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The Conicity Index Compared to Other Anthropometric Indicators as a Predictor of Excess Weight and Obesity in Adolescents

Maria Aparecida Zanetti Passos[1]; Eliana Pereira Vellozo[2]; Carla Cristina Enes[3]; Peter Richard Hall[4]; André Luiz Monezi Andrade[5]; Andressa Melina Becker da Silva[6]; Cecília Costa Arcanjo[7]; Francisco Plácido Nogueira Arcanjo[8]; Maria Sylvia de Souza Vitalle[9].

Abstract

To compare the performance of the CI with the other anthropometric indicators (waist-to-height ratio (WHtR), and waist-to-hip ratio (WHR)) in the prediction of excess weight/obesity in adolescents and to establish the respective cutoff points through ROC curves. Demographics: 557 adolescents aged 10-15 years participated in the study. Setting: This study was conducted at four state-run schools in the municipality of São Paulo. Methodology: This was a longitudinal study with a non-probabilistic sample design. Analysis: Anthropometric measurements were taken at 1-year intervals during a period of 3 years. CI, WHtR and WHR values were calculated, and their performance for the prediction of excess weight/obesity was analyzed, calculating the respective cutoff values using ROC curves. Findings: Among the anthropometric indicators, WHtR showed the highest predictive capacity for excess weight/obesity. The CI only proved effective in the 3rd measurement for male participants with a cutoff point of 1.1450 (sensitivity = 0.565, specificity = 0.164). There was a significant correlation for all anthropometric variables with excess weight/obesity, except muscle mass, in the complete sample and according to sex. Implications: The use of WHtR and simple anthropometric measurements, with the cutoff points presented, provided effective predictability in screening for excess weight in this sample.

Keywords: Conicity index; Adolescents; Prediction; Anthropometric indicators; Overweight; Obesity.

1. Introduction

The continuous increase in the incidence of excess weight and obesity in children and adolescents in recent decades has aroused the concern of specialists, mainly because this condition is associated with the occurrence of chronic diseases, in addition to the greater risk of obesity in adulthood (Goldhaber-Fiebert *et al*, 2013; World Health Organization, 2016).Obesity is related to several metabolic disorders such as dyslipidemia, arterial hypertension, insulin resistance and diabetes, favoring the occurrence of cardiovascular events, particularly coronary artery disease (Stefan *et al*, 2013; Tchernof & Després, 2013; Bray *et al*, 2017).

In this context, the assessment of both body composition and body fat distribution has gained greater importance in clinical practice. Although imaging tests such as tomography and magnetic resonance offer good

[1] Postdoctoral fellow at the Postgraduate Program in Education and Health in Childhood and Adolescence, Universidade Federal de São Paulo (ESIA, UNIFESP).
[2] Researcher and Supervisor of the Adolescent Medicine Sector, Department of Pediatrics, Escola Paulista de Medicina / Universidade Federal de São Paulo. Postdoctoral fellow at the Department of Pediatrics at EPM / UNIFESP.
[3] Professor at the Faculty of Nutrition at Pontifícia Universidade Católica de Campinas. Permanent professor of the Stricto Sensu Graduate Program in Health Sciences at Pontifícia Universidade Católica de Campinas
[4] Professor at the Faculty of Medicine, Centro Universitário INTA, UNINTA.
[5] Professor at the Faculty of Psychology at Pontifícia Universidade Católica de Campinas. Permanent professor of the Stricto Sensu Graduate Program in Psychology at Pontifícia Universidade Católica de Campinas.
[6] Professor at the Faculty of Psychology and Physical Education, Universidade de Sorocaba, UNISO. Post-Doctorate and Doctorate in Psychology at Pontifícia Universidade Católica de Campinas.
[7] Master's fellow in Health Sciences at the Universidade Federal do Ceará, UFC.
[8] Adjunct Professor at the Universidade Federal do Ceará, UFC.
[9] Head of the Adolescent Medicine Sector and Adjunct Professor of the Department of Pediatrics at Escola Paulista de Medicina / Universidade Federal de São Paulo. Permanent Professor of the Postgraduate Program ESIA, UNIFESP.

accuracy in measuring body fat (Armellini *et al*, 1993; Pescatori *et al*, 2019) their use in population studies has been limited due to high cost and complex methodology. Thus, anthropometric indicators stand out as satisfactory instruments for assessing excess body fat, given their simplicity of use and ease of interpretation (Pelegrini *et al*, 2015; Lichtenauer *et al*, 2018).

Among the main indicators, the Body Mass Index (BMI) has been the most used in population studies with adolescents (Henriksson *et al*, 2019).Historically, the most widely used indicators to identify obesity are the waist-to-hip ratio (WHR), waist circumference (WC) and more recently the waist-to-height ratio (WHtR).However, new indicators have been proposed in order to detect obesity and the distribution of body fat, such as the conicity index (CI) (Valdez, 1991; Sousa *et al*, 2016), determined from weight, height and waist circumference measurements, CI has shown a strong correlation with cardiovascular risk factors (Carneiro *et al*, 2014).

