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PERFORMANCE OF MELÃO JUNIOR FORMULA TO IDENTIFY OF HIGH BODY FAT IN ADOLESCENTS

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ABSTRACT

Background: Is there a lack of data on the predictive capacity of the formula proposed by Melão Juniorin the diagnosis of excess body fat in Brazilian adolescents. **Aim:** To evaluate the performance of the formula proposed by Melão Juniorin the prediction of high body fat in adolescents. **Subjects and methods**: This is a cross-sectional study with a sample of 507 students, aged 10–19 years, from public schools. The following indicators were assessed: weight, height, body mass index, Melão Junior's formula, waist circumference, conicity index, and the waist-to-height ratio; percentage: body fat, lean body mass and water. The software SPSS® was used for database and statistical analysis. **Results:** Melão Junior's formula displayed the largest areas under the ROC curve in the prediction of excess body fat. Cut-off points of excess body fat for women and men, respectively, were Melão Junior's formula 18.15 and 17.35 , BMI 17.54 $kg \cdot m^2$ and 17.29 $kg \cdot m^2$, WC 58.50 cm and 60.5 cm, C-index 1.00 and 1.03, and WHtR 0.37 for both genders. **Conclusion:** Even though Melão Junior's formula presents the highest prognostic power in relation to the body mass index formula, it is highlighted the need to adjust in the Melão formula or to build a new calculation that takes into consideration factors like gender, level of physical activity and ethnicity, for example.

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INTRODUCTION

Overweight and obesity are characterized by an increased body fat mass resulting from an imbalance between food intake and energy expenditure (Escobar-Cardozo 2016). Obesity is a major health issue for children and adolescents in developed and developing countries. A child or adolescent who is obese has an increased risk of obesity in adult life (Gasser 2016). Many lifestyle factors, including diet and physical activity, contribute to obesity (Gasser 2016).

In Brazil, from 1974/5 to 2002/3 there was an overall increase in mean body mass index (BMI) and prevalence of overweight and obesity among adolescents (Conde 2016). The latest data show that 20.5% of Brazilian adolescents aged 10–19 years are overweight (IBGE 2010). One of the most used methods in the evaluation of body composition is anthropometry because of its good reproducibility, simplicity, low cost, and possibility to be applied to a large number of individuals (Pelegrini 2015; Frignani2015).BMI is the most commonly used measure for defining overweight and general obesity in clinical practice and population surveys (Zhang 2016; Wickel2014). The Quetelet Index, expressed as body weight in kilograms divided by the square of their height in meters, was first described nearly two centuries ago and later popularized in 1974 by Ancel Keys as BMI on the issue of obesity (Wang 2014). BMI is the main standard measure used to estimate fatness in individuals and populations (Conde 2016; Frignani2015). When used indiscriminately, it can lead to false results, as it is still a controversial measure, in addition to the fact that it is particularly difficult to determine body fat in children and adolescents (Frignani2015; Wang 2014; Duggan 2010; McCarthy 2006). Recently, authors such as Trefethen (2016) and Melão Junior (2009) proposed a modified BMI to reflect that the growth of our body is not only two-dimensional (Wang2014). Melão Junior (2009) proposed a new formula to calculate body mass index based on concepts of Structural Engineering and Fractal Geometry which, according to the author, will produce more reliable diagnoses than any other formula used to date. Thus, this study aimed to evaluate the performance of the formula proposed by Melão Junior (2009) in the prediction of high body fat in adolescents in São Luís (Maranhão State, Northeastern Brazil).

