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Trabajo Original

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Waist circumference as a prognostic index of childhood abdominal obesity: findings in the Spanish population

Circunferencia de la cintura como índice pronóstico de obesidad abdominal infantil: hallazgos en la población española

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Abstract

Introduction: early detection of childhood obesity plays a crucial role in the prevention of diseases during adulthood. At present, the most commonly used screening tool for detecting overweight/obesity in children is the percentile for age of body mass index, although this rate is unable to provide information about fat distribution. An emerging marker of abdominal fat distribution is waist circumference (WC).

Objective: the aim of this study was to evaluate the differences between the different diagnostic criteria available to define overweight and obesity in order to establish the optimal WC cut-off values for the Spanish children population.

Methods: a cross-sectional study was carried out in 8,241 schoolchildren aged 3 to 12 years from Villanueva de la Cañada (Madrid, Spain). WC (cm), weight (kg) and height (cm) were measured according to the recommendations of the Society for the Advancement of Kineanthropometry (ISAK). The values obtained for the diagnostic criteria (Spanish Orbegozo Foundation (OF), the International Obesity Task Force (IOTF), and the World Health Organization (WHO) were compared using McNemar's test for paired proportions. The kappa coefficient (κ) was used to assess the degree of agreement of the three classifications. We analyzed the validity of body mass index (BMI) and WC using the receiver operating characteristic (ROC) curve analysis. The Youden index was used to determine cut-off values for WC that identify childhood obesity

Results: overweight and obesity prevalences were calculated according to the OF, IOTF, and WHO criteria. There was a "substantial" agreement for the overweight and obesity categories between the Spanish criteria and IOTF (κ = 0.636), while agreement was "slight" between the Spanish criteria and those of WHO (κ = 0.198). The estimated cut-off WC criteria ranged from 54.5 to 88.0, varying according to sex and age.

Conclusion: the proposed WC cut-off values, stated for the first time in a young Spanish population, are a simple and valid alternative as diagnostic criteria of abdominal obesity.

Keywords:

Body mass index. Waist circumference. Abdominal obesity. Children. Adolescents.

Resumen

Introducción: la detección temprana de la obesidad durante la infancia es de vital importancia para la prevención de patologías durante la edad adulta. En la actualidad, la evaluación de la obesidad infantil se realiza principalmente utilizando el índice de masa corporal por edad percentilado, aunque este no aporta información sobre la distribución del tejido adiposo. Un marcador emergente de distribución de la grasa abdominal es la circunferencia de la cintura (CC).

Objetivo: el objetivo de este trabajo fue evaluar las diferencias entre diferentes criterios diagnósticos para definir el sobrepeso y la obesidad con el fin de establecer el punto de corte óptimo de la CC en los niños españoles.

Método: se llevó a cabo un estudio observacional transversal de 8241 niños/as (3-12 años) en Villanueva de la Cañada (Madrid, España). Se determinaron el peso, la talla y el perímetro de la cintura atendiendo a los criterios de la Sociedad Internacional para el Avance de la Cineantropometría (ISAK). Los valores obtenidos para los criterios diagnósticos (Fundación Orbegozo (OF), el Grupo Internacional de Obesidad (IOTF) y la Organización Mundial de la Salud (OMS)) se compararon utilizando la prueba de McNemar para proporciones emparejadas. El coeficiente kappa (κ) se utilizó para evaluar el grado de acuerdo de las tres clasificaciones. Analizamos la validez del índice de masa corporal (IMC) y el perímetro de la cintura (CC) utilizando el análisis de la curva característica operativa del receptor (ROC). El índice de Youden se utilizó para determinar los valores de corte de la CC que identifican la obesidad infantil.

Resultados: se calcularon las prevalencias del sobrepeso y la obesidad de acuerdo con criterios internacionales (IOTF, OMS) y nacionales (FO). Se observó un acuerdo "substancial" para el sobrepeso y la obesidad entre el criterio diagnóstico español y el IOTF (κ = 0,636), mientras que el acuerdo fue "ligero" entre el criterio español y el de la OMS (κ = 0,198). Los puntos de corte de la CC estimados variaron de 54,5 a 88,0 cm, modificándose en función de la edad y el sexo.

