Original Article

WAIST CIRCUMFERENCE AS AN INDICATOR OF BODY FAT AND METABOLIC DISORDERS IN ADOLESCENTS: A COMPARISON OF FOUR CRITERIA

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ABSTRACT

Objective. To evaluate the diagnostic validity of four waist circumference reference tables in female adolescents for detection of lipid abnormalities, hyperinsulinemia, high homeostasis model assessment (HOMA), hyperleptinemia, and high body adiposity.

Methods. We evaluated 113 adolescents aged between 14 and 19 years enrolled in public schools of Viçosa (state of Minas Gerais, Brazil). Total cholesterol, LDL, HDL, triglycerides, insulin and leptin levels were measured. We also measured the percentage of body fat using tetrapolar bioelectrical impedance. Based on the measure of the smallest abdominal diameter, we defined the waist circumference and calculated sensitivity, specificity, positive and negative predictive values. Contingency tables for the classification of waist circumference in adolescents were developed for four criteria: Freedman et al., 1999; Taylor et al., 2000; McCarthy et al., 2001; and Moreno et al., 2007.

Results. Sensitivity values were generally low in the reference studies evaluated, and the highest values were found in the reference table by McCarthy et al. On the other hand, specificity values were high, especially for the table by Freedman et al. Positive predictive values were more relevant for total cholesterol and body fat percentage.

Conclusion. The cutoff points for waist circumference provided by McCarthy et al. proved to be the most suitable for population studies. Because it has higher specificity, the proposal by Freedman et al. is useful for clinical use and can replace high cost tests, which are often unavailable for health professionals, such as those to measure leptin and insulin levels.

Key Words: Obesity. Adolescent. Waist circumference. Metabolic syndrome X. Diagnosis.

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Introduction

Obesity is defined as excessive body fat and not only overweight.[1] This disorder is increasingly prevalent and in developed countries it is the most frequent pediatric disease.[2] In Brazil, from 1974 to 1997, overweight increased from 4.1% to 13.9% in children and adolescents[3] and it is estimated that 50%-77% of this age group will also have this condition in adulthood.[2] Additionally, excessive weight in childhood and adolescence contributes to a higher incidence of morbidity and mortality from cardiovascular causes in adulthood.[4]

In adolescence, excess of body fat may be associated with several important metabolic disorders, such as dyslipidemia, hypertension, and hyperinsulinemia, which characterize the metabolic syndrome.[5] This association between obesity and metabolic syndrome is even stronger if there is abdominal or central adiposity.[6] This is alarming given that abdominal obesity has been increasing more than overall obesity (assessed by body mass index) among adolescents.[7,8] Recently, there has been an increase in the waist circumference of children and adolescents in the United Kingdom[7] and Spain.[8] In British children, increased waist was higher than BMI in the last 10-20 years, especially in girls.[7] In Zaragoza, Spain, waist circumference values showed an increasing trend in adolescents aged 13 to 14 years, from 1995 to 2000-2002, and this increase was

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independent from changes in BMI in both sexes and most ages.[8]

Waist circumference is considered an indicator of abdominal fat.[9] However, because of the lack of an international standardization of cutoff points for the classification of abdominal adiposity specific for children and adolescents, its use as a relevant instrument for public health guidelines has been limited. With regard to adolescents, it is necessary to use cutoff points of specific waist circumference according to sex and age; and these values vary because of the intense growth and development process typical of this phase.[10]

Some studies deserve to be highlighted in this area, including the study by Freedman et al. [11] that evaluated the relationship between waist circumference and serum lipid and insulin concentrations in 2,996 children and adolescents between 5 and 17 years old; these authors established the 90th percentile of waist circumference as an indicator of metabolic disorders. Taylor et al. [12] assessed the validity of waist circumference in 580 children and adolescents (3-19 years) and established the 80th percentile as cutoff point to identify high trunk fat mass. McCarthy et al.[13] assessed the waist circumference in 8,355 children and adolescents aged 5 to 17 years and defined the 85th and 95th percentiles to identify overweight and obesity, respectively. Moreno et al.[14] is a more recent criterion based on data from 2,160 adolescents aged 13 to 18 years, and it uses the 75th, 90th, and 95th percentiles of waist to classify abdominal fat. These authors used the same waist measuring methodology, which was the smallest abdominal circumference, and suggested that these data together with data from other countries could help create a single database and standardize the cutoff points worldwide.