METHODS

Subjects: This cross-sectional research was conducted from 2012 to 2016. The sample size was determined by proportion(Lwanga and Lemeshow 1991) based on a prevalence of overweight in adolescents of 20.5% (IBGE, 2010), a suggested outcome prevalence of 26.9% (Farias et al., 2012), tolerable error rate of 5% (type I error), and power of the test of 85% (type II error), reaching 427 individuals with an additional 10% for possible losses or refusals, which resulted in a sample of 470 adolescents. The sample was obtained from a school population of 16 schools of the municipal, state, and federal education systems, in the city of São Luís, located in the state of Maranhão, northeastern Brazil. The schools were randomly chosen and the final sample consisted of 507 adolescents aged 10–19 years. The following exclusion criteria were used: pregnant or nursing adolescents, those using contraceptive pills or who had not reached menarche, and those with a physical disability that prevented or hindered measurements. This study was approved by the Human Research Ethics Committee of the University Hospital of the Federal University of Maranhão (*Hospital Universitário da Universidade Federal do Maranhão – HUUFMA*), protocol number 251/11.

Measurements

Anthropometric index: The measurement of all variables was performed by trained staff using calibrated equipment. Anthropometric measurements including weight, height, and waist measurements were obtained using standardized techniques by well-trained researchers (Lohman 1988). All measurements were performed in duplicate, with the mean being considered for data analysis. Weight was measured using a digital scale (Seca® 803, Hamburg, Germany) with a 0.1 kg resolution, height was measured using a portable vertical stadiometer (Seca® 213, Hamburg, Germany) with a 1 mm resolution, and waist circumference was measured using inextensible anthropometric tape with 0.1 cm resolution (Seca® 201, Hamburg, Germany) at the smallest horizontal girth between the costal margins and the iliac crest at minimal breathing. The Quetelet Index was calculated for each participant as a ratio of weight divided by height squared (kg/m^2). The formula proposed by Melão (2009) was calculated by the formula: [1.67 x body weight (kg)/Height $(m)^3$], and the waist-to-height ratio (WHtR) was calculated by the formula (Ashwell and Hsieh, 2005): [WC (cm)/height (cm)]. The conicity index (C-index) was determined by measuring weight, height, and WC, and applying the equation (Valdez 1991).

Body composition: For the body fat percentage that will be used as reference method in the ROC Curve analysis, a horizontal tetrapolar bioimpedance apparatus was used. According to Neves et al. (2015) this technique is preferred for application in population studies, since it meets the respective characteristics: non-invasive, portable, fast application and low cost, with minimal intra and inter researcher/observer variation. In addition, it displayed a high correlation coefficient when compared to the standard gold double X-ray Absorption (DEXA) (Neves 2015). The percentages of: body fat, lean body mass and water was estimated using a bioimpedance device quadruple model (Maltron®, BF-906, Cardiomed/Brazil) according to the protocols established in the user's manual. The cut-off points used for excess body fat classification were established by Lohman et al. (1986) where values above 20% for boys and 25% for girls classified adolescents with excess body fat; this method was also used as a reference in the ROC curve analysis.

Statistical Analysis: The SPSS® version 19.0 (Statistical Package for the Social Sciences, Chicago, IL, USA) was used for database and statistical analysis. The results were expressed as mean, median and standard deviation (mean or median ± SD). The normal distribution of the data was tested using the Kolmogorov-Smirnov test. The assessment of the means or median between the two groups (stratified by gender) was carried out with the Student's t-test for 2 independent samples, in the case of normally distributed variables, or Mann-Whitney U-test for 2 independent samples if variables were not normally distributed. The ROC curve analysis was performed to evaluate the diagnostic performance of BMI, Melão Junior's formula (MJF), WC, C-index, and WHtR in detecting body fat. The accuracy refers to the ability of BMI, MJF, WC, C-index, and WHtR to discriminate adolescents with excess body fat from those without excess body fat. Areas under the ROC curve and confidence intervals were determined. Sensitivity and specificity were considered for each gender to better determine the optimal critical values of anthropometric indicators with greater accuracy in the excess fat detection. The Pearson correlation coefficient was used to assess associations between the anthropometric indexes (BMI, MJF, WC, WHtR, and C-index) and body fat percentage. For all tests, statistical significance was established at p-value <0.05.

