

Accuracy of abdominal circumference for diagnosing overweight in six-to-seven-years-old children

Acurácia da circunferência abdominal para o diagnóstico de excesso de peso em crianças de seis a sete anos de idade

Precisión de la circunferencia abdominal para diagnosticar el sobrepeso en niños de seis a siete años

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Abstract

Objective: To estimate the accuracy of abdominal circumference measurement as a method of diagnosing overweight in six-to-seven-years-old children. **Methods:** A cross-sectional study involving 1026 six-to-seven-years-old schoolchildren in southern Brazil was carried out. Children's weight and height were collected at schools. Body mass index were calculated and categorized in z-score in eutrophy, overweight and obesity. Abdominal circumference was measured in centimeters with a tape with children in standing position at midpoint between the lower ribs margin and the iliac crest. Correlation between abdominal circumference and body mass index was performed through Pearson's correlation coefficient. Sensitivity, specificity, positive and negative predictive values of abdominal circumference were estimated. The Receiver Operating Characteristic Curve was used to measure the accuracy. **Results:** A positive linear correlation value of 0.582 and a determination coefficient 0.39 were observed. The accuracy value of 0.859 was observed. Sensitivity, specificity, positive and negative predictive values varied according to each value in centimeters of abdominal circumference. **Conclusion:** Abdominal circumference measure showed to be an accurate method for detecting overweight and obesity in six-to-seven-years-old children.

Keywords: Pediatric obesity; Body mass index; Abdominal circumference.

Resumo

Objetivo: Estimar a acurácia da medida da circunferência abdominal como método de diagnóstico de excesso de peso em crianças de seis a sete anos. **Métodos:** Foi realizado um estudo transversal envolvendo 1.026 escolares de seis a sete anos de idade no sul do Brasil. O peso e a altura das crianças foram coletados nas escolas. O índice de massa corporal foi calculado e categorizado em escore z em eutrofia, sobrepeso e obesidade. A circunferência abdominal foi medida em centímetros com fita, com as crianças em pé, no ponto médio entre a margem inferior das costelas e a crista ilíaca. A correlação entre a circunferência abdominal e o índice de massa corporal foi realizada por meio do coeficiente de correlação de Pearson. Foram estimados a sensibilidade, especificidade, valores preditivos positivos e negativos da circunferência abdominal. A *Receiver Operating Characteristic Curve* foi usada para medir a precisão. **Resultados:** Observou-se um valor de correlação linear positiva de 0,582 e coeficiente de determinação de 0,39. Foi observado o valor de acurácia de 0,859. Sensibilidade, especificidade, valores preditivos positivo e negativo variaram

de acordo com cada valor em centímetros da circunferência abdominal. Conclusão: A medida da circunferência abdominal mostrou-se um método acurado para detecção de sobrepeso e obesidade em crianças de seis a sete anos.

Palavras-chave: Obesidade pediátrica; Índice de massa corporal; Circunferência abdominal.

Resumen

Objetivo: Estimar la precisión de la medición de la circunferencia abdominal como método de diagnóstico de sobrepeso en niños de seis a siete años. **Métodos:** Se realizó un estudio transversal con 1026 escolares de seis a siete años del sur de Brasil. El peso y la estatura de los niños se recopilaban en las escuelas. El índice de masa corporal se calculó y categorizó en puntaje z en eutrofia, sobrepeso y obesidad. La circunferencia abdominal se midió en centímetros con una cinta con los niños en posición de pie en el punto medio entre el margen inferior de las costillas y la cresta ilíaca. La correlación entre la circunferencia abdominal y el índice de masa corporal se realizó mediante el coeficiente de correlación de Pearson. Se estimaron la sensibilidad, especificidad, valores predictivos positivos y negativos de la circunferencia abdominal. Se utilizó la *Receiver Operating Characteristic Curve* para medir la precisión. **Resultados:** Se observó un valor de correlación lineal positiva de 0.582 y un coeficiente de determinación de 0.39. Se observó un valor de precisión de 0,859. La sensibilidad, especificidad, valores predictivos positivos y negativos variaron según cada valor en centímetros de circunferencia abdominal. **Conclusión:** La medición de la circunferencia abdominal demostró ser un método preciso para detectar el sobrepeso y la obesidad en niños de seis a siete años.

