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Agreement between anthropometric indicators in the identification of high adiposity in schoolchildren

Concordância entre indicadores antropométricos na identificação de alta adiposidade em escolares

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Abstract – This study aimed to evaluate the agreement between the use of body mass index (BMI), conicity index (CI), waist-to-height ratio (WHtR), and body fat percentage (%BF), estimated via the Deurenberg equation, in the diagnosis of excess adiposity in schoolchildren. This cross-sectional study took place in 2023, with an anthropometric assessment of 1,459 kindergarten and elementary school students from municipal schools and municipal early childhood education centers in the municipality of Diamantina, state of Minas Gerais, Brazil. We compared anthropometric diagnoses obtained through BMI, CI, WHtR, and %BF to verify potential agreement between them according to sex and age group. The analysis was conducted through Cohen's kappa and Fleiss tests. A p-value less than 5% was considered significant. Excess adiposity was identified in 9.5% of the schoolchildren by BMI, in 11.7% by WHtR, in 16.7% by CI, and in 20% by %BF. Regardless of sex, the WHtR showed moderate agreement with BMI (Cohen's kappa: 0.426 for girls and 0.425 for boys; p value <0.001) and with %BF (kappa: 0.515 for girls and 0.494 for boys; p-value <0.001). Regardless of age, WHtR showed moderate agreement with %BF (<6 years – Cohen's kappa=0.527, ≥6 years – 0.502; p-value <0.001) and weak agreement with CI and BMI among those under six years of age. However, it was strongly correlated with BMI among schoolchildren ≥6 years (Kappa: 0.619; p-value <0.001). Our results show that, regardless of sex, the WHR, with age over six, showed moderate agreement with BMI and %BF, differently from the CI, showing to be an alternative for studies aimed at evaluating adiposity and the risk of cardiometabolic diseases.

Key words: Adiposity; Body mass index; Students; Waist-height ratio.

Resumo – *O objetivo deste estudo foi avaliar a concordância entre o uso do índice de massa corporal (IMC), índice de conicidade (IC), relação cintura/estatura (RCE) e percentual de gordura corporal (%GC), estimado pela equação de Deurenberg. para triagem de adiposidade elevada em escolares. Estudo transversal conduzido no ano de 2023, com avaliação antropométrica de 1459 escolares do ensino infantil e fundamental I de escolas municipais e centros municipais de ensino infantil no município de Diamantina-MG. Foi realizada uma comparação entre os diagnósticos antropométricos obtidos por meio do IMC, IC, RCE e pela %GC para verificar possível concordância entre eles, segundo gênero e faixa de idade. Para essa análise, foram aplicados o teste Kappa de Cohen e de Fleiss. Considerou-se resultado significativo valores de p abaixo de 5%. Excesso de adiposidade foi identificado em 9,5% dos escolares pelo IMC, em 11,7%, pela RCE, em 16,7%, pelo IC, e em 20%, pelo %GC. Independentemente do sexo, a RCE apresentou concordância moderada com o IMC (Kappa de Cohen: 0,426 – meninas e 0,425 – meninos; p-valor <0,001) e com o %GC (Kappa: 0,515 – meninas e 0,494 – meninos; valor de p <0,001). A RCE, independentemente da idade, apresentou concordância moderada com o %CG (< 6 anos – Kappa de Cohen = 0,527, ≥ 6 anos – 0,502; valor de p <0,001) e fraca concordância com o IC e o IMC entre os menores de seis. No entanto, apresentou boa correlação com o IMC entre os escolares ≥ 6 anos (Kappa: 0,619; valor de p <0,001). Os resultados deste estudo identificaram que a RCE, independentemente do sexo, e idade acima de seis, apresentou concordância moderada com o IMC e %GC para adiposidade elevada, diferentemente do IC, demonstrando, assim, ser uma alternativa para estudos cujo objetivo é avaliar adiposidade e risco de doenças cardiometabólicas.*

Palavras-chave: *Adiposidade; Estudantes; Índice de massa corporal; Razão cintura-estatura.*

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INTRODUCTION

Periodic assessment of children's nutritional status allows us to identify potential nutritional imbalances by analyzing various aspects, such as weight, height, body composition, and food intake, which can prevent nutrition-related health problems[1]. Thus, monitoring the nutritional status of schoolchildren can help prevent malnutrition and excess weight, which can harm child and adolescent development and influence health/disease processes[2].

