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Abdominal obesity in adolescents: Development of age-specific waist circumference cut-offs linked to adult IDF criteria

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Abstract

Objectives: The purpose of this study was to develop age- and sex-specific waist circumference (WC) cut-off points, linked to older adolescent and adult criteria for abdominal obesity, to be applied to children in the clinical setting.

Methods: A total of 16,788 adolescents aged 10 to 16 years were assessed for WC. Smoothed age and sex-specific WC curves were obtained using Cole's LMS method.

Results: Percentiles that corresponded to the International Diabetes Federation (IDF) recommendations used for older adolescents and adults (16+ years old) were the 97th percentile for boys and the 87th percentile for girls. Using these cutoffs, a total of 368 boys and 1138 girls were categorized as abdominally obese, in contrast to 1654 boys and 987 girls that were identified using the current IDF pediatric criteria (90th percentile).

Conclusions: We provide age- and sex-specific cut-off points that can be used to identify abdominal obesity in adolescents. The present findings provide a tool that can be used in the clinical setting for the early detection and prevention of adult obesity. Population-specific cutoffs may be required for pediatric ages to diagnose children at risk.

1 | INTRODUCTION

The prevalence of pediatric overweight and obesity has increased substantially over the past decades in both developed and developing countries (Ng et al., 2014; de Onis, Blosser, & Borghi, 2010). The risk of overweight and obese youth becoming overweight adults is at least twice as high as their regular-weight peers (Singh, Mulder, Twisk, Van Mechelen, & Chinapaw, 2008).

Body mass index (BMI) is a widely recognized surrogate of obesity that is routinely used to identify overweight and obese individuals in pediatric populations (Cole, Bellizzi, Flegal, & Dietz, 2000; de Onis et al., 2007). However, BMI does not provide information on body fat distribution (Brambilla et al., 2006) and thus waist circumference (WC) has been acknowledged as a better predictor of metabolic risk (Kahn, Imperatore, & Cheng, 2005; Lee, Bacha, Gungor, & Arslanian, 2006b; Savva et al., 2000).

WC is a practical anthropometric measure of abdominal obesity, in terms of both central subcutaneous and visceral fat, and in pediatric populations it is an independent predictor of insulin resistance, lipid levels, and blood pressure (Freedman et al., 2007; Hirschler, Aranda, Calcagno, Maccalini, & Jadzinsky, 2005; Lee, Bacha, & Arslanian, 2006a; Lee et al., 2006b; Mesa et al., 2006; Moreno et al., 2002; Rosini et al., 2013; Savva et al., 2000), all components of the metabolic syndrome (MetS).

The International Diabetes Federation (IDF) states that abdominal obesity is the most important criteria of the MetS

(Alberti, Zimmet, & Shaw, 2006; Zimmet et al., 2007). The IDF suggests that a WC above 94 cm in men and 80 cm in women (Alberti et al., 2006) should be used for European descendent adults and older adolescents (16+ years old) as the criteria for abdominal obesity. The early diagnosis of MetS in adolescents would help to identify those at increased risk (Eisenmann, Welk, Wickel, & Blair, 2004; Katzmarzyk et al., 2001). The IDF consensus (Zimmet et al., 2007) established that below 10 years of age the MetS cannot be diagnosed, while from 16 years old and older the criteria is the same as that used for adults. Consequently, the IDF developed a new definition for the diagnosis of MetS in adolescents aged 10-<16 years using modified adult criteria with all risk factor cut-off points being similar to those for adults with the exception of WC, for which the 90th percentile was established as a criteria for abdominal obesity. Accordingly, youth with a WC above the 90th percentile are more likely to present multiple risk factors than their counterparts (Zimmet et al., 2007). On the other hand, hormonal, metabolic and psychological changes in adolescence increase the level of instability in the control of cardiovascular risk factors, due to the direct influence of insulin sensitivity (Tfayli & Arslanian, 2007), suggesting that the 90th percentile might not compensate for adolescents' age- and sex-specific metabolic variations. Therefore, the IDF states in its consensus report that an effort should be made to reassess these WC cut-off points to modify its guidelines, if necessary, based on the new data (Zimmet et al., 2007).