Conclusiones: los puntos de corte de la CC propuestos, establecidos por primera vez para niños españoles, son una alternativa simple y válida como criterio diagnóstico de obesidad abdominal.

Palabras clave:

Índice de masa corporal. Circunferencia de la cintura. Obesidad abdominal. Niños. Adolescentes.

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INTRODUCTION

According to the World Health Organization (WHO), worldwide obesity has nearly tripled since 1975. In fact, in 2016 it was estimated that 340 million children and adolescents aged 5-19 years, and 41 million children under the age of 5 were overweight or obese (1). Childhood obesity is associated with a greater risk of premature death and disability in the adulthood. Moreover, obese children experience breathing difficulties, increased risk of fractures, hypertension, cardiovascular disease, insulin resistance and/or diabetes mellitus, pathologies previously observed only in adults (1). Specifically, in the population group aged 2 to 19 years old, Spain occupies an important place regarding obesity prevalence, which is 7.5-10.0 % higher than in other European countries such as France, Belgium, Germany, or England (2), being the second European country, just after Greece, in terms of overweight/obesity prevalence among primary school children (3). Moreover, in this population group, the prevalence of severe obesity is 4.0 % according to the criteria established by WHO (3). Results of the ANIBES (Anthropometric data, macronutrients and micronutrients intake, practice of physical activity, socioeconomic data and lifestyles in Spain) study, carried out recently in Spain, showed a prevalence of overweight and obesity of 27.9 % and 8.8 %, respectively, in the population aged 9 to 17 years (4). Likewise, according to the ENPE (*Estudio Nutricional de la Población Española*) study, overweight and obesity prevalence in Spanish populations aged 3 to 24 years exceeded 30 %, whereas 16 % were overweight and had concomitant abdominal obesity (5). However, data from the latest ALADINO study (Diet, Physical Activity, Child Development and Obesity) from 2019 has shown a downward trend in overweight since 2011 and a stabilization against 2015 edition (6).

Currently, the evaluation of childhood obesity is mainly determined by the body mass index (BMI) for age percentile (pBMI) as a tool for early diagnosis in the pediatric population (7,8). In consequence, reference tables have been developed and are being used interchangeably at both national and international level. Moreover, nowadays it is highly recommended that, in the absence of a widely-shared consensus, prevalence studies consider several reference values (9), specifically the WHO and International Obesity Task Force (IOTF) standards at internationally level and the Orbegozo Foundation (OF) ones in Spain since it is well known that results and their comparison in terms of overweight and obesity prevalence are highly dependent on the methodology used (10,11). On the other hand, the use of pBMI has several limitations, including its inability to provide information about body fat distribution (12). However, there are available some alternative indices that reflect abdominal adiposity, such as waist circumference (WC) or the waist-to-hip ratio (WHR). In fact, according to a recently published consensus statement, WC is a critical factor that could be used to evaluate the reduction in cardiovascular disease risk. Precisely, in children and adolescent populations, it has been suggested that is better to use WC than WHR since the former is more strongly associated with visceral adipose tissue (13), whereas WHR in youth show a weak correlation with central adiposity (14,15). Moreover, Arellano-Ruiz et al. (16) demonstrated that both WC and WHR could be used to identify children with cardiometabolic abnormalities owing to their good accuracy for triglycerides, insulin, and metabolic syndrome analysis, whereas Schröder et al. (17) observed a high proportion of abdominal obesity in young patients who are normal or overweight. In fact, different authors suggest that this measurement should be included routinely in the evaluation and management of patients with overweight or obesity (17,18). Hence, there is a strong need to validate WC data as a simple and reliable prognostic index of abdominal obesity in different countries, including Spain, since WC seems to be a simple and reliable technique that could be used in children. Therefore, the aim of this study was to evaluate the potential differences between the different diagnostic criteria to define overweight and obesity in order to establish, for the first time, the optimal cut-off values of WC as a prognostic index of visceral obesity in Spanish children aged 3 to 12 years.

