Brazil and other countries.[7,9,12,13,15-18,20] The results of the present study also show that there was a moderate positive correlation between NC and BMI in both genders according to age group, supporting the results from studies conducted with Turkish, American and Chinese children.[7,12,18]

However, some important limitations should be considered. First, the lack of other studies considering the same age group (children under two years of age) made it difficult to compare data. Second, radiographic measurements to quantify upper-body fat deposits were not performed. The cutoff points described in this study should therefore be used with caution, as NC is a proxy for upper-body subcutaneous fat.[11] Furthermore, the moderate correlations and low specificity observed in the present study may be a consequence of the rapid growth and development that occurs during early years. Third, the cross-sectional nature of the data does not allow conclusions relating to causality. Finally, the relatively small number of children that participated in the study made it difficult to estimate sensibility and specificity by stratifying for gender and age groups.

Although the literature currently contains no data on the correlation between NC and other anthropometric measurements in children under two years of age, the moderate correlation found in the present study corroborates the results of other studies involving older children and adults.[7,12,18] However, some authors have also reported moderate to high correlations between NC and age;[10-13] a result not found in the current study. A lack of correlation between NC and age may be due to the young age of the children in the study, as demonstrated by the similarity of NC cutoffs among age groups.

The high values of AUC for NC found in the present study (70% to 81% for girls and 80% to 90% for boys) suggest high accuracy of this measure. The values for sensitivity were also high and similar to those of other studies that have investigated the use of NC as a measure to evaluate excess body weight in children and adolescents.[7,12,15,16,18] However, in the present study, specificity was lower than that found in other studies,[7,12,15,18,21] resulting in a higher number of false-positives, i.e., a high proportion of children classified as having excess body weight when in fact they did not.

Choosing cut-off points that have greater sensitivity or specificity has important heath implications.[25] In terms of public health, it is important that the method for diagnosing excess body weight presents good sensitivity so as to identify the largest number of children with the condition that can be targeted for appropriate programs or interventions.[25] One of the first steps toward controlling the epidemic of childhood obesity is to make monitoring tools available that are low-cost, quick and easy to use, and that are acceptable to both patients and health practitioners. Traditionally, BMI has been used for identifying individuals with obesity;[12] although the accuracy of BMI varies according to the percentage body fat of the child. As an alternative to BMI, WC has been used as a proxy for body fat accumulation,[8,9] especially for screening purposes.[18] Nevertheless, WC can be affected by postprandial

abdominal distension,[12] is time-consuming, and may be culturally and/or environmentally problematic,[7] i.e., some individuals are reluctant to remove their clothing.[7] As an alternative to WC, the measurement of NC appears to be a good option for identifying excess body weight and assessing upper body fat.

In addition to obesity,[13] NC measurements have been shown to be suitable for assessing other risk factors in adults and children, including metabolic syndrome,[10,26] obstructive sleep apnea,[16] perioperative adverse respiratory events,[13] and cardio-metabolic risk factors.[9,11,14] Furthermore, in addition to its accuracy in identifying excess body weight and risk of other related health outcomes, La Berge *et al*.[27] have reported that NC showed good inter- and intra-rater reliability and that it does not require multiple measurements for precision and reliability. The technique can also easily be learned by community caregivers and is simple to apply in general practice and epidemiological studies.[27] Using the NC measure eliminates the need for scales, a pediatric anthropometric ruler and undressing the child, thereby saving time and enabling clinicians and researchers to increase the number of children investigated.

The results of the present study therefore suggest that NC can be used in children under two years of age to identify excess body weight. These findings are important for screening purposes early in life, especially in children living in rural areas, remote parts of large cities or when there is no means to obtain weight and height.

Another important contribution of this study is that it supplies information that is necessary to establish international cut-off points for identifying excess body weight using the measurement of NC in children. Neck size varies according to age, gender and development and age- and gender-standardized NC values for children are needed to translate this measurement into clinical practice.[17] Until the publication of this study, only NC measures with children five years of age or over had been reported.[7,9,12,13,15-21]

This study has several strengths. It is a home-based design, which includes primary data from a non-institutionalized population. All data, including anthropometric measures, were collected by the same research group, which reduces possible inter-observer biases.

In conclusion, NC can be used to screen for excess body weight in children aged 13-24 months. However, further studies with larger sample sizes need to be conducted in order to complement the data reported in this study.

Acknowledgement

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