To relate the IDF cut-off point for WC that is used in those aged 16 years and older (Alberti et al., 2006) to the need for adjustment due to adolescence, the aim of this study was to develop age- and sex-specific WC cut-off points linked to adult criteria for 10 to <16-year-old boys and girls using the *Lambda Mu Sigma* (LMS) growth curve, a method previously described (Benmohammed, Valensi, Balkau, & Lezzar, 2016; Jolliffe & Janssen, 2007).

2 | METHODS

2.1 | Participants

Data derived from a nationally representative cross-sectional school-based survey, designed to evaluate physical activity, physical fitness, incidence of overweight/obesity, and related factors in the Portuguese population. Study design and sampling were described in another study (Sardinha et al., 2011). Data were collected by means of proportionate stratified random sampling by location (the Portuguese administrative regions of Alentejo, Algarve, Centro, Lisboa, and Norte) and the number of students by age and sex in each location.

The sample included 16,788 adolescents aged 10 to 16 years, and written informed consent was obtained from their parents or guardians (89% response rate). Participants with a WC above ± 5 SD from the corresponding age- and sex-Z score were excluded from the analysis, resulting in a final sample total of 8277 boys and 8511 girls. The protocol and procedures for this study were approved by the local Ethics Committee and conducted in accordance with the Declaration of Helsinki for human studies of the World Medical Association (World Medical Association, 2013).

2.2 | Anthropometric measurements

WC was measured using anthropometric tape in accordance with the National Health and Nutrition Examination Survey (NHANES) procedures (CDC, 2007). With the participant in a standing position, a flexible tape was placed horizontally just above the uppermost lateral border of the right ilium crest at the end of a normal expiration (CDC, 2007). WC was recorded to the nearest 0.1 cm and the mean of two measurements was obtained. If the two measurements differed by more than 1 cm, a third measurement was taken, and the two closest measurements were averaged. A correction formula suggested by Patry-Parisien and colleagues (Patry-Parisien, Shields, & Bryan, 2012) was then applied to report measurements according to WHO procedures (midway between the lower rib margin and the iliac crest), given that the IDF MetS definition (Alberti et al., 2006) is in accordance with WHO procedures. The formula applied is described in Equations 1 and 2:

$$\text{Boys}: \text{Predicted WC}_{\text{WHO}}(\text{cm}) = [\text{WC}_{\text{NHANES}}(\text{cm}) + 0.89911 - 0.05164 \times \text{age (years)}]/1.01829 \quad (1)$$

$$\text{Girls}: \text{Predicted WC}_{\text{WHO}}(\text{cm}) = [\text{WC}_{\text{NNHANES}}(\text{cm}) + 0.70299 - 0.12297 \times \text{age (years)}]/1.01891 \quad (2)$$

Body height and body weight were determined by standard anthropometric methods. Height was measured to the nearest mm in bare or stocking feet with the adolescents standing upright against a Holtain portable stadiometer. Weight was measured to the nearest 0.10 kg, lightly dressed (underwear and t-shirt) using a portable digital beam scale (Tanita Inner Scan BC 532).

Body mass index was calculated from the ratio of weight/height^2 (kg/m^2). Subjects were classified into non-overweight, overweight and obese categories according to age- and sex-specific cut-off points proposed by the International Obesity Task Force (IOTF) (Cole et al., 2000) and by the World Health Organization (WHO) (de Onis et al., 2007).

2.3 | Statistics

Age was calculated as the difference between the date of birth and date of data collection. Each age group was categorized according to the midpoint of an age range. For

example, the group of participants aged 16 years included all participants between 15.50 and 16.49 years.

Age- and sex-specific growth curves were estimated using Cole's LMS method (Cole & Green, 1992). The summary distribution of the WC is represented by Lambda (L), Mu (M), and Sigma (S) curves, representing the skewness, median, and coefficient of variance of the distribution at each age, respectively.