Nutritional status is multifaceted, and its main determinants are related to the child's lifestyle and environment[3]. Inadequate habits such as high consumption of ultra-processed foods and sedentary behavior can contribute to excess weight in children and adolescents, a trend that both Brazil and the world have experienced in recent decades[4].

Obese children and adolescents are five times more likely to be obese in adulthood, which is linked to complications such as high blood pressure, insulin resistance, diabetes mellitus, dyslipidemia, and increased cardiovascular morbidity and mortality in adulthood. Therefore, assessing excess body adiposity in childhood has become a strategy for preventing the development of chronic diseases in the future[5].

Thus, monitoring children's nutritional status to prevent current and future problems is highly important. Therefore, identifying practical, easy-to-use body composition assessment methods to be applied in epidemiological studies has become increasingly essential for the early diagnosis of this global epidemic[6]. Accurate and early determination of adiposity distribution can aid in the development of mechanisms to prevent and treat obesity, which is a major risk factor for the above-mentioned complications[7].

Body mass index (BMI) is among the indices used to assess adiposity, being a low-cost, easily determined method that correlates with body adipose tissue. Therefore, it allows for both classification of nutritional status and identification of the risk of developing and/or having comorbidities[8]. However, it is worth mentioning the limitations of BMI since it neither measures body fat distribution nor detects more harmful abdominal fat[9].

The waist-to-height ratio (WHtR) is a measurement for estimating abdominal obesity. It is a simpler measure and can be used in children, as it requires no adjustments for age or sex. It is a quick, effective, inexpensive, and easier-to-measure and easier-to-calculate screening measure than BMI[10,11]. However, WHtR also has limitations since it is based on waist circumference, thus requiring specific values for each ethnicity, which can lead to potential inaccuracies[12].

WHtR is commonly used to identify individuals who are overweight or at high cardiometabolic risk. It has also been shown to be strongly associated with several cardiovascular risk factors in both adults and children[13] for providing a measure of central adiposity. According to a study from the United Kingdom[14], a cutoff value of WHtR > 0.5 can be considered to classify high central adiposity in any age group, regardless of sex. A systematic review[10] reported a value > 0.49 to predict abdominal obesity in children and adolescents, regardless of sex.

However, aiming to estimate the accuracy of different WHtR cutoff ranges as indicators of cardiometabolic health risk in different populations of children and adolescents[11], another systematic review with meta-analysis identified ideal WHtR cutoff values for use in children and adolescents from different regions. According to these authors[11], although the WHtR cutoff of 0.50 is widely accepted, a single cutoff value may be inadequate; a value ≥ 0.54 is ideal for predicting abdominal obesity in children and adolescents of Latino/ descent.

The conicity index (CI) is yet another anthropometric indicator for identifying body fat concentration in the central region. This index assumes that the morphological profile of the human body, with a relatively high concentration of body fat in the central region, exhibits a double-cone shape with a common base; however, it shows a cylindrical appearance upon relatively low amounts of fat in the central region[15]. Despite being a useful tool for identifying individuals at increased risk of cardiovascular disease and metabolic syndrome, it has several disadvantages. Some important limitations include the lack of universally accepted cutoff points for different populations and the complexity of its calculation compared with simpler measures such as BMI[16]. Nevertheless, studies involving Brazilian children and adolescents[17,18] have demonstrated that the conicity index is an effective indicator of central obesity by allowing to predict body fat percentage in children.

Equations for predicting body adiposity based on body mass, height, and body circumference have also been used to replace skinfold measurements. Deurenberg et al.[19] proposed an equation based on BMI and age that has been applied to children to estimate adiposity. These variables are easy to use, even in school settings, since they do not depend on an adipometer or bioimpedance device. The Deurenberg equation has high sensitivity and satisfactory performance in predicting excess body fat in children and adolescents[20].

Given the several ways to assess adiposity, it is crucial to review current measures for detecting obesity and overweight in children, as the global prevalence of this problem in children and adolescents has been rapidly increasing in recent decades, becoming a veritable global epidemic[4]. Furthermore, different anthropometric indicators assess different dimensions of body composition and can generate divergent classifications regarding the associated risk. This divergence reinforces the importance of comparative studies, especially given that the agreement between these methods remains little researched or controversial in the literature. While most studies have compared these methods two by two[17,18], with a more restricted age range, for example, 4-9 years[17], our study compares measurements from preschoolers and elementary school students.

