ORIGINAL ARTICLE

Evaluation of predictive measurements of excess weight in brazilian children

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INTRODUCTION

Obesity is considered a chronic non-communicable disease (NCD), of multifactor etiology. Its prevalence is rising rapidly, even in children and adolescents; its consequent metabolic changes, which before were only found in the adult population, can already be found in the younger population[1,2]. Among the factors most closely associated with obesity is the change in eating habits and lifestyle. Overall, there has been a change in diet, characterized by the high consumption of high-energy-density foods, rich in simple sugars and fat, combined with a reduction of physical exercises and an increase of screen time[2,3].

The Body Mass Index is the main instrument used to identify obesity. However, the BMI is not able to evaluate central obesity, the main predictor of comorbidities associated with obesity[4]. A measurement that can be used for this purpose is the waist circumference (WC), which is considered a good indicator of visceral fat, presenting a strong relationship with atherosclerotic cardiovascular diseases, insulin resistance, and the metabolic syndrome[5]. Like the WC, the waist/height index (W/H) is also a tool used to measure the deposition of fat in the abdominal region, presenting an important correlation with cardiovascular risk factors[6]. Current research reported that the circumference of the neck (NC) could identify patients with obesity and overweight, which can be directly related to factors associated with metabolic syndrome[7].

The objective of this study is to verify the distribution of body fat using the waist and neck circumference and the W/H index and to compare NC, WC and the N/H index with the BMI of children and adolescents aged 2-14 years treated by the *Projeto Bandeira Científica* in Acreúna (GO) in 2016.

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METHODS

This is a cross-sectional study with children and adolescents aged 2-14 years treated by the *Projeto Bandeira Científica* in the city of Acreúna (GO), between the second and third weeks of December 2016.

The *Projeto Bandeira Científica* project was created in the Medical Faculty of USP in 1957. It is an initiative of university extension led by students from various programs of the University of São Paulo.

The city of Acreúna is a municipality in the Serra do Caiapó mountain range. It has a territorial extension of 1,824 km² and an estimated population of 21,905 inhabitants, of which 5,049 were children between 0-14 years old in 2010. It is a predominantly urban area (86.70%), and its economy revolves around agriculture and services. Its MHDI (Municipal Human Development Index) is 0.686 and has full coverage of the Family Health Program.

The directors of the project made eight previous visits to the city of Acreúna with the objective to learn about the reality of local health, present the initiative and invite the public to participate in the project. A list of people interested in receiving care via the project was drawn up, and they were called on the day the project team started their work. The project team was distributed daily into two different locations, organized every day in different spaces made available by the city hall, in order to facilitate the access of citizens. The units were set up in schools that had enough space for the team and the work material. The selection of the study population was made using an anthropometric assessment in the care units of the Project, where children and adolescents up to 18 years and 11 months old, the elderly and pregnant women were required to go through. A total of 205 children and adolescents were evaluated.

Were excluded from the research children and adolescents who had the following chronic diseases: encephalopathies, lung diseases, heart, liver, and kidney diseases, HIV infection, genetic syndromes, and oncologic diseases. Children aged between 2 and 4 years were characterized as preschoolers; from 5 to 10 years, as schoolchildren; and those from 11 to 14 years old, as adolescents[8].

The methodological instruments used were: a questionnaire for collecting personal, anthropometric, and clinical data, and the following measurements and index:

Weight and height were measured according to the standardized methodology[9]. The NC was measured using an inelastic measuring tape positioned at the middle point of the neck, at the level of the thyroid cartilage, with the individual standing up, looking forward and breathing normally[10]. The WC was measured with a measuring tape by obtaining the smallest circumference between the anterior superior iliac crest and the last costal arch[11]. The index (W/H) is the relationship between waist and height measurements, and the values were separated into two groups: < 0.5 and > 0.5 - the latter indicating an increased risk for cardiovascular diseases[12].