The WC growth curve was linked to the respective IDF cutoff point established for older adolescents (+16 years old) (Alberti et al., 2006). The first step in creating a growth curve involved defining the Z-score (or percentile) that corresponded to the IDF cut-off point at the age of 16 years (94 cm for boys and 80 cm for girls), represented by the following equation:

$$Z \, score = \left[(Y/M)^L - 1 \right] / (LS) \quad (3)$$

where Y is the adult cut-off point and L, M, and S are the respective values at the age of 16 (Cole & Green, 1992). The second step involved calculating points on the growth curve at each age by regressing the previously defined z-score through adolescence and childhood, as follows:

$$point \, on \, curve = M \, (1 + LSz)^{1/L} \quad (4)$$

where L, M, and S are the respective age- and sex-specific values and z is the z-score that corresponded to the adult cut-off point (Cole & Green, 1992). Accordingly, by defining the percentile that corresponded to the IDF cut-off point at 16 years of age and regressing through adolescence to the end of childhood, at the age of 10 years, adolescent cut-off points for WC were able to be linked to those of adults.

The IDF recommended percentile for adolescents was estimated using Cole's LMS method (Cole & Green, 1992).

Data management, descriptive, and analysis were performed using IBM SPSS® Statistics version 22 for Windows (SPSS Inc., an IBM Company, Chicago IL, USA), whereas LMS regressions were performed using LMS Pro software (The Institute of Child Health, London, UK).

3 | RESULTS

In Table 1 are presented the descriptive characteristics of participants by age and sex. Using IOTF cut-off points the prevalence of overweight and obesity was 18.2% and 6.0% in boys, and 18.0% and 5.0% in girls, respectively, whereas the prevalence of overweight and obesity was 22.0% and 11.5% in boys, and 20.7% and 7.7% in girls, respectively, when using WHO cut-off points.

Table 2 lists the cut-off point for each age group in accordance with the criteria used: current pediatric IDF criteria (90th percentile) and age-specific growth curves linked to

TABLE 1 Sample waist circumference means and SD in boys and girls

	All Sample (*n* = 16,788)	Boys (*n* = 8277)	Girls (*n* = 8511)
	Mean (±SD)	Mean (±SD)	Mean (±SD)
WC (cm)	69.7 (±8.8)	71.0 (±9.0)	68.5 (±8.4)
BMI (%) IOTF			
Non overweight	76.3	75.7	76.9
Overweight	18.1	18.2	18.0
Obese	5.5	6.0	5.0
BMI (%) WHO			
Non overweight	69.0	66.4	71.5
Overweight	21.3	22.0	20.7
Obese	9.6	11.5	7.7

BMI, Body mass index; SD, Standard deviation; WC, Waist circumference.

the cutoff points at 16 years of age, indicating the number of adolescents identified as being abdominally obese according to both standards. Additionally, Figure 1 shows the growth curves for both criteria in boys and girls.

Based on the LMS growth curves method, the percentiles that corresponded to IDF recommendations for adults were the 97th and the 87th percentiles for boys and girls, respectively (Figure 1).

Overall, when using the 90th percentile as suggested by the IDF, 1654 boys were identified as abdominally obese. When using the LMS growth curve method linked to the recommended adult cut-off point, only 368 were within this category. Considering girls, a total of 987 participants were identified as abdominally obese using current IDF pediatric criteria, but, when using the LMS growth curves method linked to the recommended adult cut-off point, this number increased to 1138.

4 | DISCUSSION

WC percentiles have been produced for pediatric ages in different populations worldwide (Eisenmann, 2005; Fernandez, Redden, Pietrobelli, & Allison, 2004; Fredriks, van Buuren, Fekkes, Verloove-Vanhorick, & Wit, 2005; Hatipoglu et al., 2008; Inokuchi, Matsuo, Anzo, Takayama, & Hasegawa, 2007; McCarthy, Jarrett, & Crawley, 2001; Moreno et al., 1999; Sardinha et al., 2011, 2012; Schwandt, Kelishadi, & Haas, 2008; Yan et al., 2008). However, this is the first study to present age- and sex-specific WC cutoff points for identifying abdominal obesity in European adolescents, by linking the current IDF criteria that is used for older adolescents and adults to adolescence periods using the *LMS* method.