The objective of the present study was to comparatively evaluate the sensitivity and specificity of the cutoff points of waist circumference from these four different criteria available in the literature in order to detect changes in total cholesterol, LDL, HDL, triglycerides, insulin, homeostasis model assessment (HOMA), leptin, and body fat.

Methods

We conducted a cross-sectional study with 113 female adolescents, aged between 14 and 19 years, enrolled in primary and secondary public schools of the municipality of Viçosa, state of Minas Gerais, Brazil. In terms of nutritional status, 78 (69%) participants had normal weight and 35 (31%) were overweight according to the World Health Organization.[15] Screenings were performed at the schools to check if the participants met the following criteria: menarche at least one year preceding the date of study, no chronic illness, no smoking, no use of drugs interfering with lipid and glucose metabolism, and not being pregnant. Those who met the inclusion criteria of the study were referred for outpatient care when anthropometric measurements were obtained along with biochemical test. All individuals who had dystrophy or nutritional disorder received dietary intervention and were followed up with the purpose of correcting these inadequacies.

Waist circumference was measured twice at the smallest circumference of the abdomen, with the participants undressed and at the end of a normal expiration, using a flexible and non-elastic measuring tape.[11-14,16] We used the mean value of both measurements. The assessment of body composition was performed using a tetrapolar bioelectrical impedance device (Biodynamics model 310) according to a specific protocol recommended for this type of evaluation.[17]

Participants were instructed to fast for 12 hours before blood sample collection, which was carried out at the clinical analysis laboratory of the Health Division of Universidade Federal de Viçosa. After blood collection, the samples were centrifuged (Centrifuge Excelsa model 206 BL) for 10 minutes at 3,500 rpm, allowing enough time for blood clotting. Total cholesterol, HDL, and triglycerides were measured using the enzymatic method automated by the equipment Cobas Mira Plus (Rocheâ and LDL was calculated using the Friedewald formula.[18] Glycemia was measured by the enzymatic glucose-oxidase method using the automation equipment Cobas Mira Plus (Rocheâ). Insulinemia was measured using the electrochemiluminescence method automated by the equipment Modular E (Rocheâ). Leptin concentration was measured using the radioimmunoassay method based on the double antibody/PEG technique, with readings by the gamma counter Wizard (Perkin Elmer).

For classification of dyslipidemia, we used the value above the desirable level for total cholesterol ³150 mg/dL, LDL $\geq$ 100 mg/dL, and triglycerides $\geq$ 100 mg/dL, whereas for HDL, we considered the value below the desirable level < 45mg.[19] Fasting plasma insulin $\geq$ 15 μ U/mL was considered hyperinsulinemia.[19] Insulin resistance was assessed using the homeostasis model assessment (HOMA = IR_{HOMA}), with HOMA $\geq$ 3.16 meaning presence of insulin resistance.[20] Leptin was measured by the radioimmunoassay method, with the reference value being 17 ng/mL (Kit LINCO Research). The cutoff point established for high percentage of body fat (%BF) was 28%. This value was set with the purpose of achieving greater accuracy for the classification of excess of body fat considering the proposal of > 25% for this definition.[21]

The present study was approved by the Research Ethics Committee of Universidade Federal de Viçosa. Participants voluntarily agreed to take part in the study after being informed verbally and through the written consent form, by which the authorization was obtained from adolescents and their parents and/or guardians.

Contingency tables were prepared to evaluate the predictive value of waist circumference as an indicator of body fat and metabolic disorders. In these tables, we compared the presence or absence of high waist circumference according to the cutoff points suggested by Freedman et al., Taylor et al., McCarthy et

Table 1 - Anthropometric and laboratory characteristics of the population studied

Variables	Mean (SD)	Median (min-max)
BMI (kg/m2)	22.8 (4.09)	22.03 (17.8-41.4)
%BF	28.7 (5.1)	29.7 (20.1-42.4)
Waist (cm)	71 (7.8)	69.6 (60.4-105.2)
Total cholesterol (mg/dL)	157.4 (29)	155 (97-287)
HDL (mg/dL)	49.6 (12.5)	49 (28-94)
LDL (mg/dL)	93.5 (24.8)	92.4 (46.6-195)
Triglycerides (mg/dL)	71.5 (29.3)	66 (24-219)
Glucose (mg/dL)	80.9 (7.5)	80 (45-104)
Insulin (mcU/mL)	11.9 (7.4)	10.6 (2.1-47.8)
HOMA	2.4 (1.7)	2.1 (0.4-12.3)
Leptin (ng/mL)	14.4 (15.4)	10.8 (2.2-120.2)