RESULTS

The sample consisted of 69% (n = 350) of female adolescents with median age 15.0 ± 2.14 years and 31% (n = 157) of males aged 15.0 ± 2.37 years. Mean values, medians and standard deviation of the anthropometric variables of the studied sample are described in Table 1. Female adolescents showed higher values in Melão'sformula ($p<0.001$), BMI ($p=0.001$), WHtR ($p<0.001$) and body fat percentage ($p<0.001$), and lower values of height ($p<0.001$), lean body mass percentage ($p<0.001$) and water percentage ($p<0.001$) in comparison to male adolescents.

Table 1. Anthropometric characteristics of boys and girls aged 10–19 years (n=507)

Variables	All (n=507)	Girls (n=350)	Boys (n=157)	p-value
Age (years) †[b]	14.9 ± 2.21	15.0 ± 2.14	15.00 ± 2.37	0.189
Body weight (kg) †[b]	55.5 ± 12.64	53.0 ± 11.43	56.0 ± 14.93	0.140
Height (m) †[b]	1.59 ± 0.09	1.57 ± 0.06	1.67 ± 0.12	<0.001
MJF†[b]	22.7 ± 4.34	22.7 ± 4.32	20.4 ± 4.02	<0.001
BMI (kg/m²)†[b]	21.6 ± 4.07	21.3 ± 4.06	20.2 ± 4.00	0.001
WC (cm) †[b]	70.4 ± 10.11	69.0 ± 10.29	69.0 ± 9.74	0.982
C-index†[b]	1.10 ± 0.08	1.09 ± 0.09	1.09 ± 0.08	0.624
WHtR†[b]	0.44 ± 0.06	0.43 ± 0.06	0.41 ± 0.05	<0.001
%BF*[a]	25.7 ± 9.36	28.37 ± 8.09	19.87 ± 9.36	<0.001
% LBM*[a]	73.80±10.25	71.01±8.93	80.02±10.29	<0.001
%Water*[a]	54.43±7.32	52.35±6.36	59.07±7.20	<0.001

Abbreviations:BMI – body mass index; MJF- Melão Junior´s Formula; WC – waist circumference; C-index – conicity index; WHtR – waist-to-height ratio; %BF – body fat percentage; %LBM – lean body mass percentage; %Water – Water percentage. *: Student's t-test for independent samples; † Mann –Whitney test; [a]Values are given as mean ± SD (standard deviation); [b]Values are given as median ± SD (standard deviation).

Table 2. Area under the ROC curve, sensitivity and specificity of cutoff points according to anthropometric indexes

Anthropometric index	ROC curve (CI 95%)	Cut-off point	Sensitivity % (CI 95%)	Specificity % (CI 95%)	p-valor
All					
MJF	0.87 (0.84-0.90)*	-	-	-	<0.001
BMI (kg/m²)	0.84 (0.80-0.88)*	-	-	-	<0.001
WC (cm)	0.80 (0.76-0.83)*	-	-	-	<0.001
C-index	0.69 (0.64-0.73)*	-	-	-	<0.001
WHtR	0.85 (0.81-0.88)*	-	-	-	<0.001
Boys					
MJF	0.84 (0.77-0.90)*	17.35	97.1	80.7	<0.001
BMI (kg/m²)	0.76 (0.68-0.84)*	17.29	94.1	80.7	<0.001
WC (cm)	0.75 (0.67-0.83)*	60.5	92.6	76.7	<0.001
C-index	0.76 (0.67-0.83)*	1.03	97.1	80.7	<0.001
WHtR	0.86 (0.80-0.92)*	0.37	97.1	80.7	<0.001
Girls					
MJF	0.87 (0.84-0.91)*	18.15	97.4	80.2	<0.001
BMI (kg/m²)	0.87 (0.84-0.91)*	17.54	95.2	79.3	<0.001
WC (cm)	0.83 (0.79-0.88)*	58.50	97.4	84.3	<0.001
C-index	0.67 (0.61-0.73)*	1.00	89.9	80.2	<0.001
WHtR	0.83 (0.79-0.88)*	0.37	95.6	80.2	<0.001

Abbreviations: CI95% – confidence interval; BMI – body mass index; MJF- Melão Junior´s Formula; WC – waist circumference; C-index – conicity index; WHtR – waist-to-height ratio. *: Area under the ROC curve demonstrating discriminatory power for body fat (lower limit of CI95%>0.50).