TABLE 2 Age-specific waist circumference cut-off point and corresponding percentiles for boys and girls

Age (years)	Boys WC (cm)					Girls WC (cm)				
	IDF youth		Age-specific			IDF youth		Age-specific		
	(90th)	N+	(97th)	N+	Pa	(90th)	N+	(87th)	N+	Pa
10	76.5	63	84.3	20	*	73.0	90	71.5	59	*
11	77.5	142	85.2	38	*	75.1	148	73.6	159	*
12	79.3	173	86.9	63	*	77.4	142	75.8	170	*
13	81.1	174	88.5	77	*	78.9	151	77.3	182	*
14	82.5	137	89.8	45	*	79.6	133	78.0	152	*
15	83.9	150	91.2	63	*	80.4	170	78.8	179	*
16	85.2	126	94.0	61	_	81.5	153	80.0	235	_
Total	_	1654	_	368	*	_	987	_	1138	*

IDF youth: International Diabetes Federation pediatric criteria; Age-specific: Growth curve using the LMS method; N+: Number of subjects identified with abdominal obesity.

[a]Compares the prevalence of abdominal obesity of the pediatric IDF criteria with the LMS growth curves method.

*($P < .05$) χ^2 test.

The present study provided WC age- and sex-specific cutoff points for boys and girls aged 10 to 15 years that are in accordance with current IDF recommended cutoff points for those aged 16 years and older. A similar approach has been used by Jolliffe and Janssen (2007), with North American adolescents (12 to 19 years old). They identified the 83rd percentile for boys and the 50th percentile for girls as intercepting the WC cut-off point for adults established by the IDF. Benmohammed et al. (2016) conducted a similar approach in Algerian adolescents, observing that the 95th percentile for boys and the 67th percentile for girls crossed the IDF cutoffs of 94 cm for men and 80 cm for women, respectively. In the present study, it was shown that the percentile for identifying girls with abdominal obesity was lower than that observed for boys, with the 97th and 87th percentile for boys and girls, respectively, corresponding to the adult criteria. This study shows that the use of the 90th percentile, currently recommended by the IDF for 10–15 year-olds, might not compensate for each population-specific characteristics because it either underestimates or overestimates the number of adolescents at risk.

Furthermore, for both boys and girls, the percentiles created for North American (Jolliffe & Janssen, 2007) youth and for Algerian girls (Benmohammed et al., 2016) were different than those observed in the current investigation. This indicates that there is a need for demographic and ethnic-specific growth curves to be produced, as previously suggested by the IDF (Zimmet et al., 2007). Worldwide, the prevalence of abdominal obesity varies from 3.8% to 51.7% among adolescents from developing countries and from 8.7% to 33.2% among those from developed countries (de Moraes et al., 2011). Consequently, it is essential that a method that
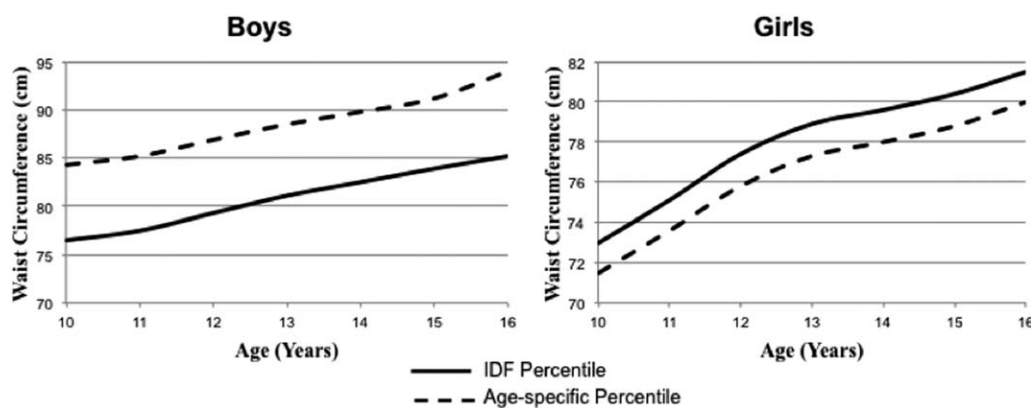