Given the above-mentioned issues, this study aimed to evaluate the agreement between the use of BMI, CI, WHtR, and %BF, estimated by the Deurenberg equation, for screening for high adiposity in schoolchildren.

METHOD

Type of study, location, and research subjects

This is a cross-sectional study with preschool and elementary school students from municipal schools and CMEIs in the municipality of Diamantina, state of Minas Gerais, Brazil. This study includes no sample size calculation since all students enrolled in 2023 and present on the days of data collection were evaluated. Data were collected upon consent by the Municipal Department of Education and from the students' parents or legal guardians, who had been informed on the application of the procedures. The students were evaluated after the informed consent form (ICF) signed by the parents or guardian was returned.

The ethical issues of this study were guided by the provisions of Resolution No. 466 of December 12, 2012, of the National Health Council. The research was approved by the UFVJM Ethics Committee under Opinion No. 3,602,675.

Variables assessed

Weight, height, and waist circumference data were collected by trained evaluators according to the procedures described below. Information on the students' birth dates was provided to the project coordinator by the schools and CMEIs where the students attended.

Body weight was measured via a digital scale, with the student wearing light clothing and barefoot and standing in the center of the scale platform. Height was measured by a portable stadiometer, with the student standing upright, arms extended alongside the body, feet together, and barefoot. Waist measurement was performed using a flexible, inelastic tape measure at the smallest circumference of the abdomen, under thin clothing, and at the end of normal exhalation. These measurements were performed following the protocols proposed by Lohman et al.[21].

The body mass index/age (BMI/age) was calculated on the basis of weight and height, which was determined from the ratio between weight and height squared (BMI = weight [kg]/height [m2]). The waist-to-height ratio (WHtR) was calculated by dividing the waist circumference (cm) by the height (cm)[14]. The conicity index (CI) was calculated using the variables waist circumference, weight, and height (CI = WC (meters)/0.019 * weight (kg)/height (meters))[15]. Body adiposity (%BF) was identified through the body fat percentage obtained via the equations proposed by Deurenberg et al.[19] (%BF = 1.51 × BMI – (0.70 × age) – (3.6 * Y) + 1.4, where Y = 1 for boys and 0 for girls). Overweight was defined as a student with a BMI/A ≥ 2 Z score[22]. Z-score values were identified via the Anthro-2007 and Anthro Plus programs.

The cutoff point was greater than or equal to 0.54, regardless of sex and age[11]. with the WHtR being used to classify high abdominal adiposity. WHtR is directly related to growth, justifying a single value for the cutoff points regardless of age[17]. Schoolchildren with WHtR values above 1.25 (males) and above 1.18 (females) were classified as having high abdominal adiposity[16]. High adiposity according to %BF was classified according to sex, with values above 25% for girls and above 20% for boys[23].

Data analysis

Anthropometric measurements (BMI, WHtR, CI, and %BF) were compared to assess agreement by sex (male and female) and age group (<6 years and ≥6 years) separately. Cohen's kappa test[24] and Fleiss's kappa test[25] were used to analyze the results to determine agreement and disagreement between the methods for each sex and age group. A significance level of 0.05 was set for both tests.

The data were initially organized into spreadsheets in Microsoft Office Excel® (Microsoft Corp., USA) and subsequently transferred to SPSS® (Statistical Package for Social Sciences) version 25.0.

RESULTS

A total of 1,459 students from preschools (nursery schools I, II, III, 1st, 2nd, and 3rd periods) and elementary schools (1st to 5th grades) participated in this study. All students were enrolled in schools and municipal early childhood education centers (CMEECs) in the city of Diamantina, state of Minas Gerais, Brazil, in 2023. Among the students evaluated, 777 (53.2%)

were male, and 682 (46.7%) were female. Among these, 58.12% (n=848) were under six years old, and 48.88% (n=611) were over six years old.

Table 1 shows the adiposity parameters of the students, according to sex, age, and the total sample. By classifying these parameters by sex, 9.5% of the total sample had high body adiposity according to BMI, followed by WHtR (11.7%), CI (16.7%), and %BF (20%). Except for WHtR, all classifications differed between the sexes (Table 1). By comparing these parameters by age group, except BMI, all the differences were statistically significant, with greater changes in BMI and %BF among boys.