MATERIALS AND METHODS

DESIGN AND SUBJECTS

The "THAO Salud Infantil" programme is a community-based intervention programme focused on the prevention of overweight and obesity within the EPODE (*Ensemble Prévenons l'Obesité Des Enfants*) International Network. The THAO Foundation developed this program through municipalities, in order to promote healthy life habits in children aged 3 to 12 years (19). Briefly, THAO was mainly devoted to evaluate longitudinally (4 years) the BMI and the efficacy of different actions organized to prevent obesity. The THAO Salud Infantil programme was implemented in 2007 in Villanueva de la Cañada (Madrid, Spain) as a pilot town. Namely, only 5 towns were selected in Spain as pilots for global evaluation and targeted actions.

This school-based, cross-sectional study was carried out during the academic years 2010-11, 2011-2012 and 2012-13, surveying schoolchildren aged 3 to 12 years of both genders (n = 8,241), from both state, charter and private schools in Villanueva de la Cañada (Madrid, Spain). A parental written consent on behalf of each participant was obtained prior to his or her inclusion in the study. The study protocol was in accordance with the Declaration of Helsinki, and was approved by the Clinical Research Ethics Committee of the CEU San Pablo University (Madrid) (ethical code 121/16/07). The final sample of the study presented an error of ± 1 % with a margin of confidence of 95 %, according to the tables by Arkin and Colton (20).

ANTHROPOMETRIC MEASUREMENTS

The anthropometric measurements were made according to the recommendations of the International Standards for Anthropometric Assessment (ISAK) (21) by accredited anthropometrists (level I and II). WC measurements were carried out using a flexible steel tape (CESCORF, Porto Alegre, Brazil) and

corresponded to the narrowest point between the lower lateral costal border (tenth rib) and the top of the iliac crest, perpendicular to the longitudinal axis of the trunk (21). Body weight was measured to the nearest 0.1 kg using an electronic scale (Seca 710 scale, Seca Gmbh & Co, Hamburg, Germany). Height was measured to the nearest 0.5 cm using a stadiometer (Seca 213 Telescopic Height Rod for Column Scales, Seca Gmbh & Co, Hamburg, Germany). BMI (kg/m^2) was calculated as weight (kg) divided by squared height (m). The criteria used for the international cut-offs to define overweight or obesity were: a) WHO reference standards, which are based on the calculation of BMI-Z scores (BMI for age Z-score to categorize children as 'overweight' (Z-BMI/age + 2 SD to + 3 SD), and 'obesity' > + 3 SD) (22); b) overweight/obese according to age- and sex-specific cut-offs based on the IOTF ([23). For the Spanish BMI cut-offs the OF values were employed: 'overweight' (percentile 79 for boys and 89 for girls) and 'obesity'(percentile 97.5 for boys and 99 for girls) (24).

STATISTICAL ANALYSIS

Values are presented as mean (95 % confidence interval) or percentage. Differences were considered significant at $p < 0.05$. Variables were tested for normality with a Kolmogorov-Smirnov test using the SPSS 24.0 Software (IBM Corp., Armonk, NY, USA). Receiver operating characteristic (ROC) curves and area under the curve (AUC) were analyzed with the Matlab (R2010a) software, version 7.11 (The MathWorks, Inc., Massachusetts, USA). The values obtained for the three diagnostic criteria (OF, IOTF, and WHO) were compared using McNemar's test for paired proportions. The kappa coefficient (κ) was used to assess the degree of agreement of the three classifications. Agreement interpretation was based on established categorizations: "poor" ($\kappa < 0.00$), "slight" (0.00-0.20), "fair" (0.21-0.40), "moderate" (0.41-0.60), "substantial" (0.61-0.80), and "almost perfect" (0.81-1.00) (25).

