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Relationship between body mass index and waist-to-height ratio in childhood

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SUMMARY

OBJECTIVE: To evaluate whether there is an association between the body mass index z-score and waist-to-height ratio of children and adolescents.

METHODS: This was a cross-sectional study conducted in a school in Santo André, SP, between June and August 2019. Body mass index was measured for all participants, adopting the z-score cutoff of +2 recommended by the World Health Organization. The waist-to-height ratio was determined in children over two years of age and considered abnormal when ≥0.5. The qualitative variables are presented as absolute numbers and percentages. To compare qualitative data, we used the χ^2 test or Fisher's exact test. Pearson's test was applied to assess the correlation between BMI and waist-to-height ratio. The level of significance adopted was 5%.

RESULTS: The body mass index was calculated for 518 children and the waist-to-height ratio for 473 children. Regarding body mass index, 60.6% of the participants had normal weight, 3.1% were underweight, and 36.3% were overweight. overweight (24.7%) and obesity (22.7%) were more prevalent in adolescents. The waist-to-height ratio was abnormal in 50.5% of the sample. There was an increasing association between body mass index and waist-to-height ratio with age, according to the Pearson correlation coefficients for the age groups <5 years (r=0.459; p<0.001), 5 to 10 years (r=0.687; p<0.001) and >10 years (r=0.805; p<0.001).

CONCLUSION: There was a significant correlation between body mass index and waist-to-height ratio. This association was higher in adolescents. The waist-to-height ratio is easy to apply and may be useful as a predictor of cardiometabolic risk.

KEYWORDS: Body mass index. Waist-height ratio. Overweight. Child.

INTRODUCTION

The prevalence of overweight and obesity among children and adolescents has been growing significantly[1]. The percentage of obese children aged five to 19 years has increased ten-fold in the last 40 years[2]. In 2010, there were 35 million overweight children in the world, and that number was expected to double in 2020[3]. In Brazil, one-third of children between five and nine years of age were overweight in 2010[4].

Different anthropometric measures have been proposed to identify cardiometabolic risk (CMR) in children. Body mass index (BMI), although it does not provide any indication of the distribution of body fat, is the most commonly used parameter worldwide[5].

In adults, it is well established that increased abdominal fat, compared to BMI, is associated with greater CMR[6]. However, in children and adolescents, this association has not yet been fully established. A publication compiling data from five studies (n=4,255) showed that the magnitude of associations for BMI and waist-to-height ratio (WHtR) in children and adolescents were similar in relation to the clustered CMR factors (lipid profile, HOMA-IR, and blood pressure) and performed better at higher BMI values. However, the accuracy of these anthropometric variables to classify the increased risk was low[7]. On the other hand, a recent study (n=1,201) showed that the prevalence of individuals with metabolically unhealthy obesity in a pediatric population

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was high and that the WHtR was an independent predictor of this form of obesity[8].

Most authors correlate WHtR p≥0.5 with increased abdominal adiposity and CMR[9]. Because the cutoff value is the same for everyone, the WHtR is easy to interpret[10].

A national study with children aged four to seven years showed that when the normal weight group was evaluated using indicators of abdominal adiposity, the prevalence of abnormal nutritional status was higher than that when evaluated by BMI/age[11]. However, this association between BMI and WHtR in the identification of excess weight has not yet been fully elucidated for all age groups in Brazil. The objective of this study was to evaluate whether there is an association between the BMI z-score and WHtR of children and adolescents.

METHODS

This cross-sectional study was conducted at *Instituição Cidade dos Meninos Maria Imaculada* ("Cidade dos Meninos Maria Imaculada" Rehabilitation Center) in the municipality of Santo André, state of São Paulo (SP), Brazil, between June and August 2019.

All participants were invited to enroll in the study.

Children who did not want to participate, those whose family members did not sign the consent form and those with short stature were excluded. A systematic review suggested that there is a risk of misinterpretation of the WHtR in children with short stature[12].

Height was measured using a vertical stadiometer, graduated in centimeters and millimeters. Weight was measured using a digital scale with a precision of 10 grams. BMI was calculated by dividing the weight in kilograms by the height in meters squared.

Waist circumference was assessed for children aged two years or older, using a centimeter and millimeter graduated tape measure. The tape measure was placed at the midpoint between the iliac crest and the last rib. This anatomical point has the strongest correlation with abdominal adiposity[13]. The WHtR was obtained by dividing the waist circumference in centimeters by the height.