Abbreviations: Min: minimum; Max: maximum; BMI: body mass index; BF: body fat; HDL: high density lipoprotein; LDL: low density lipoprotein HOMA: homeostasis model assessment. Values expressed as mean (standard deviation) and median (minimum-maximum)

al., and Moreno et al. and the presence or absence of increased values of total cholesterol, LDL, HDL, triglycerides, insulin, HOMA, leptin, and body fat.

We calculated sensitivity, specificity, positive and negative predictive values of the four criteria to detect cardiovascular risk factors in the adolescents.

Results

Table 1 shows the anthropometric and laboratorial characteristics of the population investigated. The mean age of the participants was 15.8 years (standard deviation: 1.26). In terms of nutritional status, 78 (69%) participants had normal weight and 35 (31%) were overweight. Of the total, 84 (74.3%) showed lipid abnormalities; 61 (54%) had total cholesterol above the desirable value, 40 (35%) had high LDL, 18 (16%) had high triglycerides, 40 (35%) had low HDL, 25 (22.1%) had hyperinsulinemia, 23 (20%) had high HOMA, and 27 (23.9%) had hyperleptinemia.

The performance of the four reference criteria for the detection of dyslipidemia is shown in Table 2. The criterion suggested by McCarthy et al. showed the highest sensitivity levels, although the sensitivity values we found were low for all criteria used, while the specificity values were high, mainly for Freedman et al. and Moreno et al.

Total cholesterol showed the highest positive predictive value, followed by LDL in the proposal by Freedman et al. Triglyceride levels had the highest negative predictive values.

The number of false positive results was low, especially for Freedman et al. and Moreno et al., since false-negative results were high, except for HDL.

The remaining abnormalities are shown in Table 3. Sensitivity values were low for all four criteria and for all abnormalities investigated, except for the table suggested by McCarthy et al. for insulin and HOMA, which showed values close to 70%. Sensitivity values were always higher for the tables suggested by Taylor et al. and McCarthy et al., the latter showing the best performance for all lipid indicators.

Specificity values were high for all criteria, but those suggested by Freedman et al. and Moreno et al. showed the highest values. The specificity value suggested by Freedman et al. ranged from 95.3 to 100, while the one by Moreno et al. ranged from 91.9 to 100. The lowest specificity value was found for LDL.

The best positive predictive values were found for %BF for the four criteria, followed by insulin and HOMA for the criterion suggested by Freedman et al. On the other hand, negative predictive values were significant only for insulin, HOMA, and leptin.

False-positive results in general were low, being higher for McCarthy et al., except in terms of %BF, showing no differences between the cutoff points used, whereas false-negative results were very high.

Discussion

Among the four reference criteria of cutoff points for waist circumference assessed, the one suggested by McCarthy et al. showed the highest sensitivity, i.e., had fewer false-negative

Table 2 - Performance of waist circumference measures according to the cutoff points suggested by four different criteria for the detection of lipid abnormalities in female adolescents

	Total cholesterol				LDL				HDL				Triglycerides			
Criteria	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Sens.	10	16	28	15	12.5	20	27.5	17.5	10	18	35	18	6	17	39	17
Spec.	98	88	77	94	97.2	89	75.3	93.2	96	88	79	93	94	86	77	91
+ PV	86	63	59	75	71.4	50	37.9	58.3	57	44	48	58	14	19	24	25
- PV	48	47	59	75	66.3	67	65.5	67.3	66	66	69	67	84	85	87	85

Abbreviations: Sens. = sensitivity; Spec. = specificity; +PV = positive predictive value; - PV = negative predictive value. 1= Freedman et al. (1999); 2= Taylor et al. (2000); 3= McCarthy et al. (2001); 4=Moreno et al. (2007).