Table 1. Anthropometric profile of the students, according to sex and age, and total sample for body mass index, conicity index, waist/height ratio, and body fat percentage.

Variables assessed	Boys (n=769)		Girls (n=690)		Total (n=1459)		p Value *
	n	%	n	%	n	%	
BMI/age							
Adequate	680	88.4	640	92.8	1320	90.5	**0.005**
High	89	11.6	50	7.2	139	9.5	
Conicity Index							**<0.001**
Adequate	729	94.8	487	70.6	1216	83.3	
High	40	5.2	203	29.4	243	16.7	
Waist/height ratio							0.948
Adequate	679	88,3	610	88.4	1289	88.3	
High	90	11.7	80	11.6	170	11.7	
% Body fat							
Adequate	577	75.0	590	85.5	1167	80.0	**<0.001**
High	192	25.0	100	14.5	292	20.0	
Variables assessed	**< 6 years (n=848)**		**≥ 6 years (n=611)**		**Total (n=1459)**		**p Value ***
	n	%	n	%	n	%	
BMI/age							
Adequate	772	91.0	548	89.7	1320	90.5	0.387
High	48	9.1	91	9.8	139	9.5	
Conicity Index							
Adequate	687	81.0	529	86.6	1216	83.3	**0.005**
High	161	19.0	82	13.4	243	16.7	
Waist/height ratio							
Adequate	711	83.8	578	94.6	1289	88.3	< **0.001**
High	137	16.2	33	5.4	170	11.7	
% Body fat							
Adequate	651	76.8	516	84.5	1167	80.0	< **0.001**
High	197	23.2	95	15.5	292	20.0	

A significant difference in age was identified between CI (p value = 0.005), WHtR (p value <0.001), and %BF (p-value <0.001). The highest prevalence of changes in these variables occurred among students under five years of age. Considering that WHtR has been recommended to replace BMI, including in studies with children for better discriminating abdominal adiposity and hence the risk of CVD, we chose to verify the agreement between the parameters assessed here and WHtR. Table 2 shows the results of the analysis performed via Cohen's kappa test according to sex and age range.

Table 2 shows that the agreement between WHtR and BMI and %BF can be considered moderate, whereas it is considered weak for CI, regardless of sex. Regarding the age group, the group of individuals under six years of age showed a weak agreement between WHtR and BMI and CI, while moderate for %BF. Among those over six years of age, the agreement between WHtR and BMI was good, with the %BF being moderate and the CI being weak.

Furthermore, we also compared the agreement of the four parameters assessed here regarding the identification of high adiposity. This analysis was performed via Fleiss's kappa test, and the results indicate a weak agreement (Fleiss's kappa = 0.33; p-value <0.001), regardless of sex and age group, meaning that none of them can be used to screen for high adiposity. Table 2 indicates that the CI was not a good discriminator of excess body fat in schoolchildren; therefore, the agreement between the WHtR, %BF, and BMI was also verified. The results indicate moderate agreement among the three methods (Fleiss's kappa = 0.506, p-value <0.001) regarding the identification of high adiposity among schoolchildren, regardless of age group and sex.

Table 2. Measure of agreement between the waist-to-height ratio (WHtR) and the variables body mass index (BMI), CI, and % body fat (%BF) according to sex and age.

	WHtR x BMI		WHtR x CI		WHtR x %BF	
	Cohen's Kappa	p-value	Cohen's Kappa	p-value	Cohen's Kappa	p-value
Sex						
Boys	0.425	< 0.001	0.337	< 0.001	0.494	< 0.001
Girls	0.426	< 0.001	0.301	< 0.001	0.515	< 0.001
Age						
< 6 years	0.337	< 0.001	0.301	< 0.001	0.527	< 0.001
≥ 6 years	0.619	< 0.001	0.313	< 0.001	0.502	< 0.001

Note. Cohen's kappa between 0.21 and 0.40 = weak agreement; 0.41 and 0.60 = moderate agreement; and 0.61 and 0.80 = good agreement.

DISCUSSION

It is crucial to learn the distribution pattern of body adiposity since this variable is related to cardiometabolic risk factors. When assessed and monitored in childhood, it can be used to guide early interventions to prevent adolescents or adults from reaching very high risk.