To assess their nutritional status, children and adolescents were classified according to the BMI indicated per age in z-score (BMI/I), using as a reference the growth curves of the World Health Organization[13] and the WHO cut-offs for overweight and obesity risk[14]. The Anthro Plus software, developed by the WHO[15] was used for classifying the nutritional status.

In the statistical analysis, the numerical variables were evaluated using averages and standard deviations and the categorical variables using absolute frequencies. The software used was SPSS Statistics 20. We considered the BMI a outcome variable and the WC, NC, and W/H index predictor variables. Analyses were carried out using Pearson correlation and linear regression between variables and outcome predictors. Then, we made the ROC curve, accuracy, sensitivity, specificity, positive and negative predictive values and precision by age for the variables: W/H index, WC, and NC; the level of significance was set at $p < 0.05$.

The research was approved by the Research Ethics Committee of the Medical Faculty of the University of São Paulo (Process number: 119885/2016), and the parents or guardians signed informed consent for the use of the collected data.

RESULTS

In total, 205 children and adolescents took part in the research, with an average age of 8 years and 2 months (SD = + 3 years and 6 months), 51.20% (n=105) males. Table 1 presents the average anthropometric measurements collected, minimum, maximum, mean and standard deviation, in addition to the classifications according to the z-score.

Regarding nutritional status according to BMI/age, 67.80% were classified as eutrophic, 3.41% as underweight, 4.87% as in risk of overweight, 12.68%

TABLE 1 - CHARACTERIZATION OF THE POPULATION STUDIED ACCORDING TO THE ANTHROPOMETRIC DATA (ACREÚNA, 2016).

	N	Mini-mum	Maxi-mum	Aver-age	Standard deviation
Age (years)	205	2.03	14.99	8.13	3.56
Weight (kg)	205	9.10	82.90	30.69	15.81
Height (cm)	205	81.00	177.20	127.23	22.46
Weight/Age*	134	-3.96	3.44	0.17	1.28
Height/Age	205	-3.66	2.44	-0.03	1.10
BMI/Age (z-score)	205	-3.20	4.26	0.35	1.34
BMI	205	12.30	32.10	17.68	3.86
WC (cm)	205	20.50	99.80	60.32	11.68
NC (cm)	205	16.90	44.50	28.58	3.82
W/H Index	205	0.16	0.65	0.48	0.06

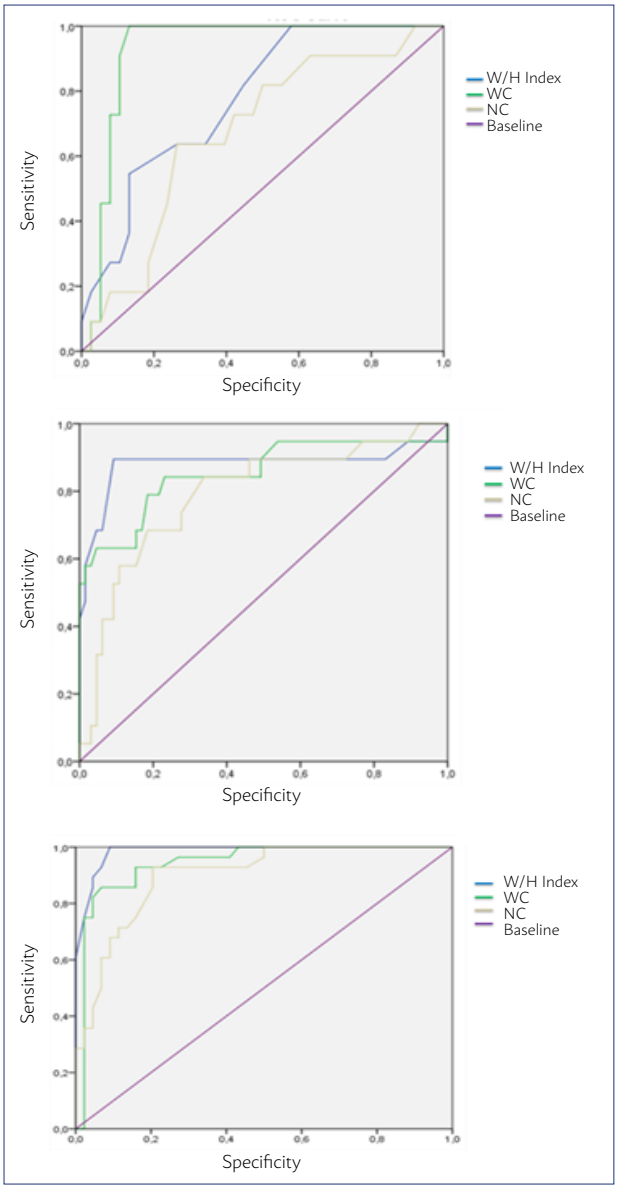
*The classification according to weight/age applies only for children from 0 to 10 years old.