Due to the scarcity of studies in Brazil that evaluated the performance of CI as a predictor of excess weight/obesity in adolescents, and recognizing the importance of establishing cutoff points for the diagnosis of this condition, the present study aimed to compare the performance of CI with other anthropometric indicators (WHtR, WHR, WC, neck circumference (NC), hip circumference (HC) and arm circumference (AC)) in the prediction of excess weight/obesity in adolescents.

2. Methods

2.1. Study design

This is a longitudinal study, with probabilistic sampling of adolescents enrolled in state-run schools, and 3 collection waves at 12-month intervals.

2.2. Participants

In the first phase of data collection, 1,774 students were assessed and inclusion in the study was based on the following criteria: 1) being between 10 and 15 years old; and 2) being enrolled between the last year of middle school and the third year of high school. Participants who met the following criteria were excluded from the study: 1) participation in any weight loss programs or following diets; 2) patients with chronic or mental illnesses; 3) use of medications that could interfere with body composition and blood pressure; and 4) pregnant or lactating women. Thus, a total of 837 adolescents were included in the sample. During the study, 280 students were lost in the 2nd and 3rd data measurements (38 moved to a different school (outside the study sample), 40 no longer wished to participate, 200 were absent during at least one of the data collection moments, and 2 had incomplete/inconsistent data).

The final sample of the study was composed only by the adolescents who participated in the three measurements, totaling 557 students (M_{age} = 12.03; SD = 1.11) from four state-run schools in the municipality of São Paulo (1 in the southern region, 2 in the central region and 1 in the western region).

2.3. Criteria for sample selection and calculation

To estimate the sample, the sample size calculation equation was used considering a sample error of approximately 2.0%, which represents a minimum sample size of 541 adolescents (Lohman *et al*, 1988).

Approval was sought from the Secretary of Education of the municipality of São Paulo and schools were selected considering the following criteria: 1) proximity to the Adolescent Assistance and Support Center (condition determined by the municipality's teaching department); and 2) easy access to public transport to facilitate the travel logistics of field researchers. Participation was authorized the school directors and all students who met the established inclusion criteria were invited to participate in the study and received a free and informed consent term.

2.4. Procedures

The adolescents were evaluated in their own schools by a team of properly trained nutritionists and supervised by three experts in the field of anthropometric assessments. Data collection was carried out annually over a period of three years. Structured forms were used, and anthropometric information (weight, height, and waist, hip, neck, arm, and thigh circumferences) and sexual maturation were obtained.

2.5. Anthropometric assessment

Weight was measured on a portable electronic scale from Seca®, with a capacity of 150kg. Height was measured using a Seca® stadiometer, fixed at 90º in relation to the floor, on a wall without baseboard. BMI (weight [kg] / height [m^2] was calculated from weight and height data and nutritional status from parameters established by WHO (de Onis *et al*, 2007), considering the following BMI Z-scores for age: <-3: severe thinness; ≥-3 and <-2: thinness; ≥ + 2 and ≤ + 1: normal; ≥ + 1 and ≤ + 2: overweight; ≥ + 2 and ≤ + 3: obesity; > +3: severe obesity.

WC was obtained at the midpoint between the last costal arch and the iliac crest without compressing the tissues. HC was measured in the largest apparent circumference of the gluteal region. All circumference measurements were performed using a flexible and inelastic measuring tape from Seca. The measurements of weight, height, WC and HC followed the procedures recommended by Lohman *et al* (1988) From WC and HC information, the WHR (waist circumference (cm) / hip circumference (cm)) was calculated, and WHtR was also calculated from the ratio between waist circumference (cm) / height (cm) (Harries *et al*, 1984). NC was obtained according to the criteria established by Ben-Noun & Laor (2003) and AC was obtained using the assessment technique proposed by Frisancho (1974). Thigh circumference (TC) was obtained in an orthostatic position, with the legs slightly apart; the tape was placed at the level of the meso-femoral point, midpoint between the inguinal crease and the upper edge of the patella, in a horizontal plane.

The assessment of sexual maturation was performed using the self-assessment technique proposed by Tanner (1962), B1 and G1 adolescents were considered prepubertal, B2 to B4 and G2 to G4 pubertal, and B5 and G5 post-pubertal. In this way, each participant was taken to an isolated location in the room, where the researcher explained the importance of assessing sexual maturation and presented the clipboards with pictures of breasts/genitalia and pubic hair, being adapted by Matsudo & Matsudo (1994) for the adolescent population and used by several authors (Elias *et al*, 2019; Piola *et al*, 2019; Santos *et al*, 2019; Abou El Ella *et al*, 2020).This procedure was carried out very carefully and judiciously, so as not to cause embarrassment for the student or cause discomfort due to the fact that the adolescent does not feel comfortable and runs the risk of identifying a maturation stage indiscriminately. It was decided to use the development of organs for both sexes, since pubic hairiness on its own can be influenced by ethnic characteristics.