FIGURE 1 Waist circumference growth curves for boys and girls in accordance with two methods: 90th percentile (recommended by the International Diabetes Federation for adolescents) and age-specific growth curves linked to adult's cut-off

not only reduces ethnic differences but is also accepted globally can be adopted, similar to the IDF cut-off points for adults (Alberti et al., 2006).

In the IDF experts' consensus statement (Zimmet et al., 2007), the 90th percentile was suggested as the cut-off point for adolescents aged 10 to 15 years, adopting adult criteria at the age of 16 and above. The establishment of the 90th percentile in the IDF experts' consensus statement was based on a study performed on 818 pre-pubertal children aged 3 to 11 years old (Maffeis, Pietrobelli, Grezzani, Provera, & Tato, 2001) indicating that those with a WC above the 90th percentile had a higher probability of developing multiple risk factors, particularly an adverse lipid profile and hypertension (Maffeis et al., 2001). Evidence supporting the previous IDF recommendations arises from an investigation with children younger than 11 years, but hormonal, metabolic and psychological changes caused by puberty have been recognized (Tfayli & Arslanian, 2007). It was thus considered in this study that a cross-sectional percentile throughout adolescence might not compensate for metabolic instability.

Taking into account previous findings (Benmohammed et al., 2016; Jolliffe & Janssen, 2007) and based on information from the present study, it is believed that the *LMS* growth curves method for developing age- and sex-specific cut-off points linked to current IDF adult criteria might better compensate for sex differences throughout adolescence, as they are a more suitable diagnostic tool in both research and clinical practice. Furthermore, it should be noted that the WC is an inexpensive, highly sensitive and reproducible tool, which is useful for measuring abdominal obesity and enables large sample sizes.

However, the results of this study are subject to the following limitations. The lack of the inclusion of a measure of sexual maturation in the analysis may be regarded as a drawback. In fact, the growth curves are related to changes in chronological age rather than maturational level, but this approach would not be suitable for clinical use as maturational level would have to be assessed.

Another important issue is the lack of other MetS variables. It would be of interest to extend the analysis to the remaining variables so that a complete diagnostic set could be obtained. Nevertheless, it is important to emphasize that the IDF states that abdominal obesity is the *sine qua non* condition for the MetS diagnosis both in adult (Alberti et al., 2006) and pediatric ages (Zimmet et al., 2007). Additionally, although it is a common practice to use cross-sectional data for developing growth curves, it would be preferable to use the method with longitudinal data.

This study presents the first age- and sex-specific WC cut-off points, linked to internationally recommended cut-off points for older adolescents and adults (16+ years old), for diagnosing abdominal obesity in adolescents aged 10 to 15

years. The current IDF pediatric cutoff points for WC might not compensate for adolescents' metabolic instability. More important than the discussion about the method for diagnosing abdominal obesity in youth, it is expected that healthcare professionals could benefit from the results of this study when used in a clinical setting. Using these cutoffs will allow clinicians to identify those at risk for adulthood abdominal obesity. Particularly when using multiple time-points, those boys and girls falling in the 97th and 87th percentiles should be targeted for lifestyles interventions.

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AUTHORS' CONTRIBUTIONS

Designed the study: Luís B. Sardinha.
Responsible for data collection: Jorge Bravo, Armando M. Raimundo, and Diana A. Santos.
Analyzed the data and drafted the manuscript, which was reviewed by Rafael Timón and Luís B. Sardinha: Jorge Bravo, Armando M. Raimundo, and Diana A. Santos.

CONFLICT OF INTEREST STATEMENT

No conflict of interest was declared.

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