Palabras clave: Obesidad pediátrica; Índice de masa corporal; Circunferencia abdominal.

1. Introduction

Obesity is an inflammatory disease characterized by abnormal or excessive accumulation of body fat. Its etiology is multifactorial and complex, and may involve genetic, environmental, behavioral and emotional factors (Associação Brasileira para o Estudo da Obesidade e da Síndrome Metabólica, 2016; Santos, et al., 2018).

Childhood obesity is considered one of the most serious public health problems of the 21st century, an epidemic that affects children mainly in urban areas in low and middle-income countries (WHO, 2021). Recent data released by the WHO (WHO, 2020) showed that in the past four decades, the number of obese children and adolescents in the world has increased considerably.

The main cause of overweight is believed to be the imbalance between the intake of calories and calories spent (WHO, 2020). Individuals are eating large amounts of foods rich in carbohydrates and fats and are increasingly sedentary (Wannmacher, 2016). The concentration of fat in the abdominal region leads adults and children to suffer the effects of the so-called plurimetabolic syndrome (impaired glucose tolerance or diabetes mellitus, insulin resistance, systemic arterial hypertension, dyslipidemia, visceral obesity and albuminuria). In addition, they become more predisposed to cardiovascular diseases (Mandviwala, et al., 2016; Santos, et al., 2018).

The measurement of abdominal circumference (AC) has been considered a simple measure, easily accessible and with high sensitivity for diagnosing overweight in adults (Lee, et al., 2006; Franks, et al., 2010). AC is measured around the line of greatest volume in the abdominal region, usually coinciding with the level of the umbilical scar. The reading should be performed at the end of an expiration (Ferreira, 2014). The Body Mass Index (BMI - weight over the square of height) for age, expresses the relationship between the child's weight and the square of height, and is used to measure overweight in children (Freedman & Berenson, 2017). In children and adolescents, the classification of overweight and obesity, considering only the BMI is dispensable, and has no association with morbidity and mortality in the way obesity is defined in adults (Associação Brasileira para o Estudo da Obesidade e da Síndrome Metabólica, 2016). As a result, the limit of normal weight has been defined by percentile curves or z-scores of BMI, (Brasil, 2020) for children up and over 5 years of age. The WHO (WHO, 2020) defines overweight a BMI located in the z-score curves between the values 1 and 2 (or percentile between 85th and 97th) for the age group. The obesity classification corresponds to the BMI value located on the curve above the value of 2 (or above the 97th percentile). Also, due to the difference in the development of the musculoskeletal structure, different charts were developed for boys and girls (Brasil, 2020).

Studies indicate AC as an index of childhood obesity diagnosis and reveal its importance for a more effective control of overweight (Freedman, et al., 1999; Taylor, et al., 2020). As overweight is a public health problem due to its high prevalence and the important health repercussions that it can have on the individual, it is necessary to investigate more about the accuracy of AC for the diagnosis of childhood obesity. Thus, the objective of this research was to estimate accuracy indicators of abdominal circumference for diagnosing overweight in six-to-seven-years-old children.

2. Methodology

A cross-sectional study involving six-to-seven-years-old schoolchildren of Palhoça/SC, southern Brazil was carried out. This study was part of a major longitudinal study named *Coorte Brasil Sul* (Traebert, et al., 2018). Children enrolled in the first grade of elementary school from public and private schools in 2015 were invited to participate. The sample size was determined considering a relative error of 2%, an unknown anticipated prevalence ($P=50\%$) and 95% confidence level. The total population of six-to-seven-years-old schoolchildren was 1.756. According to these parameters, the minimum sample size was estimated in 1,015. Children were randomly selected.