CI was determined by measuring weight, height, and WC according to the following mathematical equation:

$$Conicity\ Index = \frac{Waist\ circumference\ (m)}{0.109\ \sqrt{\frac{Body\ weight\ (kg)}{Height\ (m)}}}$$

The value 0.109 is the constant that results from the root of the ratio between 4π (from the deduction of the perimeter of the circle of a cylinder) and the average density of a human body of 1,050kg/m³.Its main concept is that those individuals with less accumulation of fat in the central region would have a body shape similar to that of a cylinder and those with greater accumulation would resemble a double cone, having a common base, arranged one on top of the other (Valdez, 1991).CI has also been used in several studies and that is why it was used in the present study (Neta *et al*, 2017; Wu *et al*, 2018; Cassiano *et al*, 2019; Filgueiras *et al*, 2019).

2.6. Data analysis

For the initial characteristics, the mean and standard deviations (SD) of the continuous variables and the absolute and relative frequencies of the categorical variables were calculated. All variables were subjected to the Kolmogorov-Smirnov test to verify the normal distribution of data. A descriptive analysis of the anthropometric parameters of the participants was performed with data from the 3 measurements, using the Independent Samples t Test (two-tailed) for continuous variables or the Chi-square test for categorical variables.

Pearson's correlation coefficient was used to assess the correlation between CI, WHtR and WHR and the means of the other anthropometric variables, according to sex.

The performance of the study variables to identify the presence of excess weight/obesity according to sex, in the three measurements, was determined using ROC curves.[30] Performance was considered satisfactory when the area under the ROC curve was greater than 0.70.In addition, the sensitivity and specificity of the cutoff points of the study variables were calculated using the highest Youden Index.

The statistical software SPSS 23.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyzes, and the level of significance was set at $\alpha < 0.05$.

2.7. Ethical Considerations

This study followed the ethical principles for research involving human beings, according to resolution number 466/12 of the Brazilian National Health Council and was approved by the ethics committee of the Post-Graduation and Research Council at the *Universidade Federal de São Paulo*, under protocol number 080309. Consent was obtained from the participants and their legal guardians with the signing of the assent term and the free and informed consent term, respectively.

3. Results

The sample consisted of 557 adolescents, 256 of whom were male (45.96%) and 301 were female (54.04%). All variables had a normal distribution (data not shown). The mean age of the participants was 12.03 ± 1.11 years at the 1st measurement, 13.05 ± 1.12 at the 2nd and 13.84 ± 1.14 at the 3rd. Female participants presented statistically higher mean BMI values for BMI in the 3 measurements, $p = .38$, .34, and .13, respectively; as well as the highest percentage of body fat, $p < .0001$.

For the anthropometric variables, a greater mean WC was observed in female adolescents in the 3 measurements (84.39 ± 13.15 *vs.* 81.11 ± 10.34 cm, $p < .0001$; 86, 90 ± 12.31 *vs.* 83.79 ± 11.50 cm, $p = .002$; 90.19 ± 10.45 *vs.* 86.41 ± 11.32 cm, $p < .0001$, respectively) and the mean value of TC ($p < .0001$); for male adolescents, there was a significantly greater difference for mean NC in the 3 measurements, $p < .0001$.

During the study period, there was an evolution of pubertal staging, in the first measurement 13.29% of the adolescents were in the prepubertal stage, 80.79% pubescent and 5.92% post-pubertal; in the 3rd measurement only 4 (0.72%) of the participants were in the prepubertal stage (Table 1).

For the CI, a significant correlation was found among all participants for weight ($p < .0001$), BMI ($p < .0001$), BW% ($p < .0001$), bone mass ($p = .017$), AC ($p < .0001$), WC ($p < .0001$), HC ($p < .0001$), NC ($p < .0001$), TC ($p < .0001$), WHtR ($p < .0001$), WHR ($p < .0001$) This significance was also observed in male adolescents, except for NC (Table 2).

Table 3 presents the analysis of the correlation between WHtR and the anthropometric variables according to sex. When considering the total sample, there was a significant correlation for all anthropometric variables, except muscle mass; this correlation remained significant in the analyses according to sex.

Table 1. Descriptive analysis of the participants' anthropometric variables, according to sex.