as overweight, and 11.22% as obese (Table 2). Concerning gender, of 100 girls assessed, 29.75% were eutrophic, 1.95% had low weight, 2.44% risk of overweight, 8.78% were overweight, and 5.85% were obese. As to males, 38.04% of the boys were eutrophic, 1.46% had low weight, 2.44% risk of overweight, 3.90% were overweight, and 5.36% were obese (Table 2). The nutritional status of overweight/obesity was more frequent in children over 10 years old than in other age groups.

The average value of neck and waist circumference was 28.56±3.82 cm and 60.32±11.68 cm, respectively. In 66.30% (n=136), the classification of waist circumference per height (W/H) was lower than 0.5 and in 33.70% (n=69) it was greater than this value (Table 2).

The values of the correlation and simple linear

FIGURE 1. ROC CURVES FOR THE W/H INDEX, WC, AND NC IN RELATION TO PEDIATRIC AGE GROUPS.



A. ROC curve for children 2-5 years old. **B.** ROC curve for children 5-10 years old **C.** ROC curve for children over 10 years old

TABLE 2 - CLASSIFICATION OF NUTRITIONAL STATUS ACCORDING TO BMI/AGE IN RELATION TO AGE, GENDER, AND CLASSIFICATION OF THE INDEX W/H INDEX (ACREÚNA, 2016).

		Low weight %(n)	Eutrophy %(n)	Overweight risk %(n)	Overweight %(n)	Obesity %(n)	Total
Age range	2 |– 5	0	18.53 (38)	4.87 (10)	0.48 (1)	0	49
	5 |– 10	1.95 (4)	29.75 (61)	0	4.39 (9)	4.87 (10)	84
	10|–15	1.46 (3)	19.51 (40)	0	7.8 (16)	6.35 (13)	72
Gender	Female	1.95 (4)	29.75 (61)	2.44 (5)	8.78 (18)	5.85 (12)	100
	Male	1.46 (3)	38.04 (78)	2.44 (5)	3.9 (8)	5.36 (11)	105
	<0.5	3.41 (7)	54.63 (112)	0	6.34 (13)	1.95 (4)	136
Classification W/H Index	>0.5	0	13.17 (27)	4.87 (10)	6.34 (13)	9.26 (19)	69
Total		3.41 (7)	67.80 (139)	4.87 (10)	12.68 (26)	11.22 (23)	205

regression between BMI, WC, NC, and W/H Index showed us that the increase in 1 centimeter in WC entails an increase of 0.274 in BMI ($R = 0.830$; $R^2 = 0.688$; $p = 0.001$; $\beta = 0.274$), the increase in 1 centimeter in NC generates an increase of 0.717 in BMI ($R = 0.711$; $R^2 = 0.506$; $p = 0.001$; $\beta = 0.717$) and the increase of 1 millimeter in the W/H Index leads to an increase of 2.770 in BMI ($R = 0.447$; $R^2 = 0.200$; $p = 0.001$; $\beta = 2.770$).

ROC curves were drawn to identify the best instrument for the anthropometric assessment of children and adolescents. To do that, we calculated the areas under the ROC curves (AUC) for WC, NC, and W/H Index per the age ranges. These were statistically significant ($p < 0.05$), except for NC in children up to 5 years old (Figure 1).