Data concerning weight and height were collected at schools by a team of investigators, composed of two nutritionists and two research assistants duly trained, according to the methodology proposed by the Brazilian Ministry of Health (Brasil, 2020). BMI cut-off points in z-score were: eutrophy (≥ -2 and $<+1$), overweight ($\geq +1$ and $<+2$) and obesity ($\geq +2$). AC was measured in centimeters with a tape with children in standing position at midpoint between the lower ribs margin and the iliac crest (WHO, 2008). Gender and type of school were also collected.

Data were analyzed in the SPSS 18.0 software. Correlation between AC and BMI was carried out through Pearson's correlation coefficient. Sensitivity, specificity, positive and negative predictive values of AC were estimated. Receiver Operating Characteristic Curve (ROC) was used to measure the accuracy of AC as a diagnostic method for overweight.

The research project was submitted to and approved by the *Universidade do Sul de Santa Catarina* Ethics Committee on Research with Humans, under number 38240114.0.0000.5369.

3. Results

A total of 1,026 children were included in this study, 82.3% from public schools and 17.7% from private schools. Male children were slightly predominant (51.6%); 64.5% of schoolchildren were eutrophic, 18.6% were with overweight, 9.7% were with obesity and 7.2% were with severe obesity.

The range of values of AC varied between 17.0 cm and 104.0 cm, with an average of 58.7 cm ($SD= 8.3$). The median and mode values were 57.0 cm and 55.0 cm respectively.

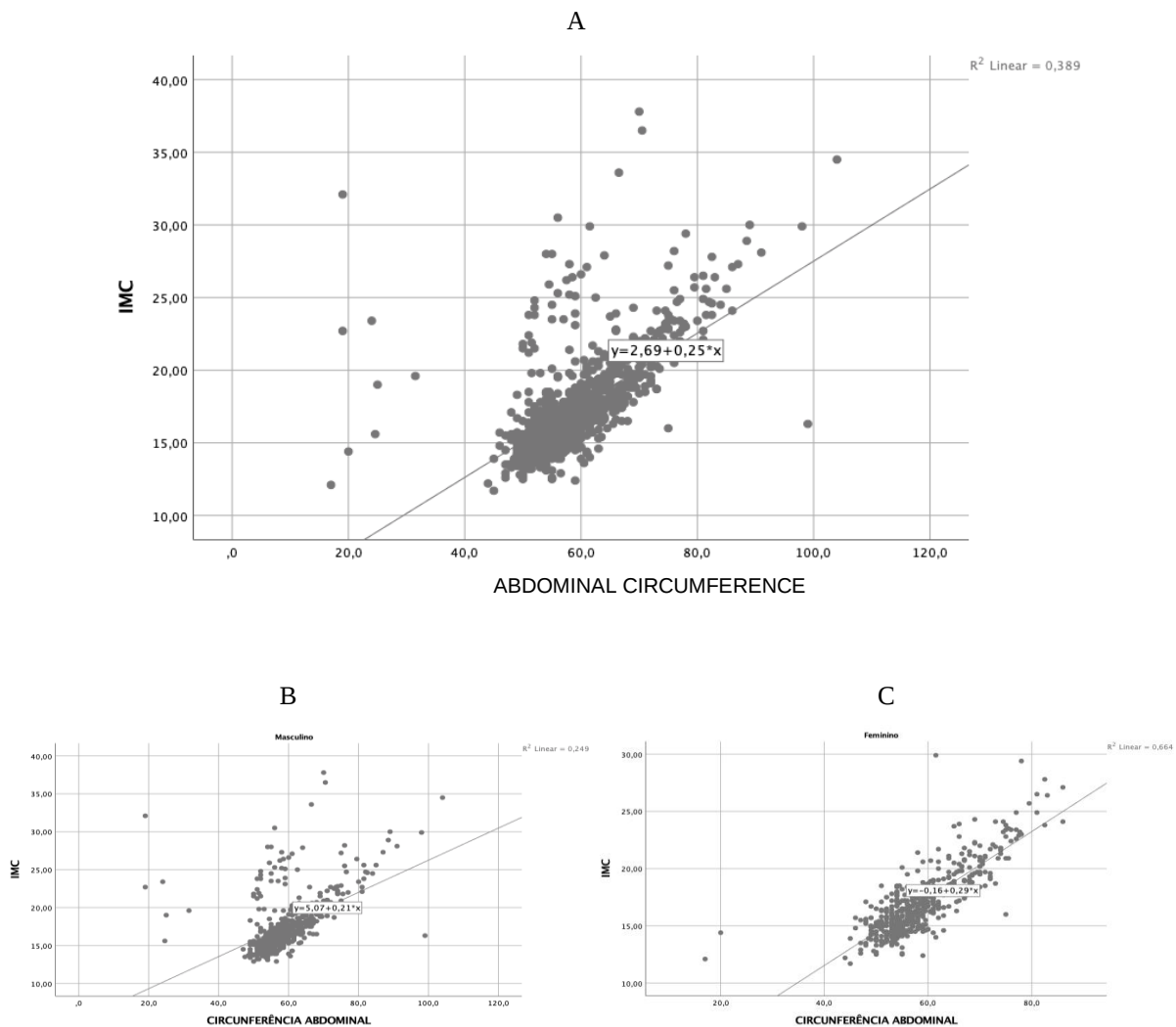
The distribution of AC measures according to BMI values is shown in Figure 1. There was found a positive correlation ($r= 0.582$; $p<0.001$) between AC and BMI with a determination coefficient $R^2= 0.39$ (Figure 1A). The correlation for male children was $r= 0.469$ ($p<0.001$) with a $R^2= 0.25$ (Figure 1B). For female children the found correlation was $r= 0.764$ ($p<0.001$) with a $R^2= 0.66$ (Figure 1C). The different values of abdominal circumference as well as sensitivity, specificity and general positive and negative predictive values are reported in Table 1.