Variable		1st measurement				2nd measurement				3rd measurement			
		Total	Male	Female	p-value	Total	Male	Female	p-value	Total	Male	Female	p-value
Age (years)	$\bar{X}$	12.03	12.07	11.99	.37[a]	13.05	13.08	13.02	.50[a]	13.84	13.86	13.82	.64[a]
	SD	1.11	1.16	1.06		1.12	1.18	1.07		1.14	1.20	1.10	
Weight (kg)	$\bar{X}$	46.60	45.80	47.28	.17[a]	51.48	50.96	51.92	.38[a]	54.56	54.35	54.75	.72[a]
	SD	12.58	13.34	11.86		12.93	13.75	12.19		12.90	14.11	11.81	
Height (cm)	$\bar{X}$	152.02	151.77	152.22	.57[a]	156.74	157.47	156.12	.07[a]	160.13	161.50	158.97	<.0001[a]
	SD	9.26	10.61	7.93		8.61	10.48	6.57		8.14	9.86	6.10	
BMI (kg/m^2)	$\bar{X}$	19.95	19.55	20.30	**.038[a]**	20.78	20.35	21.16	**.034[a]**	21.22	20.72	21.64	**.013[a]**
	SD	4.22	3.98	4.39		4.46	4.46	4.43		4.32	4.25	4.34	
BF%	$\bar{X}$	15.63	9.76	20.60	**<.0001[a]**	18.88	13.56	23.19	**<.0001[a]**	19.97	14.12	24.91	**<.0001[a]**
	SD	11.65	10.66	10.05		10.46	11.15	7.48		14.74	10.44	16.01	
BW%	$\bar{X}$	50.03	47.10	52.51	**.004[a]**	55.87	56.92	55.02	.10[a]	57.17	59.13	55.52	**.001[a]**
	SD	22.41	28.40	15.26		13.41	18.93	5.91		12.60	16.45	7.67	
Bone mass	$\bar{X}$	38.42	39.14	37.81	.41[a]	20.03	24.71	16.25	**<.0001[a]**	30.24	33.98	27.07	**<.0001[a]**
	SD	18.93	24.72	12.04		24.43	23.56	24.51		20.17	23.09	16.72	
Muscle mass	$\bar{X}$	5.19	5.46	4.97	.36[a]	28.81	28.58	28.99	.81[a]	20.02	22.05	18.31	**.027[a]**
	SD	6.29	7.16	5.45		20.01	23.94	16.19		19.72	22.19	17.21	
Arm C. (cm)	$\bar{X}$	23.26	23.06	23.44	.27[a]	24.15	23.84	24.41	.14[a]	25.14	24.72	25.49	**.043[a]**
	SD	4.05	3.98	4.11		4.56	4.54	4.58		4.46	4.14	4.69	
Waist C. (cm)	$\bar{X}$	68.36	68.31	68.39	.94[a]	68.18	68.15	68.21	.95[a]	70.47	70.55	70.39	.86[a]
	SD	11.65	11.81	11.54		10.93	11.18	10.73		10.65	11.26	10.13	
Hip C. (cm)	$\bar{X}$	82.88	81.11	84.39	**<.0001[a]**	85.47	83.79	86.90	**.002[a]**	88.45	86.41	90.19	**<.0001[a]**
	SD	12.04	10.34	13.15		12.04	11.50	12.31		11.01	11.32	10.45	
Neck C. (cm)	$\bar{X}$	30.01	30.75	29.39	**<.0001[a]**	30.63	31.37	30.00	**<.0001[a]**	31.11	31.80	30.51	**<.0001[a]**
	SD	4.39	4.44	4.26		3.65	4.72	2.20		2.80	3.07	2.39	
Thigh C.(cm)	$\bar{X}$	43.84	42.46	45.01	**<.0001[a]**	44.81	42.95	46.39	**<.0001[a]**	45.55	43.47	47.32	**<.0001[a]**
	SD	7.32	6.01	8.11		6.85	6.47	6.77		7.04	6.46	7.05	
WHtR	$\bar{X}$	0.56	0.56	0.56	.37[a]	0.44	0.43	0.44	.47[a]	0.44	0.44	0.44	.27[a]
	SD	0.03	0.04	0.03		0.07	0.07	0.07		0.06	0.06	0.06	
WHR	$\bar{X}$	1.04	1.06	1.02	**.002[a]**	0.81	0.81	0.80	.35[a]	0.80	0.82	0.78	**<.0001[a]**
	SD	0.16	0.13	0.18		0.21	0.07	0.28		0.07	0.06	0.08	
Conicity index	$\bar{X}$	1.14	1.15	1.14	.19[a]	1.10	1.11	1.09	.07[a]	1.11	1.12	1.10	**.010[a]**
	SD	0.14	0.14	0.14		0.11	0.11	0.10		0.08	0.08	0.09	
Prepubertal (Tanner)	n	74	52	22		19	14	5		4	3	1	
	%	13.29	20.31	7.31		3.41	5.47	1.66		0.72	1.17	0.33	
Pubertal (Tanner)	n	450	201	249	**<.0001[b]**	475	236	239	**<.0001[b]**	453	235	218	**<.0001[b]**
	%	80.79	78.52	82.72		85.28	92.19	79.40		81.33	91.80	72.43	
Post-pubertal (Tanner)	n	33	3	30		63	6	57		100	18	82	
	%	5.92	1.17	9.97		11.31	2.34	18.94		17.95	7.03	27.24	

[a] Calculated using t-test for independent samples according to sex; [b] Calculated using chi-square test between prepubertal, pubertal and post-pubertal according to sex; SD = Standard deviation; BMI = Body mass index; BF% = Body fat percentage; BW% = Body water percentage; Arm C. = Arm circumference; Waist C. = Waist circumference; Hip C. = Hip circumference; Neck C. = Neck circumference; Hip C. = Hip circumference; WHtR = Waist-to-Height Ratio, WHR = Waist-to-Hip Ratio.

Table 2. Correlation between the conicity index and anthropometric variables according to sex.