Table 3. Pearson correlation coefficients between anthropometric parameters and body fat percentage lean body mass percentage and water percentage

Variables	%BF	%LBM	%Water
All			
MJF	0.70**	-0.62**	-0.65**
IMC (kg/m³)	0.64**	-0.57**	-0.59**
WC (cm)	0.54**	-0.48**	-0.51**
C-index	0.32**	-0.26**	-0.31**
WHtR	0.64**	-0.56**	-0.60**
Girls			
MJF	0.71**	-0.61**	-0.62**
IMC (kg/m³)	0.71**	-0.62**	-0.62**
WC (cm)	0.64**	-0.54**	-0.57**
C-index	0.33**	-0.25**	-0.32**
WHtR	0.64**	-0.53**	-0.57**
Boys			
MJF	0.64**	-0.57**	-0.65**
IMC (kg/m³)	0.51*	-0.48**	-0.54**
WC (cm)	0.48**	-0.47**	-0.51**
C-index	0.42**	-0.39**	-0.41**
WHtR	0.66**	-0.60**	-0.67**

**p<0.001. Abbreviations: %BF – body fat percentage; MJF- Melão Junior´s formula; %LBM – lean body mass percentage; %Water – water percentage.

For the other anthropometric variables, no statistically significant differences were identified between the genders (p>0.05). All anthropometric indicators were able to predict the high body fat in the sample (Table 2), however, in the total sample, Melão Junior's formula presented the largest area under the ROC Curve (0.87; p<0.001). When stratified by gender, MJF and BMI presented the same value for the area under the ROC Curve (0.87, p <0.001) for female adolescents. In relation to the boys' MJF and WHtR also presented adjacent values for the area under the ROC Curve (0.84 and 0.86, p <0.001, respectively). The Pearson correlation coefficients between the anthropometric variables and body fat percentage, lean body mass percentage and water percentage are shown in Table 3. Melão Junior's Formula anthropometric indicator showed the highest correlation to body fat percentage, lean body mass percentage and water percentage (r=0.70; r= -0.62; r= -0.65, respectively) compared to the other indicators studied, such as waist circumference and C index. In relation to the female, Melão Junior'sFormula and BMI showed very close correlation (r = 0.71 and r = 0.72, respectively).

DISCUSSION

All indicators could predict the high body fat (area under the ROC curve>0.5) in the sample (Table 3). However, MJF presented the largest area under the ROC curve (ROC area = 0.87), in the analysis with the whole sample studied. Melão Junior's formula is supported by the experimental data, theoretical concepts of physics and mathematics(Biometry or Biophysics) (Melão Junior 2009), the inclusion of these concepts of physics and mathematics in the formula proposed by Melão Junior (2009) provided a significative improvement in the predictive power of high body fat when compared to BMI formula. Another important point is in the fact that BMI is the implicit assumption that the human body is a two-dimensional object, when in fact; the human body is a fractal structure with dimensions between 2 and 3 (Melão Junior 2009). Since the BMI formula proposes that the height is squared (h^2), it infers that humans have only two dimensions (Melão Junior 2009; Wang 2014). It is highlighted still that beyond the corporal dimension, other factors influence the overweight diagnosis in child-juvenile population, such as sexual maturation and gender. The results obtained in this study corroborate with these matters mainly regarding the question of the female gender, where it must be taken into consideration the hormonal differences.