The sensibility and specifity of BMI and WC as markers of childhood obesity by sex and age were determined with cut-off values. ROC curves and AUC were calculated using the trapezoid method; a 95 % confidence interval was constructed using the DeLong test. Youden index was used to determine optimal values, whereas the sensitivity and specificity in the optimal range, accompanied by their confidence intervals using the binomial distribution, were also calculated. The results were obtained with a MATLAB function (R2010a) programmed by our research group.

RESULTS

The study population included 4,150 boys and 4,091 girls, as shown in table I. Anthropometric characteristics for each gender and age class of the study participants are also included.

The prevalence of overweight in the study population is presented stratified by sex and age (Table II). Based on the different diagnostic criteria, overweight prevalence in the total study population was 13.1 %, 16.8 %, and 20.2 % according to the OF, IOTF, and WHO reference values, respectively (Table II). For girls in all age groups, except those aged 12 years, IOTF and WHO criteria estimated a significantly higher prevalence of overweight when compared to the Spanish OF criteria. In addition, in girls aged 3 and 4 years, the prevalence of overweight estimated by the WHO criteria was significantly higher than that estimated by the IOTF criteria (Table II). Conversely, the proportion of overweight in boys aged 3-7 years was significantly lower according to the IOTF references when compared to the Spanish OF criteria, whereas in those aged 9 and 11 years the prevalence of overweight was significantly higher using the IOTF criteria as compared to the OF reference. When using the prevalence of overweight according to WHO criteria, these proportions were significantly higher in boys aged 4, 5, 6, 9, 10 and 11 years as compared to the Spanish OF reference values (Table II).

Table II lists the κ values obtained, which are indicative of the degree of agreement found between national (OF) and international (IOTF and WHO) criteria, for overweight classification. In the population under study, the degree of agreement between the three diagnostic criteria was "substantial" for the overweight category between the Spanish OF criteria and the IOTF one ($\kappa = 0.636$), whereas the agreement for overweight between the OF and the WHO criteria was only "slight" ($\kappa = 0.198$). In boys, the degree of agreement of the OF and IOTF references was "almost perfect" or "substantial" in all age groups. Nevertheless, the degree of agreement between these reference values in girls was only "fair" or "moderate" in all age groups except for those aged 3 and 12 ("substantial" or "almost perfect" agreement, respectively) years. In addition, the results of the agreement between the OF and WHO reference values were "poor", "slight" or "fair" in both boys and girls, across all ages, except for boys aged 3 and 6, and girls aged 12 tears ("moderate" agreement in all cases).

The prevalence of obesity according to the OF, WHO, and IOTF criteria stratified by sex and age is shown in table II. The proportion of obesity in Spanish children aged 3-12 years was 1.7 %, 3.8 %, and 9.4 % according to the Spanish OF, IOTF, and WHO references, respectively. Data analysis stratified by sex and age revealed that the prevalence of obesity based on the Spanish OF reference criteria was significantly lower than the prevalence results obtained using the WHO references, except for volunteers aged 12 years in both sexes.

The κ values obtained between diagnostic criteria (OF, IOTF, WHO) indicated a "substantial" agreement for the obesity category between the Spanish OF and the IOTF criteria ($\kappa = 0.602$), while the agreement for obesity was "fair" ($\kappa = 0.285$) according to the WHO criteria. Specifically, in boys aged 3, 6, and 8 years there was an "almost perfect" agreement, with κ coefficients ranging from 0.818 to 0.950. Moreover, in boys aged 4, 10, and 11 years a "substantial" agreement was found, whereas in those aged 5 and 7 years a "moderate" agreement was determined. These findings indicate a comparable ability to estimate the prevalence of obesity in the two sets of references in boys.