Variable	Total		Male		Female	
	r	p-value[a]	r	p-value[a]	r	p-value[a]

Weight (kg)	0.172	**<.0001**	0.230	**<.0001**	0.121	**.035**
Height (cm)	-0.028	.50	-0.063	.31	0.001	.99
BMI (kg/m²)	0.212	**<.0001**	0.322	**<.0001**	0.144	**.012**
BF%	0.047	.27	0.137	**.033**	0.111	.06
BW%	-0.186	**<.0001**	-0.276	**<.0001**	-0.094	.10
Bone mass	-0.103	**.017**	-0.208	**.001**	-0.055	.34
Muscle mass	0.023	.59	0.019	.76	0.002	.97
Arm C. (cm)	0.218	**<.0001**	0.264	**<.0001**	0.196	**.001**
Waist C. (cm)	0.593	**<.0001**	0.627	**<.0001**	0.570	**<.0001**
Hip C. (cm)	0.261	**<.0001**	0.332	**<.0001**	0.244	**<.0001**
Neck C. (cm)	0.202	**<.0001**	0.122	.05	0.262	**<.0001**
Hip C. (cm)	0.188	**<.0001**	0.238	**<.0001**	0.215	**<.0001**
WHtR	0.589	**<.0001**	0.677	**<.0001**	0.523	**<.0001**
WHR	0.214	**<.0001**	0.264	**<.0001**	0.198	**.001**

[a] Calculated using Pearson correlation according to mean of the 3 measurements; BMI = Body mass index; BF% = Body fat percentage; BW% = Body water percentage; Arm C. = Arm circumference; Waist C. = Waist circumference; Hip C. = Hip circumference; Neck C. = Neck circumference; Hip C. = Hip circumference; WHtR = Waist-to-Height Ratio, WHR = Waist-to-Hip Ratio.

Table 3. Correlation between waist-to-height relationship and anthropometric variables according to sex.

Variable	**Total**		**Male**		**Female**	
	r	p-value[a]	R	p-value[a]	r	p-value[a]
Weight (kg)	0.460	**<.0001**	0.362	**<.0001**	0.558	**<.0001**
Height (cm)	-0.281	**<.0001**	-0.303	**<.0001**	-0.265	**<.0001**
BMI (kg/m²)	0.705	**<.0001**	0.657	**<.0001**	0.746	**<.0001**
BF%	0.381	**<.0001**	0.339	**<.0001**	0.505	**<.0001**
BW%	-0.393	**<.0001**	-0.299	**<.0001**	-0.542	**<.0001**
Bone mass	-0.155	**<.0001**	-0.133	**.039**	-0.195	**.001**
Muscle mass	-0.068	.12	-0.061	.35	-0.075	.20
Arm C. (cm)	0.532	**<.0001**	0.506	**<.0001**	0.553	**<.0001**
Waist C. (cm)	0.638	**<.0001**	0.636	**<.0001**	0.644	**<.0001**
Hip C. (cm)	0.456	**<.0001**	0.456	**<.0001**	0.460	**<.0001**
Neck C. (cm)	0.260	**<.0001**	0.205	**.001**	0.362	**<.0001**
Thigh C. (cm)	0.471	**<.0001**	0.438	**<.0001**	0.512	**<.0001**
Conicity index	0.589	**<.0001**	0.677	**<.0001**	0.523	**<.0001**
WHR	0.180	**<.0001**	0.248	**<.0001**	0.174	**.003**

[a] Calculated using Pearson correlation according to mean of the 3 measurements; BMI = Body mass index; BF% = Body fat percentage; BW% = Body water percentage; Arm C. = Arm circumference; Waist C. = Waist circumference; Hip C. = Hip circumference; Neck C. = Neck circumference; Hip C. = Hip circumference; WHR = Waist-to-Hip Ratio.

In the same manner, in the analysis of correlation between WHR and the anthropometric variables according to sex. All correlations were significant except BMI (females, p = .07), BW% (all participants and females, p = .52 and .54), bone mass (all participants and females, p = .72 and .72), muscle mass (all participants, males, and females, p = .43, .06, and .58), WC (females, p = .10), and NC (females, p = .23) (Table 4).

Table 4. Correlation between waist-to-hip ratio and anthropometric variables according to sex.

Variable	Total		Male		Female	
	r	p-value[a]	r	p-value[a]	r	Valor-p[a]
Weight (kg)	-0.281	**<.0001**	-0.583	**<.0001**	-0.165	**.004**
Height (cm)	-0.314	**<.0001**	-0.642	**<.0001**	-0.214	**<.0001**
BMI (kg/m²)	-0.186	**<.0001**	-0.370	**<.0001**	-0.106	.07
BF%	-0.230	**<.0001**	-0.376	**<.0001**	-0.122	**.036**
BW%	-0.028	.52	-0.176	**.006**	0.036	.54
Bone mass	-0.015	.72	-0.217	**.001**	0.021	.72
Muscle mass	0.034	.43	0.122	.06	-0.032	.58
Arm C. (cm)	-0.255	**<.0001**	-0.489	**<.0001**	-0.164	**.005**
Waist C. (cm)	-0.154	**<.0001**	-0.301	**<.0001**	-0.097	.10
Hip C. (cm)	-0.433	**<.0001**	-0.650	**<.0001**	-0.349	**<.0001**
Neck C. (cm)	-0.153	**<.0001**	-0.474	**<.0001**	-0.070	.23
Thigh C. (cm)	-0.306	**<.0001**	-0.533	**<.0001**	-0.193	**.001**
Conicity index	0.214	**<.0001**	0.264	**<.0001**	0.198	**.001**
WHtR	0.180	**<.0001**	0.248	**<.0001**	0.174	**.003**

[a] Calculated using Pearson correlation according to mean of the 3 measurements; BMI = Body mass index; BF% = Body fat percentage; BW% = Body water percentage; Arm C. = Arm circumference; Waist C. = Waist circumference; Hip C. = Hip circumference; Neck C. = Neck circumference; Hip C. = Hip circumference; WHtR = Waist-to-Height Ratio.