In this context, the prevalence of high adiposity among the schoolchildren evaluated in this study varied according to the different indices studied, with a higher prevalence observed for %BF, followed by CI, WHtR, and BMI. Notably, however, comparisons by sex revealed greater changes in BMI and %BF among boys, while when compared by age group, schoolchildren under six years of age showed greater changes, except for BMI. This result does not agree with those found by Lopes et al.[26] and Andrade et al.[27], who also assessed adiposity in schoolchildren and reported higher adiposity and BMI values among girls. This difference is likely to have occurred due to those authors having evaluated schoolchildren aged between six and 11, while our study most include individuals under six years of age. Importantly, during puberty, the transitional phase between childhood and adulthood, occurring between eight and 13 years of age in girls, and between nine and 14 years of age in boys, it is common for adiposity to increase. During this period, girls experience greater gains in total mass and adipose mass than boys[27].

According to Macêdo et al.[2], boys are often taller than girls are, and greater height can lead to higher values of anthropometric indices, such as BMI. Their study[2] reports greater height leading to higher BMI; however, this correlation was stronger for males.

Table 2 shows results indicating that CI did not have good agreement, regardless of age or sex, with the parameters assessed to estimate adiposity, unlike the other parameters, which showed moderate to good agreement. These results indicate that BMI and WHtR can be used to screen for high adiposity in the students evaluated.

Other studies have also shown that both WHtR[28,29] and BMI[28] can be recommended for obesity screening, unlike CI, which shows weak agreement with WHtR, being an anthropometric indicator with low discriminatory power for adiposity in the studied group. A study involving Brazilian adolescents also revealed the low predictive value of CI for identifying obesity[28]. By assessing indicators of body fat location, including BMI, WC, skinfold thickness, CI, and WHtR, Sant'anna[29] reported that WHtR had better discriminatory power for excess body fat than WC and CI did in both sexes and at all ages.

Ferreira et al.[30] evaluated the ability of the anthropometric indicators BMI, %BF, waist circumference, and waist-to-hip ratio to predict metabolic syndrome in children. The results showed that the CI was not a good predictor of MS, despite being able to estimate visceral fat predominantly, which the authors attributed to the children evaluated being below puberty, hence far from peak height, compared to the adult population, for which the CI has been validated as a predictor of cardiovascular disease. Given that the children evaluated in this study were also below puberty, this could explain why this indicator showed weak agreement with the other adiposity indicators.

Our study indicates that BMI, WHtR, and %BF show moderate agreement in detecting elevated adiposity among schoolchildren, regardless of age group or sex. By comparing WHtR with other variables, we found that no good agreement between WHtR and BMI only for schoolchildren under six years of age. This suggests that, except for this group, WHtR could replace BMI as a simple estimate for assessing adiposity, especially central adiposity, also in addition to being used to detect cardiometabolic risk factors[15].

Thus, the age range to be evaluated must be considered in studies estimating body fat in children through anthropometric measurements and equations that relate these measurements to body composition, that is, doubly indirect methods, for assessing childhood adiposity. Nevertheless, these methods are practical, low-cost, and easy to apply, making them suitable for use in field research and clinical studies.

It is worth highlighting the limitations of this study regarding the use of doubly indirect measures to estimate body adiposity; however, in assessing nutritional status and body composition in children and adolescents, such measures are commonly used and recommended by health agencies.

CONCLUSION

Our results show that there was no good agreement between CI and WHtR among the schoolchildren evaluated, regardless of sex or age group, which has been recommended for assessing excess central adiposity in different age groups. However, WHtR showed good agreement with BMI among schoolchildren over six years of age and moderate agreement with %BF, regardless of sex or age group. These findings reinforce that WHtR is a simple, reproducible, reliable, and low-cost index, allowing for greater reach in health monitoring, including among schoolchildren. Moreover, our study also highlights the importance of the school environment in encouraging healthy food choices and regular physical activity as a means to prevent excess weight and improve quality of life.

Compliance with ethical standards

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Data Availability Statement

The data that support the findings of this study are available by the corresponding author upon reasonable request.

Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee –Universidade Federal dos Vales do Jequitinhonha e Mucuri, and the protocol (no. 3.602.675/2019) was written following the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflicts of interest to declare.

Author Contributions

Experiment planning and design: LNN; Conducting experiments: RCS, FOFS, NMGM, ACSS, LNN; Data analysis: LNN; Contribution with materials/analysis tools: ACSS; Manuscript writing: RCS, FOFS, NMGM, ACSS, LNN.

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