Table 1 – Sensitivity, specificity and predictive values of abdominal circumference as an overweight diagnostic method in six-to-seven-years-old schoolchildren (n=1,026).

AC (cm)[#]	Se[*]	Sp^{**}	PPV[^]	NPV^{^^}
<50.0	1.6	93.8	12.8	38.8
50.0 - 55.0	9.3	51.8	9.6	51.0
55.1 - 59.9	15.9	67.4	21.2	59.3
60.0 - 65.0	26.9	88.7	56.6	68.1
60.0 - 60.9	9.7	73.8	42.1	29.4
61.0 - 61.9	15.2	72.6	52.1	30.3
62.0 - 62.9	9.1	85.7	55.6	32.4
63.0 - 63.9	10.3	86.9	60.7	33.0
64.0 - 65.0	8.5	92.8	70.0	34.1
65.1 - 69.9	18.4	98.6	88.1	68.7
65.1 - 65.9	8.5	96.4	82.4	34.9
66.0 - 66.9	12.7	95.2	84.0	35.7
67.0 - 67.9	7.9	97.6	86.7	35.0
68.0 - 68.9	9.7	98.8	94.1	35.8
69.0 - 69.9	8.5	100.0	100.0	35.7
70.0 - 79.9	21.7	99.8	98.7	69.9
≥80	6.0	99.8	95.6	65.9

Abdominal circumference in centimeters; *Sensitivity; **Specificity; ^Positive Predictive Value; ^^Negative Predictive Value.
Source: Authors.