BMI was classified by BMI/age according to sex, adopting the z-score cutoff of +2 recommended by the World Health Organization[14]. Thus, children under five years old with overweight and obesity and children older than five with obesity and severe obesity were included in the group with excess weight. The WHtR was considered abnormal when the value was ≥0.5[10].

A total of 23 children were excluded from the analysis due to their short stature. The BMI was calculated for 518 children. The WHtR was calculated for children aged 24 months or older (n=473). Three children had no waist circumference recorded because they missed the days that the evaluators were at the school, and thus, the WHtR was not calculated for these children, only the BMI.

The data were entered into an Excel spreadsheet (Microsoft) and analyzed using Epi Info™, version 7.2.2.6. The qualitative variables are presented as absolute numbers and percentages. To compare the qualitative data, we used the $\chi 2$ test or Fisher's exact test. The level of significance was set at 5%. Pearson's test was used to correlate BMI with WHtR.

The study was approved by an ethics and research committee, opinion number 3.058.583, CAAE: 02670518.7.0000.0082

RESULTS

Table 1 shows the general characteristics of the children in the study. The mean age was 72.5±12.2 months (range 9 to 186 months), with a slight predominance of males (288; 53.2%).

Regarding nutritional status, 314 (60.6%), 188 (36.3%), and 16 (3.1%) were classified as normal weight, above the ideal weight (risk of overweight, overweight, obesity, and severe obesity) and thin, respectively. The WHtR was rated abnormally for 239 children (50.5%) (Table 1).

Overweight was present in 19% of children under the age of two years, 9.1% of children from two to five years, 15.3% of children from five to ten years and 22.7% of children older than 10 years. Among the adolescents, the prevalence of overweight was also high (24/24.7%). When comparing the prevalence of overweight and abnormal WHtR by sex in each age group, there was no significant difference (Table 2).

When correlating BMI, using the z-score +2 as the cutoff point, with the WHtR, using 0.5 as the cutoff point, the correlation between the two increased with age. The Pearson correlation coefficients were 0.459, 0.687, and 0.805 (p<0.001) in children younger than five years, children five to ten years old, and children older than 10 years, respectively (Figure 1). There was no difference between sexes (male: 0.535, p=0.000; female: 0.589, p=0.000).

DISCUSSION

The number of children above the ideal weight was ten times higher than the number of children classified as malnourished (36.3 vs. 3.1%). Studies have indicated an increase in the prevalence of excess weight in children, but the observed values in this study were above those described in Brazilian population studies[2,3].

Almost half of the adolescents evaluated were above the ideal weight. Data from the 2016 Brazilian Institute of Geography and Statistics showed that 23% of Brazilian adolescents had excess

Table 1. General characteristics and nutritional status of the children included in the study.

	n	%
Gender (n=518)		
Male	272	52.5
Female	246	47.5
Age (n=518)		
Children under 2 years old	42	8.1
2–5 years	209	40.3
5–10 years	170	32.8
10 years or more	97	18.7
Nutritional diagnosis body mass index z-score (n=518)		
Marked thinness	5	1
Thinness	11	2.1
Normal weight	314	60.6
Risk of overweight	57	11
Overweight	77	14.9
Obesity	41	7.9
Severe obesity	13	2.5
Waist-to-height ratio (n=473)		
<0.5	234	49.5
≥0.5	239	50.5

Table 2. Nutritional diagnosis by body mass index and classification of waist-to-height ratio by sex and age group.

Age	Classification	Male		Female		p-value
		n	%	n	%	
Body mass index (BMI)						
<2 years	No excess weight	20	47.6	14	33.3	0.68*
(n=42)	Excess weight	6	14.3	2	4.8	
2–5 years	No excess weight	97	45.9	93	43.1	0.74**
(n=209)	Excess weight	11	5.7	8	5.3	
5–10 years	No excess weight	82	48.2	62	36.5	0.42**
(n=170)	Excess weight	12	7.1	14	8.2	
≥10 years	No excess weight	35	36.1	40	41.2	0.81**
(n=97)	Excess weight	9	9.3	13	13.4	
Waist-to-height ratio (WHtR)						
2–5 years	<0.5	24	11.5	28	13.5	0.47**
(n=208)	≥0.5	83	39.9	73	35.1	
5–10 years	<0.5	72	42.6	51	30.2	0.28**
(n=169)	≥0.5	22	13	24	14.2	
≥10 years	<0.5	26	27.1	33	34.4	0.81**
(n=96)	≥0.5	18	18.7	19	19.8	

*p: significance level by Fisher's exact test; **p: significance level by the chi-squared test.