Table 3 shows the different cutoff points for WC, NC, and W/H Index and their respective values of accuracy, sensitivity, specificity, positive and negative predictive values, and precision, separated by age and sex. In children aged 2 to 5 years, the WC has proved to be the best instrument (89.8±0.04%), and in children from 5 to 10 years and over 10 years, the W/H Index had the best results (90.1±0.03% and 94.4±0.03%, respectively).

DISCUSSION

This study evaluated the relationship between the WC, NC, and W/H Index variables with the BMI in children and adolescents. The main result found was that the WC of children younger than 5 years and the W/H Index of children older than 5 years have proved to be accurate measurements to identify excess weight.

In the present study, 23.90% of the individuals were classified as having excess weight (12.68% overweight and 11.22% obese), the majority of them females over 10 years old. In the study by Petroski et al.[16], 6.80% of the schoolchildren were classified with excess weight, and there was also a predominance of females over 10 years old. Silva et al.[17] found a higher percentage of overweight among the children analyzed, but lower rates of obesity (14.50% and 8.30%, respectively), and Pelegrini et al.[18] observed that 24.30% of their study population showed excess weight. Such statistical variations are possibly due to regional variations. By analyzing the data from the 2008-2009 HBS, we found that 33.50% of children from 5 to 9 years old are overweight, while in adolescents from 10 to 19 years old the number drops to 20.50%. Thus, the prevalence statistics observed in the present study lies between the HBS values for children and adolescents[19].

Regarding the evaluation per genre, this study found that the prevalence of excess weight is higher in females than in males, with 8.78% of the girls overweight and 5.85% obese, while these number in males are 3.90% and 5.36%, respectively. The data from the 2008-2009 HBS show that excess weight is slightly higher in males: 32% of female children from 5 to 9 years old have excess weight, whereas this value increases to 34.80% in males; in the age range of 10 to 19 years, the HBS data show that the prevalence of excess weight is 19.40% in females and 21.70% in males[19]. The rates of excess weight and obesity are very high. In Brazil, over half of the adult population

TABLE 3 - CUT-OFF POINTS, SENSITIVITY, SPECIFICITY, ACCURACY, POSITIVE AND NEGATIVE PREDICTIVE VALUES FOR WC, NC AND W/H INDEX (ACREÚNA, 2016).

Age range		Entire sample (n=205)	Females (n=100)	Males (n=105)	A (%)	S (%)	E (%)	PPV (%)	NPV (%)	P (%)
2-5 years	W/H Index	0.55	0.55	0.54	80	55	87	55	87	80
	WC (cm)	52.40	52.40	53.00	90	69	100	100	87	90
	NC (cm)	27.50	26.20	26.60	76	40	80	18	92	76
5-10 years	W/H Index (cm)	0.49	0.49	0.49	90	74	97	89	90	90
	WC (cm)	63.00	63.00	65.80	88	80	90	63	95	88
	NC (cm)	29.50	32.00	29.50	82	61	88	58	89	82
Over 10 years	W/H Index (cm)	0.46	0.49	0.46	94	88	100	100	91	94
	WC (cm)	73.00	73.50	73.00	90	89	91	86	93	90
	NC (cm)	30.70	30.90	33.00	85	74	95	93	80	85

A: accuracy; S: sensitivity; E: specificity; PPV: positive predictive value; NPV: negative predictive value; P: precision; WC (waist circumference); NC (neck circumference); W/H Index (waist/height). Values calculated for the total sample.

is overweight[20], a situation that affects both genders similarly.

The increase in ultra-processed food consumption, or even of minimally processed ones, over in natura food, and the increasingly sedentary lifestyle of children and adolescents, characterized by an increase in screen time[3], have been associated with high rates of overweight among children.