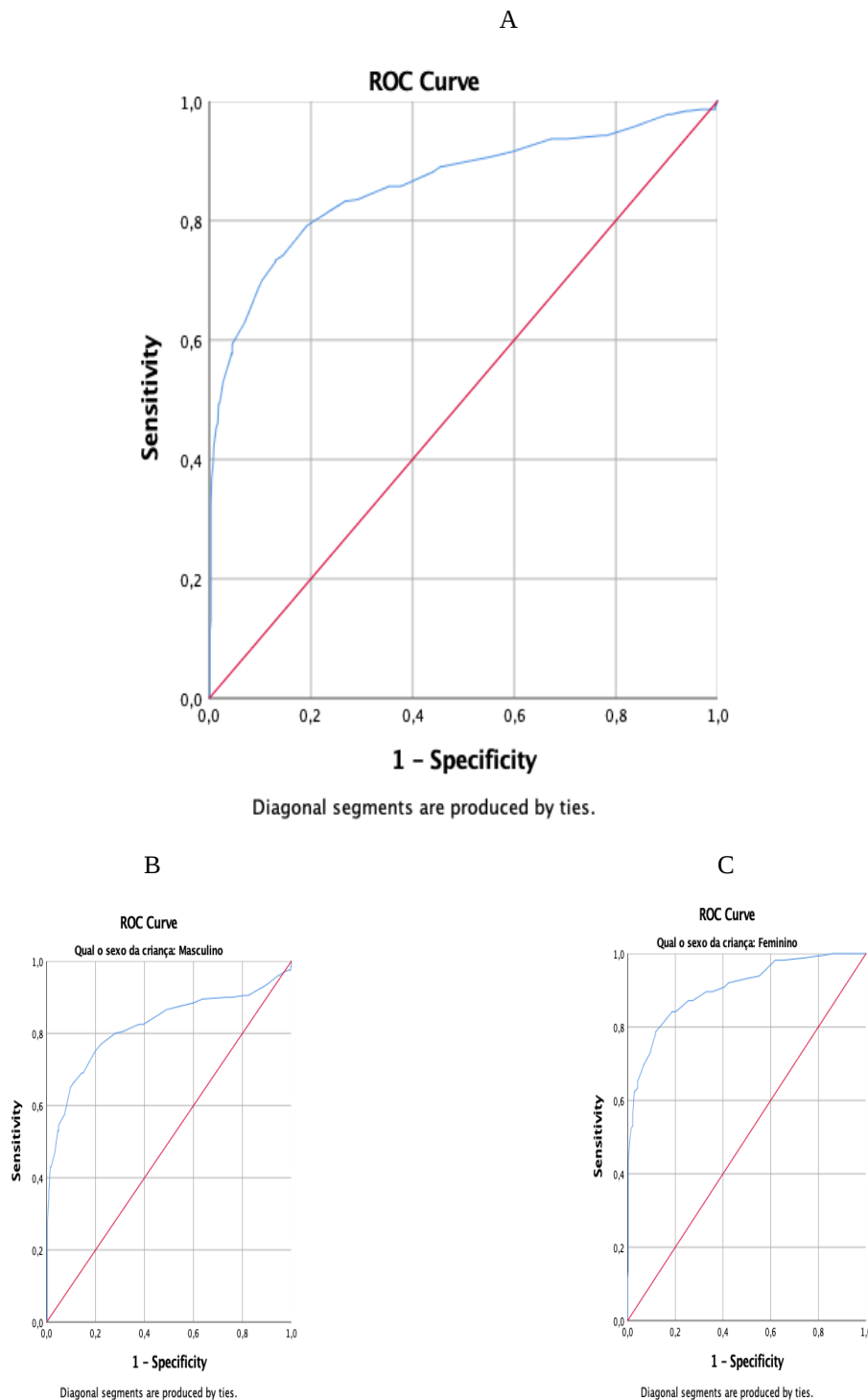
Figure 1 – Correlation between values of abdominal circumference and BMI in six-to-seven-years-old schoolchildren (n=1,026). General correlation (A), male (B) and female (C).



Source: Authors.

Figure 2 shows the ROC curves. The general accuracy value was 0.859 (95% CI 0.832; 0.886 $p < 0.001$) (Figure 2A). Accuracy for male children was 0.820 (95% CI 0.778; 0.862 $p < 0.001$) (Figure 2B) and 0.903 (95% CI 0.874; 0.933 $p < 0.001$) for female children (Figure 2C).