In the performance analysis of the CI, WHtR and WHR as predictors of excess weight/obesity, only WHtR showed satisfactory performance (area under the ROC curve > 0.70) in the 2nd and 3rd measurements (p < .0001) with the following cutoff points: WHtR = 0.44 (sensitivity = 73.7%, specificity = 12.2%) in the second measurement; and WHtR = 0.45 (sensitivity = 81.1%, specificity = 12.4%) in the third measurement. In addition, the CI obtained satisfactory predictive power only in the third measurement for male participants with a cutoff point of CI = 1.14 (sensitivity = 56.5%; specificity = 16.4%) (Table 5).

Table 5. Performance of the conicity index, waist-to-height ratio, and waist-to-hip ratio for the identification of excess weight and obesity, according to sex, in the three measurements.

Variable			**Area under the ROC curve**	**p-value**	**95% CI**	**Cutoff value†**	**Sens. (%)**	**Spec. (%)**
1st measurement	CI	Total	0.633	**<.0001**	0.583, 0.684	1.1650	0.518	0.288
		Male	0.695	**<.0001**	0.623, 0.767	1.1850	0.438	0.108
		Female	0.585	**.016**	0.516, 0.654	1.1650	0.510	0.356
	WHtR	Total	0.439	**.018**	0.390, 0.489	0.5034	0.964	0.956
		Male	0.399	**.008**	0.329, 0.470	0.4917	0.978	0.964
		Female	0.473	.44	0.404, 0.542	0.5921	0.144	0.113
	WHR	Total	0.125	**<.0001**	0.095, 0.155	1.5362	0.010	0.006
		Male	0.121	**<.0001**	0.078, 0.163	1.5304	0.011	0.000
		Female	0.111	**<.0001**	0.073, 0.149	1.6469	0.010	0.010
2nd measurement	CI	Total	0.618	**<.0001**	0.566, 0.669	1.1550	0.361	0.157
		Male	0.622	**.001**	0.545, 0.699	1.1650	0.375	0.137
		Female	0.619	**.001**	0.551, 0.687	1.1150	0.509	0.289
	WHtR	Total	**0.872***	**<.0001**	0.839, 0.905	0.4428	0.737	0.122
		Male	**0.865***	**<.0001**	0.815, 0.916	0.4452	0.693	0.095
		Female	**0.878***	**<.0001**	0.835, 0.920	0.4441	0.764	0.129
	WHR	Total	0.608	**<.0001**	0.557, 0.660	0.8531	0.320	0.116
		Male	0.611	**.004**	0.533, 0.688	0.8621	0.375	0.101
		Female	0.615	**.001**	0.545, 0.685	0.8075	0.453	0.216
3rd measurement	CI	Total	0.676	**<.0001**	0.626, 0.726	1.1350	0.519	0.210
		Male	**0.712***	**<.0001**	0.640, 0.785	1.1450	0.565	0.164
		Female	0.651	**<.0001**	0.583, 0.719	0.1350	0.470	0.215
	WHtR	Total	**0.921***	**<.0001**	0.897, 0.944	0.4460	0.811	0.124
		Male	**0.943***	**<.0001**	0.916, 0.969	0.4359	0.882	0.135
		Female	**0.905***	**<.0001**	0.869, 0.941	0.4490	0.800	0.130
	WHR	Total	0.678	**<.0001**	0.628, 0.727	0.8404	0.422	0.116
		Male	0.690	**<.0001**	0.617, 0.764	0.8404	0.529	0.164
		Female	0.676	**<.0001**	0.607, 0.745	0.7864	0.620	0.325

* Satisfactory level of performance when presenting an area under the ROC curve >0.70; † According to the highest value of the Youden index; ROC Curve = Receiver Operating Characteristic Curve; 95% CI 95% confidence interval; Sens. = Sensibility; Spec. = Specificity; CI conicity index; WHtR = Waist-to-Height Ratio, WHR = Waist-to-Hip Ratio.

Table 6 shows the performance of AC, WC, HC, NC, and TC as predictors of excess weight/obesity using ROC curves. All variables analyzed showed satisfactory performance in the 3 measurements (area under the ROC curve > 0.70), for all participants and for the subgroups of male and female participants ($p < .0001$).

Table 6. Performance of the study variables for the identification of excess weight and obesity, according to sex, in the three measurements.