The results of the correlation between BMI and NC, WC and W/H Index show that the NC and WC are strongly correlated with the BMI. The W/H Index presented a moderate correlation with BMI (strong positive correlation: r = 0.70 - 0.89) and moderate: r = 0.40 - 0.69). Also, the ROC curves indicate that the AUC of WC was higher in children from 2 to 5 years old, showing it to be the best instrument for indication of excess weight. In children aged 5 to 14 years, the W/H Index proved to be the best instrument. Another point that we were able to observe during the analysis is that WC, NC, and the W/H Index proved to be more significant with increasing age, i.e., there is a proportional and positive relationship with age.

In adults, the WC is a measurement widely used for verification of central obesity, which is related to the risk of cardiovascular diseases. Recently, this parameter has been proposed as an indirect measure of central obesity in children and adolescents[21,22]. The results found allow us to affirm that the WC provides very relevant and consistent information on the central body fat deposition in children when compared with the BMI. Corroborating the findings of this study, the studies of Soar et al.[23] and Ricardo et al.[24] also found a strong correlation between WC and BMI.

The present study showed that 33.70% of children and adolescents had a waist/height ratio over 0.5, i.e., a large fat tissue deposition in the abdominal region. This value is much greater than one found by Ricardo et al.[24], who found that 11.90% of children between 6 and 10 years old had abdominal adiposity and is also greater than the one found in the McCarthy and Ashwell[25] study, in which a 11.70% prevalence was observed. According to Pereira et al.[26], the W/H index can be considered a good indicator of abdominal adiposity, even better than the isolated measurement of waist circumference, because it takes into consideration the height of the individual and allows us to establish a single cut-off point. The AUC shows that the W/H Index is a good tool to identify excess weight, which is confirmed by high sensitivity and specificity values in all age groups. However, according to these results, we observed that, in younger children (2-5 years), this is not the best instrument, which corroborates a study conducted with children in Norway, according to which the W/H Index has lower sensitivity and specificity values in this age group[27].

The NC, a measurement that has been studied as a potential indicator of excess weight, was evaluated in children and adolescents. The results showed a strong positive correlation between NC and BMI, compatible with the findings of Lou et al.[28], Coutinho et al.[29] And Nafiu et al.[10]. In this study, the NC was correlated with BMI and became more significant as a predictor of excess weight as age increased, being indicated as a screening tool in older children. In contrast, the results also indicate that this is a less effective tool than others known since the NC had the lowest values of accuracy, sensitivity, specificity, positive and negative predictive values, and precision when compared with the WC and the W/H Index. The NC may reflect overweight and obesity in children and adolescents, but not in isolation; it needs to be associated with other measurements discussed in this work.

The limitations of our study are related to the gold standard parameter used for the analyses: BMI, which is known to be a high-sensitivity and low-specificity tool in the detection of excess weight. It would be interesting to compare the predictive variables with more reliable parameters of body composition diagnosis, such as densitometry by dual emission of X-rays and bioimpedance, but the dynamics and reality of the project did allow the collection of such data. Furthermore, the data collection was performed by the entire nutrition team who participated in the project in 2016 and, even though they received training to collect anthropometric measures, that did not avoid data collection errors, which are always present in studies such as this one, due to the interpersonal variation. Despite its limitations, this study showed that anthropometric measures such as WC, NC and W/H Index are useful to evaluate the nutritional status of children and adolescents in general.

CONCLUSION

After the analyses, we concluded that the children and adolescents treated by the *Projeto Bandeira Científica* showed a prevalence of 23.90% of excess weight, which is considered a high prevalence. Also, 33.70% had a W/H Index over 0.5, showing that approximately 1/3 had excess abdominal fat, which rep-

resents a risk for developing cardiometabolic diseases.

In the analysis by age groups using the ROC curve, we observed that among children aged 2 to 5 years, the WC presented a higher AUC than the W/H Index and NC. Whereas in children from 5 to 14 years old, the W/H index presented higher AUC than the WC and NC.

In summary, the WC of children younger than 5 years and the W/H Index of children older than 5 years have proved to be accurate measurements to identify excess weight.

Conflict of interest

Nothing to declare.

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PALAVRAS-CHAVE: *Obesidade. Criança. Antropometria.*

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