Table I. Anthropometric measures in Spanish children stratified by sex and age

Age (yrs.)	n	Waist circumference (cm)	Weight (kg)	Height (cm)	BMI (kg/m²)
Boys					
3	349	51.2 (50.8-51.6)	16.4 (16.2-16.6)	100.4 (100.0-100.8)	16.2 (16.1-16.4)
4	429	52.8 (52.4-53.2)	18.4 (18.2-18.7)	106.6 (106.2-107.0)	16.2 (16.1-16.3)
5	449	54.4 (54.0-54.7)	20.8 (20.6-21.0)	113.5 (113.1-114.0)	16.1 (16.0-16.2)
6	508	56.6 (56.1-17.0)	23.6 (23.3-24.0)	119.8 (119.4-120.3)	16.4 (16.2-16.6)
7	563	59.2 (58.7-59.7)	26.9 (26.5-27.3)	126.1 (125.6-126.5)	16.9 (16.7-17.0)
8	496	61.7 (61.1-62.3)	30.4 (29.8-30.9)	131.7 (131.2-132.2)	17.4 (17.2-17.6)
9	492	63.8 (63.1-64.4)	33.3 (32.8-33.8)	136.8 (136.3-137.4)	17.7 (17.5-17.9)
10	438	65.7 (65.0-66.3)	36.5 (35.9-37.1)	142.0 (141.5-142.6)	18.0 (17.8-18.2)
11	371	68.7 (67.9-69.5)	41.1 (40.2-41.9)	148.0 (147.3-148.7)	18.6 (18.4-18.9)
12	55	71.1 (68.7-73.4)	45.5 (42.9-48.0)	153.1 (151.1-155.1)	19.3 (18.5-20.1)
Girls					
3	345	51.2 (50.8-51.5)	15.8 (15.6-16.0)	98.9 (98.5-99.4)	16.2 (16.0-16.3)
4	434	52.8 (52.4-53.2)	17.9 (17.7-18.2)	105.5 (105.1-105.9)	16.1 (15.9-16.2)
5	433	55.04 (54.6-55.4)	20.5 (20.2-20.8)	112.4 (111.9-112.8)	16.2 (16.0-16.3)
6	521	57.1 (56.6-57.5)	23.3 (23.0-23.6)	118.9 (118.4-119.3)	16.4 (16.2-16.6)
7	511	59.4 (58.9-59.9)	26.5 (26.2-26.9)	125.0 (124.6-125.5)	16.9 (16.7-17.1)
8	479	61.6 (61.0-62.2)	29.9 (29.4-30.4)	130.7 (130.2-131.2)	17.4 (17.2-17.6)
9	474	63.85 (63.2-64.5)	33.2 (32.7-33.7)	136.5 (136.0-137.0)	17.8 (17.5-8.0)
10	459	66.3 (65.6-67.1)	37.4 (36.7-38.1)	142.4 (141.8-143.0)	18.4 (18.1-18.6)
11	371	67.6 (66.8-68.4)	41.1 (40.3-41.9)	148.9 (148.1-149.6)	18.5 (18.2-18.7)
12	64	69.1 (67.2-70.9)	44.8 (42.5-47.1)	152.5 (150.6-154.4)	19.1 (18.5-19.8)

Results are presented as mean and confidence interval (CI). Values of n represent the absolute number of observations in each category.

Table II. Prevalence of overweight and obesity in Spanish children by sex and age and agreement (κ) between the Spanish OF, IOTF, and WHO references

	Age (yrs.)	n	Overweight (%)			Overweight agreement (κ)		
			OF (Spain)	IOTF	WHO	OF *vs.* WHO	OF *vs.* IOTF	IOTF *vs.* WHO
Boys								
	3	349	16.0	8.9[a]	18.9[g]	0.464	0.676	0.097
	4	429	12.8	9.6[a]	19.3[d,g]	0.383	0.836	0.297
	5	449	14.0	10.5[a]	18.3[f,g]	0.369	0.835	0.329
	6	508	14.8	12.4[a]	18.1[f,g]	0.492	0.899	0.402
	7	563	19.4	17.6[b]	16.7[h]	0.345	0.94	0.343
	8	496	18.5	19.8	21.0	0.187	0.857	0.341
	9	492	14.8	18.9[c]	23.0[e,h]	-0.049	0.61	0.351
	10	438	12.6	14.8	22.4[d]	0.12	0.788	0.32
	11	371	18.9	22.1[b]	25.6[e,h]	0.357	0.868	0.504
	12	55	18.2	21.8	23.6	0.07	0.773	0.327