Table 3 - Performance of waist circumference measures according to the cutoff points suggested by four different criteria for the detection of hyperinsulinemia, high HOMA, hyperleptinemia, and body fat in female adolescents

Criteria	Insulin				HOMA				Leptin				%BF			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Sens.	20	44	68	40	22	48	74	43	11.1	25.9	51.8	18.5	8.2	21.6	39.7	16.4
Spec.	97.7	94.3	86.4	97.7	97	94	87	98	95.3	89.5	82.6	91.9	100	100	100	100
+ PV	71.4	68.7	58.6	83.3	71	69	59	83	42.9	43.8	48.3	41.7	100	100	100	100
- PV	89.6	85.6	90.5	85.2	83	88	93	87	77.4	79.4	84.5	78.2	37.4	41.2	47.6	39.6

Abbreviations: Sens. = sensitivity; Spec. = specificity; +PV = positive predictive value; - PV = negative predictive value; HOMA: homeostasis model assessment; %BF: percentage of body fat. 1= Freedman et al. (1999); 2= Taylor et al. (2000); 3= Mc Carthy et al. (2001); 4=Moreno et al. (2007).

results and greater ability to identify individuals who actually had the abnormalities investigated. Therefore, in terms of population studies, this criterion is more suitable for the classification of adolescents regarding excess of abdominal fat.

On the other hand, the four proposals showed high specificity, especially Freedman et al., which makes them more appropriate and useful for clinical/outpatient use, enabling for their use instead of more expensive measuring methods, such as tests to determine insulin and leptin concentrations, which may not be available to all health professionals. This measuring method is able to reduce expenses that are often unnecessary and enables a more cost-effective use of financial resources in the health sector.

In a study conducted by Almeida et al.,[22] the authors found sensitivity values from 24.6 to 80.7 for the criterion suggested by Taylor et al. and from 12 to 54.8 for Freedman et al.; and specificity values from 79.2 to 94.6 and from 91.9 to 99.6, respectively. Although this study investigated individuals of both sexes and from 7 to 18 years, specificity values were also higher than sensitivity values, which is in agreement with our study.

In the present study in general, positive predictive values were more significant for total cholesterol and body fat percentage, considering that the positive predictive value demonstrates the usefulness of a test and a high value means high probability of an individual with high waist circumference actually having a metabolic disorder; therefore, the simple measure of the waist circumference could be an indicator of an important dyslipidemia, as well as excess of body fat predictive of cardiovascular diseases.

The role of abdominal fat in the development of diseases has been increasingly recognized. Several studies with children and adolescents have demonstrated a significant association between cardiovascular risk factors and waist circumference.[23-29] Chronic diseases, including obesity and associated comorbidities (dyslipidemia, diabetes, hypertension, among others) have caused important harmful effects in the general population in physical, emotional, and economic terms. Thus, early identification of individuals at risk for these diseases would have great impact on the improvement of the current health situation worldwide.

Despite the relevant role of abdominal fat in the development of diseases, appropriate cutoff points have not been established so far for the adolescent group and such definition is complicated by the need to conduct large and expensive longitudinal studies because of the variation in the reference values of waist circumference from different countries (the percentiles of this measure are usually higher in U.S. adolescents) and use of several different locations for the measurement of this circumference, making it even more difficult to compare results at different locations and to develop a single database.

It is important to emphasize that adolescence is a particular phase of life characterized by intense transformations. Possibly the values that will be established to be able to correctly predict cardiovascular risk in this age group should be specific according to gender, age, and also ethnicity.[30]

Conclusion

Since adolescence is a critical period for the development of obesity, tending to be present also in adulthood and being associated with higher morbidity and mortality, it is extremely important to classify this group as to the risk of developing diseases because of the pattern of body fat distribution. We would like to emphasize the importance of waist circumference as a measure of great importance in the pediatric evaluation. The cutoff points of waist circumference by Freedman et al. proved to be the most suitable as indicators of biochemical changes within the outpatient context, whereas the proposal by McCarthy et al. is a predictor of excess of body fat in population studies.

Recommendations

Given the association of waist circumference with higher cardiovascular risk and the significant increase in the prevalence of obesity and metabolic syndrome in adolescents, the use of this measure in screenings and primary health care is useful for the early diagnosis and identification of those individuals at risk of developing such diseases in adulthood. Furthermore, the implementation of interventions in this age group is extremely important; such interventions should include promotion of physical activity and healthy eating, as well as drug therapy when necessary.

Further studies in this area, including other associated factors, should be conducted with Brazilian adolescents in order to better understand the usefulness of these criteria for the assessment and monitoring of our population in the early identification of the risk of developing cardiovascular diseases, and especial efforts should be made to establish specific cutoff points for this age group.

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