Figure 2 – ROC curves of abdominal circumference as a predictor of excess weight for the general population (A), male (B) and female (C).



Source: Authors.

4. Discussion

This study aimed to assess if the AC would be an accurate method for diagnosis of overweight in six-to-seven-year-old children. It is important to have a safe, fast and accurate method to facilitate the diagnosis of childhood obesity. However, it must be emphasized that the result of this study is addresses only for six-to-seven-year-old children.

When observing the results of sensitivity and specificity, the present study showed a low sensitivity. The highest value was 26.9% with an AC of 60-65 cm, with a specificity of 88.7%. However, a cross-sectional study conducted in another southern Brazilian city involving seven-to-ten-years-old children found sensitivity values of 89.7% for male children and 78.6% for female children, and specificity of 90.7% and 75%, respectively (Ribeiro, et al., 2014). Another study carried out with Venezuelan children and adolescents aged seven to 17 years found low sensitivity and specificity (Pérez, et al., 2009). Another study (Vieira, et al., 2018) carried out in the southeastern region of Brazil assessed abdominal circumference in children aged four to seven years and concluded that it can be used as a diagnostic method for obesity in both genders.

The reviewing of each AC measurement in centimeters separately, accuracy of 82% in females and 90.3% in males were found. This analysis confirms the performance of the test in discriminating overweight. The values found here were consistent with outcomes in previously mentioned study (Vieira, et al., 2018) suggesting that CA can accurately identify children with high BMI.

Predictive values found in the present study were higher than sensitivity and specificity. Predictive values are considered more useful in practice (Medronho, et al., 2009), as they indicate the probability of occurrence of the event, considering the results of a diagnostic test. Thus, the proportion of students who had a positive test and who presented overweight was 56.6% at an AC measurement of 60-65 cm, while 68.1% of students that had a negative test really had no excess weight. Thus, it can be said that the higher the BMI, the higher the predictive values found, which is corroborated by other study (Pérez, et al., 2009). However, it is noteworthy that for the same test, the higher the prevalence of the event, the greater the positive predictive value and the lower the negative predictive value (Medronho, et al., 2009).

Through correlation analysis, an overall determination coefficient of 39.0% was reached, which means that more than a third of overweight cases could be determined by AC, 25% in male children, and a better correlation of 66% in female children. It is suggested that AC can be used as a method of diagnosing overweight in six-to-seven-year-old children population, since it has shown a correlation between AC and overweight. This is in line with other studies (Dias, et al., 2013; Vieira, et al., 2018; Lima, et al., 2020) in which it was observed that children with increased adiposity in the abdominal region had a higher risk of becoming overweight. But there are still no guidelines suggesting reference values for this relationship, which makes it difficult to establish parameters.

On the other hand, although studies have shown that AC can be used as a diagnostic method for overweight (Dias, et al., 2013; Vieira, et al., 2018), there is an absence of international standardization of the best anatomical site for this measurement. The Anthropometric Standardization Reference Manual (Lohman, et al., 1988) recommends that the measurement should be taken on the smallest AC between the chest and the hip, whereas WHO (WHO, 2000) recommends the measurement at the midpoint between the iliac crest and the last rib, which was used in the present study. The National Institutes of Health (National Institutes of Health, 2000) indicates that the measurement should be taken immediately above the iliac crests, while other studies suggest taking the measurement at the level of the umbilical scar (Risica, et al., 2000; Klein, et al., 2007). Due to the lack of standardization, the interpretation of differences in AC between studies of different populations should be done with caution, considering that the measurement may have been performed in different anatomical locations (Magalhães, et al., 2014). Other fact that imposes caution to the interpretation of our results is that different investigators collected the data, which could be the cause of measurement bias. However, all the care was taken to prevent bias through training exercises and standardization of collection methods.

5. Conclusion

It can be concluded that AC showed to be an accurate method for diagnosing overweight in six-to-seven-years-old schoolchildren. This investigation confirmed the results of studies already published on the usefulness of AC in detecting overweight in children.

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