(Continuation in the next page)

Table II (Cont.). Prevalence of overweight and obesity in Spanish children by sex and age and agreement (κ) between the Spanish OF, IOTF, and WHO references

	Age (yrs.)	n	Overweight (%)			Overweight agreement (κ)		
			OF (Spain)	IOTF	WHO	OF *vs.* WHO	OF *vs.* IOTF	IOTF *vs.* WHO
Girls								
	3	345	6.7	10.4[b]	20.9[d,h]	0.075	0.613	0.376
	4	434	7.8	13.8[a]	18.9[d,g]	0.089	0.409	0.631
	5	433	10.6	17.8[a]	18.9[d]	0.15	0.39	0.777
	6	521	12.1	18.4[a]	18.8[d]	0.192	0.418	0.785
	7	511	12.3	21.9[a]	20.9[d]	0.081	0.383	0.762
	8	479	10.4	23.4[a]	24.4[d]	-0.073	0.264	0.707
	9	474	10.1	21.7[a]	21.7[d]	0.024	0.454	0.653
	10	459	12.0	20.0[a]	20.7[d]	0.183	0.544	0.684
	11	371	8.9	15.6[a]	16.2[d]	0.21	0.591	0.678
	12	64	10.9	14.1	14.1	0.43	0.857	0.612
Total	3-12	8241	13.1	16.8	20.2	0.198	0.636	0.521
	Age (yrs.)	**n**	**Obesity (%)**			**Obesity agreement (kappa)**		
			OF (Spain)	**IOTF**	**WHO**	**OF *vs.* WHO**	**OF *vs.* IOTF**	**IOTF *vs.* WHO**
Boys								
	3	349	1.4	1.7	7.7[d,e]	0.295	0.908	0.345
	4	429	1.9	3.0	7.0[d,e]	0.403	0.756	0.587
	5	449	0.9	2.9[b]	7.3[d,e]	0.204	0.463	0.546
	6	508	3.9	4.3	9.3[d,e]	0.573	0.950	0.615
	7	563	4.3	5.5	15.3[d,e]	0.396	0.531	0.488
	8	496	3.8	5.4[c]	15.5[d,e]	0.356	0.818	0.477
	9	492	1.0	4.5[b]	13.2[d,e]	0.126	0.360	0.470
	10	438	1.1	2.5[a]	9.1[d,e]	0.206	0.619	0.408
	11	371	1.1	1.6	8.9[d,e]	0.201	0.797	0.288
	12	55	0.0	1.8	12.7[h]	0.000	0.000	0.225
Girls								
	3	345	1.2	2.3	5.5[d,e]	0.335	0.661	0.579
	4	434	0.5	3.2[a]	5.8[d,e]	0.141	0.244	0.409
	5	433	0.9	4.8[a]	7.6[d,e]	0.203	0.309	0.764
	6	521	2.5	6.9[a]	9.8[d,e]	0.382	0.513	0.812
	7	511	1.4	5.5[a]	10.0[d,e]	0.223	0.387	0.687
	8	479	1.0	5.2[a]	10.0[d,e]	0.173	0.322	0.662
	9	474	0.6	2.3[b]	8.2[d,e]	0.133	0.423	0.419
	10	459	1.1	3.3	8.1[d,e]	0.223	0.492	0.556
	11	371	0.5	1.6[b]	5.7[d,e]	0.166	0.496	0.430
	12	64	0.0	0.0	4.7	0.000	-	0.000
Total	3-12	8241	1.7	3.8	9.4	0.285	0.602	0.557