Variables			**Area under the ROC curve**	**p-value**	**95% CI**	**Cutoff value†**	**Sens. (%)**	**Spec. (%)**
su re	Arm C. (cm)	Total	**0.924***	**<.0001**	0.901, 0.947	23.65	0.888	0.169

		Male	**0.934***	**<.0001**	0.905, 0.962	23.65	0.876	0.144
		Female	**0.918***	**<.0001**	0.883, 0.953	23.45	0.925	0.216
	Waist C. (cm)	Total	**0.890***	**<.0001**	0.860, 0.919	68.85	0.852	0.224
		Male	**0.920***	**<.0001**	0.888, 0.952	68.10	0.865	0.186
		Female	**0.869***	**<.0001**	0.823, 0.915	69.85	0.822	0.206
	Hip C. (cm)	Total	**0.866***	**<.0001**	0.835, 0.898	85.55	0.770	0.186
		Male	**0.879***	**<.0001**	0.837, 0.922	82.35	0.843	0.222
		Female	**0.873***	**<.0001**	0.829, 0.917	88.15	0.766	0.144
	Neck C. (cm)	Total	**0.796***	**<.0001**	0.758, 0.834	29.55	0.827	0.357
		Male	**0.789***	**<.0001**	0.734, 0.843	29.65	0.876	0.431
		Female	**0.810***	**<.0001**	0.758, 0.862	29.35	0.832	0.330
	Thigh C. (cm)	Total	**0.842***	**<.0001**	0.807, 0.877	44.40	0.801	0.247
		Male	**0.848***	**<.0001**	0.800, 0.897	42.65	0.831	0.246
		Female	**0.853***	**<.0001**	0.806, 0.900	46.75	0.776	0.175
2nd measurement	Arm C. (cm)	Total	**0.897***	**<.0001**	0.871, 0.924	24.60	0.8360	0.196
		Male	**0.889***	**<.0001**	0.848, 0.931	23.70	0.920	0.280
		Female	**0.904***	**<.0001**	0.870, 0.938	24.60	0.860	0.191
	Waist C. (cm)	Total	**0.874***	**<.0001**	0.842, 0.906	69.75	0.754	0.144
		Male	**0.877***	**<.0001**	0.831, 0.924	70.65	0.716	0.107
		Female	**0.871***	**<.0001**	0.827, 0.915	69.25	0.766	0.144
	Hip C. (cm)	Total	**0.853***	**<.0001**	0.819, 0.886	88.65	0.733	0.174
		Male	**0.853***	**<.0001**	0.805, 0.902	84.50	0.807	0.250
		Female	**0.866***	**<.0001**	0.822, 0.910	88.65	0.822	0.211
	Neck C. (cm)	Total	**0.782***	**<.0001**	0.744, 0.820	29.30	0.928	0.508
		Male	**0.751***	**<.0001**	0.690, 0.811	29.60	0.920	0.560
		Female	**0.825***	**<.0001**	0.778, 0.872	30.25	0.710	0.227
	Thigh C. (cm)	Total	**0.854***	**<.0001**	0.821, 0.888	45.40	0.805	0.232
		Male	**0.855***	**<.0001**	0.806, 0.903	45.25	0.682	0.125
		Female	**0.874***	**<.0001**	0.832, 0.916	46.75	0.832	0.227
3rd measurement	Arm C. (cm)	Total	**0.933***	**<.0001**	0.912, 0.953	25.80	0.903	0.164
		Male	**0.931***	**<.0001**	0.902, 0.960	24.70	0.965	0.234
		Female	**0.936***	**<.0001**	0.907, 0.966	25.75	0.931	0.175
	Waist C. (cm)	Total	**0.920***	**<.0001**	0.897, 0.944	71.15	0.839	0.148
		Male	**0.937***	**<.0001**	0.908, 0.966	70.80	0.894	0.146
		Female	**0.905***	**<.0001**	0.869, 0.941	72.25	0.772	0.115
	Hip C. (cm)	Total	**0.882***	**<.0001**	0.852, 0.912	89.85	0.833	0.205
		Male	**0.886***	**<.0001**	0.846, 0.925	88.15	0.894	0.146
		Female	**0.896***	**<.0001**	0.856, 0.936	92.25	0.812	0.135
	Neck C. (cm)	Total	**0.816***	**<.0001**	0.780, 0.853	30.35	0.887	0.388
		Male	**0.799***	**<.0001**	0.742, 0.856	33.35	0.553	0.117
		Female	**0.853***	**<.0001**	0.806, 0.900	30.35	0.871	0.255
	Thigh C. (cm)	Total	**0.866***	**<.0001**	0.834, 0.898	45.10	0.844	0.256
		Male	**0.860***	**<.0001**	0.814, 0906	44.75	0.776	0.199
		Female	**0.902***	**<.0001**	0.866, 0.938	49.10	0.782	0.105

* Satisfactory level of performance when presenting an area under the ROC curve >0.70; † According to the highest value of the Youden index; ROC Curve = Receiver Operating Characteristic Curve; 95% CI 95% confidence interval; Sens. = Sensibility; Spec. = Specificity; Arm C. = Arm circumference; Waist C. = Waist circumference; Hip C. = Hip circumference; Neck C. = Neck circumference; Thigh C. = Thigh circumference.