When Melão Junior's formula was stratified by gender, it showed area under the ROC curve larger that 0.05 (p<0.001) proving to be a good indicator of high body fat. Furthermore, in women, its predictive power was equal to BMI's, this way it is supposed that an adjustment in the formula can improve predictive power in MJF since the "p" values (BMI=weight/height $^{\text{“p”}}$) in adults are generally lower in women than in men (Burton 2007). Regarding boys, Melão Junior's formula also showed area under the ROC curve larger that 0.05 (p<0.001). The WHtR had a predictive power similar to MJF; this fact can be partly explained since the WHtR considers that, for a given height, there is an acceptable amount of fat in the torso region (Ashwell 2005), along with the fact that body fat distribution differs between the sexes, given that men have relatively more central fat ('android' distribution), whereas women have relatively more peripheral fat ('gynoid'), a difference which is explained by sex hormone actions (Santos 2016), which may have caused the similar performance between Melão's formula and WHtR. Sexual maturation is characterized by physical and biological anterations, which occur during puberty. This period is marked by the development of secondary sexual characteristics, like the development of genitals in the male gender and of breasts in the female, as well as the appearance of pubic hair in both genders. The action of sexual hormones in this phase end up generating consequences like the accentuated gain of adiposity in females and of muscular mass in males (Ferrari 2015). None of the anthropometrical indicators evaluated feature specific mathematical calculations for the child-juvenile population that take into consideration gender or sexual maturation stage, the absence of these variables end up influencing the predictive power of these parameters applied to adolescents.

Knowing of the importance of sexual maturation and gender in body fat distribution (Santos 2016; Ferrari 2015) andtheir consequent influence in the diagnosis of overweight in adolescents, the present study highlights the importance of adjusting the existing formulas or designing a new mathematical calculation for the analysis and diagnosis of excessive body fat in adolescents, once it has been demonstrated that an adjustment only in the analysis of the corporal dimensions as proposed by Melão Junior (2009) already causes an improvement in the predictive power. With regards to the cut-off points, most studies (Taylor 2000; WHO 2006)propose cut-off points by percentiles for sex and age. However, studies such as the one carried out by Pelegrini(2015)conducted with 1,268 adolescents aged 15–17 years, enrolled in public schools (State and Federal) in the state of Santa Catarina, Brazil, suggested cut-off points associated with high body fat of BMI 22.7 and 20.1 kg/m^2, WHtR 0.43 and 0.41, WC 75.7 and 67.7 cm, and C-index 1.12 and 1.06, for boys and girls, respectively. These values are close to the ones proposed in this study, but they do not converge to the same point. This diversity related to the cut-off points can be partly explained by the ethnic diversity between the sample studied by Pelegrini(2015) and the one evaluated in our study. South America has been described as having a particular growth, development, and childhood body composition characteristics resulting from the intermingling of European, Native American, and African ancestors, so it is difficult to make a clear differentiation between environmental and genetic factors (Escobar-Cardozo 2016). In a survey conducted in 2008 (Ministry of Planning2008),the Brazilian Institute of Geography and Statistics found that 64.5% of people aged 15 years or older, from the state of Rio Grande do Sul (the only one representative in southern Brazil, in the research) have European descent. Whereas only 12.1% of people aged 15 years or older, from the State of Paraíba (the only state in north-eastern Brazil, in this research) have a European origin. Thus, it is noteworthy the need for further studies in the other federal units of Brazil, aiming to consolidate the validation of Melão Junior's formula as well as the cut-off points to be used in epidemiological and clinical studies.

The use of valid measures in the evaluation of body composition is essential both in epidemiological studies and in clinical practice, as a way to identify individuals at risk of developing diseases, as well as assisting in the treatment and prevention of obesity (Pereira 2015).Therefore, one of the strategies that allows the identification of the health and nutrition conditions of children and adolescents is the anthropometric evaluation that is one of the best health indicators (Souza 2013) being universally applicable, with good acceptance of the population and proposed by the World Health Organization (Frignani2015).In this context, Melão Junior's formula emerges as a low cost, harmless, reproducible, and high sensitivity/specificity method that can be used to screen/assess the nutritional status of adolescents. However, it's important to point out the need to adjust the formulas analyzed here for the use in child-juvenile population, once they don't take into consideration important parameters such as gender, sexual maturation and ethnicity.

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