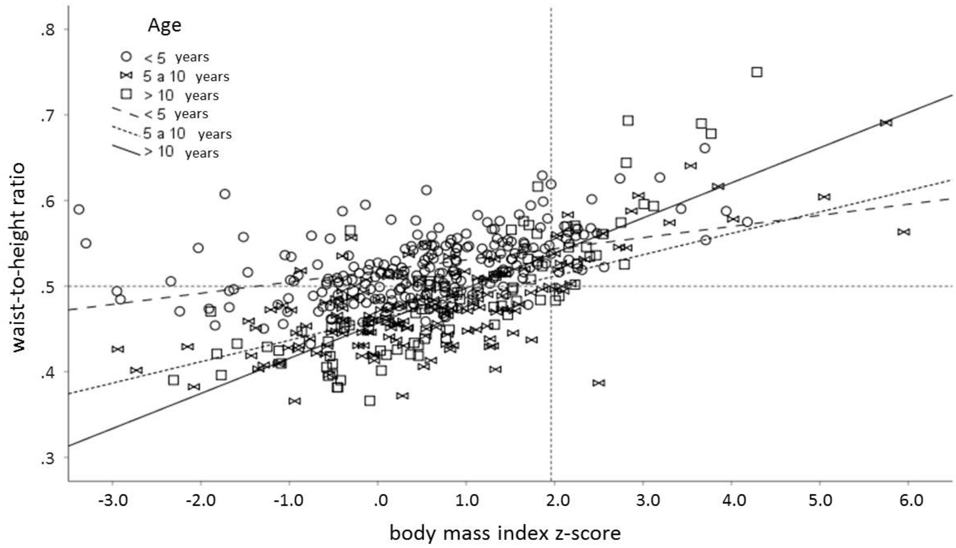

Figure 1. Correlation between body mass index z-score and waist-to-height ratio.

weight[15]. In 2015, a study conducted in Campinas, SP, found that 8.4 and 16.8% of adolescents were obese and overweight, respectively[16]. In the city of Ribeirão Preto, SP, in 2016, 30.9% of adolescents were overweight or obese[17]. Adolescents more frequently consume ultra-processed foods, favoring the emergence of obesity[18].

The correlation between BMI z-score and WHtR was stronger with increased age, ranging from r=0.459 for children under 5 years of age to r=0.805 for children over 10 years of age. A significant number of children and adolescents with a BMI z-score lower than +2 had a WHtR greater than 0.5 (Figure 1). These findings reinforce the importance of using both measurements in the pediatric age group, especially in adolescents.

Meta-analysis showed that both BMI and WHtR can be useful to define obesity in the pediatric age group when more sophisticated techniques, such as dual-energy X-ray absorptiometry, are not available[19].

The increase in WHtR is related to android obesity. We did not find differences between sexes based on WHtR. A study conducted in the state of Minas Gerais with prepubertal children found a higher prevalence of android obesity in girls[20]. Android obesity increases WHtR measurements and is associated with higher CMR[21]. In Brazil, female children and adolescents practice less physical activity than do boys, a factor that may contribute to the risk of obesity in this group[22].

A Brazilian study conducted with children aged six to ten years suggested that the WHtR could be used in conjunction with BMI to more reliably assess body fat distribution[23]. A survey conducted in Colombia with 1,919 adolescents showed that the use of BMI alone is not sufficient to predict CMR[24]. The introduction of WHtR in the pediatric routine would not increase the visit duration by much, as only an additional measurement of waist circumference would be required. In children and adolescents with excess weight, an abnormal WHtR contributes to the identification of CMR[25].

A limitation of this study was the evaluation of a single school in the municipality of Santo André, SP, thus not allowing us to extrapolate the data to the general population.

CONCLUSION

The prevalence of excess weight in the study population was higher than that described in population surveys, especially among adolescents. The WHtR is a simple, inexpensive, highly reproducible, and accurate tool for the prevention, control, and identification of childhood obesity and should be applied. The correlation between BMI z-score and WHtR increased with age, suggesting the importance of measuring both parameters, especially in adolescents.

AUTHORS' CONTRIBUITION

JCPF: Conceptualization, Data Curation, Formal Analysis, Project Administration, Writing – Original Draft. **CAV:** Data Curation, Formal Analysis. **LSS:** Data Curation, Formal Analysis. **SRC:** Data Curation. **FISS:** Formal Analysis, Writing – Original Draft. **ROSS:** Formal Analysis. Writing – Original Draft.

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