4. Discussion

It is extremely important to evaluate anthropometric indices to predict the onset of excess weight/obesity in adolescents. This study sought to assess the performance of CI with other anthropometric indicators and establish the cutoff point for the diagnosis of this condition. In the comparison between WHR, CI and WHtR for abdominal adiposity, the best areas under the ROC curves were found for WHtR. There was a significant correlation for all anthropometric variables, except muscle mass, in the complete sample and stratified according to sex, with the following cutoff values: WHtR 0.4428 (sensitivity = 0.737, specificity = 0.122) in the 2^{nd} measurement, and 0.4460 (sensitivity = 0.811, specificity = 0.124) in the 3^{rd} measurement. The CI only proved effective in the 3rd measurement for male participants with a cutoff point of 1.1450 (sensitivity = 0.565, specificity = 0.164).

Furthermore, all the anthropometric variables, used in this study, demonstrated satisfactory performance for the prediction of excess weight/obesity in the 3 measurements (area under the ROC curve > 0.70), for all participants and stratified according to sex ($p < .0001$). CI is considered a good indicator of abdominal obesity and more recently it has been related to metabolic and cardiovascular risk factors in children, young people and adults (Carneiro *et al*, 2014; Neta *et al*, 2017; Wu *et al*, 2018; Cassiano *et al*, 2019; Filgueiras *et al*, 2019). Although CI is frequently used as a promising indicator of cardiovascular risk, in the present study its performance as a predictor of excess weight/obesity was evaluated compared to other anthropometric indicators already established in the diagnosis of these conditions.

The analysis of sensitivity and specificity based on the construction of ROC curves has been recommended in epidemiological studies to obtain cutoff points (Erdreich & Lee,1981; Van der Schouw *et al*, 1992; Schäfer, 1994; Tripepi *et al*, 2009) which can be useful both in clinical practice and in studies of population diagnosis. This type of analysis allows not only the identification of the best cutoff point, but also provides the area under the curve that translates the predictive power of an indicator for the outcome of interest.

In the present study, among the anthropometric indicators that are most directly related to abdominal obesity (WHtR, WHR and CI), WHtR showed the greatest predictive capacity for excess weight/obesity. In a recent study carried out with 1,035 Brazilian adolescents in order to identify the predictive power of anthropometric indicators to discriminate the presence of metabolic syndrome, the WHtR was also the indicator that was presented as the best predictor for the studied outcome (Oliveira & Guedes, 2018). Previous studies have already indicated that the WHtR has a strong association with several cardiovascular risk factors (Pitanga & Lessa, 2006).

In addition, several studies have shown that WHtR is also a better indicator for the health of children and adolescents than other anthropometric indicators; and the cut-off point of 0.5, which has been proposed, is close to that recommended for adults(McCarthy & Ashwell, 2006; Weili *et al*, 2007). Considering that the aging process implies changes in body composition and can change the cutoff points for other anthropometric measures, the use of the WHtR can be advantageous because this indicator has a direct regulation with growth and WC. Another aspect to be considered is its ease of use, requiring only a measuring tape and the calculation is performed from a simple division between the measurements of waist and height.

In the present study, the CI was satisfactory to predict overweight and obesity only among male adolescents, while the WHR showed values considered unsatisfactory under the ROC curve, showing that it is not a good discriminator. The use of CI in population studies as a predictor of several diseases, such as cardiovascular risk, changes in lipid profile, metabolic syndrome or obesity, is more limited due to the difficulty in calculating the denominator of the proposed equation for its determination (Pitanga & Lessa, 2004). In addition, as it is a relatively recent anthropometric indicator, there are still few studies that used CI, but some studies have already proposed specific cutoff points for different outcomes among adolescent populations (Beck *et al*, 2011; Neta *et al*, 2017; Wu *et al*, 2018; Cassiano *et al*, 2019; Filgueiras *et al*, 2019).

On the other hand, all other anthropometric indicators evaluated in this study were considered good predictors for overweight and obesity in both sexes, with values under the ROC curve above 0.80.Such findings are positive, in view of the speed and ease of obtaining these measures, in addition to their low cost, evidencing their usefulness in clinical practice or in population studies for the screening and diagnosis of excess weight/obesity in adolescents.

Conducting this study in several regions of São Paulo was one of the main limitations of this study (a metropolis with high demographic density, and innumerous transportation difficulties). Also, this study was conducted at public schools, where the school schedules suffered frequent alterations, together with high levels of absenteeism of students and teachers. In view of this, all efforts were made by researchers to collect data from the participants of the study, which often resulted in repeated journeys to the schools on different dates. Despite the limitations mentioned, the results of this study are able to contribute to clinical practice, since anthropometric and central obesity rates may become simpler, less costly and therefore more accessible tools for health professionals to indirectly assess their patients' long-term health risks related to excess weight/obesity. Furthermore, the results of this study may assist in reaching the goal of one of the sustainable development objectives proposed by the World Health Organization to reduce premature mortality from non-communicable diseases in one third by the year 2030 (World Health Organization, 2013).

From the results found in the present study, simple anthropometric indicators were the most effective in the prediction of excess weight/obesity, which allows, through simple measures, the screening of this condition and planning for early intervention. Considering, the anthropometric indicators most directly related to abdominal adiposity (CI, WHR and WHtR), the best areas under the ROC curves were found for WHtR in the prediction of excess weight/obesity. This study presents cutoff values that are predicative of excess weight/obesity, enabling professionals to identify adolescents at high risk of a higher body fat build-up with simple, low-cost instruments.

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