OF (Orbegozo Foundation, Spain): Spanish references; IOTF: International Obesity Task Force; WHO: World Health Organization. Values of n represent the absolute number of observations in each category. Total n indicated in each row. [a]Significant differences between OF and IOTF references; p ≤ 0.001 (McNemar's test). [b]Significant differences between OF and IOTF references; p ≤ 0.01 (McNemar's test). [c]Significant differences between OF and IOTF references; p ≤ 0.05 (McNemar's test). [d]Significant differences between OF and WHO references; p ≤ 0.001 (McNemar's test). [e]Significant differences between OF and WHO references; p ≤ 0.01 (McNemar's test). [f]Significant differences between OF and WHO references; p ≤ 0.05 (McNemar's test). [g]Significant differences between IOTF and WHO references; p ≤ 0.001 (McNemar's test). [h]Significant differences between IOTF and WHO references; p ≤ 0.01 (McNemar's test).

However, in girls, the level of agreement for obesity between the Spanish OF and the WHO criteria ranged from slight to fair, whereas the κ values obtained between the OF and the IOTF criteria revealed a "moderate" to "slight" agreement.

Table III summarizes the WC values, AUC, and sensitivity and specificity to predict obesity according to the Spanish growth charts for BMI. In boys, the WC values that were found to optimally predict the risk of obesity ranged from 59.0 to 88.0 cm, whereas in girls these varied from 61.0 to 87.0 cm. In both boys and girls, in the ROC curves, the values were close to one, as denoted by the WC results for age. WC values resulted in around 100 % sensitivity and 94-99 % specificity for boys aged 3 to 13 years, and around 100 % sensitivity and 93-99 % specificity for girls within the same age range.

In tables IV and V, the gender- and age-specific WC values to predict obesity according to the international (IOTF and WHO) growth charts for BMI are shown. In boys, the WC values for obesity based on the IOTF criteria ranged from 59.0 to 88.0 cm, the same values obtained when using the OF criteria. On the other hand, in girls these values varied from 55.8 to 82.5 cm. In boys, the AUC values to identify obesity ranged from 0.863 to 0.998 with a corresponding 77-100 % sensitivity and 94-99 % specificity. For girls, these AUC values ranged from 0.963 to 0.990 to identify obesity with a corresponding 100 % sensitivity and 83-96 % specificity (Table IV). On the other hand, when ROC curves derived from the WHO references were constructed (the ROC curve for boys is depicted, with values of WC that ranged from 54.5 to 76.8 cm), to identify obesity these ranged from 0.897 to 0.978, with a 97-100 % sensitivity and 94-99 % specificity. Finally, WC values to determine obesity according to WHO criteria in girls were 55.2 to 76.0 cm, with AUC values from 0.762 to 0.972 to identify obesity, and with a sensitivity and specificity of 67-100 % and 83-96 %, respectively (Table V).

Table III. Waist circumference values to determine obesity with BMI according to the Orbegozo Foundation criteria. Spanish children aged 3-12 years

Age (yrs.)	n	Waist circumference cut-off (cm)	Area under curve (mean [95 % CI])	Sensitivity (mean [95 % CI])	Specificity (mean [95 % CI])
Boys					
3	349	59.0	0.996 (0.989-1.000)	100 (48-100)	98 (96-99)
4	429	59.5	0.995 (0.988-1.000)	100 (63-100)	98 (96-99)
5	449	63.9	0.764 (0.312-1.000)	75 (19-99)	99 (97-100)
6	508	64.5	0.994 (0.988-0.999)	100 (83-100)	98 (96-99)
7	563	69.0	0.989 (0.978-0.999)	96 (79-100)	97 (95-98)
8	496	73.2	0.991 (0.984-0.999)	100 (82-100)	96 (94-97)
9	492	80.0	0.987 (0.975-1.000)	100 (48-100)	97 (95-99)
10	438	84.3	0.991 (0.981-1.000)	100 (48-100)	98 (96-99)
11	371	88.0	0.994 (0.985-1.000)	100 (40-100)	98 (96-99)
12	55			-	-
Girls					
3	345	61.0	0.999 (0.996-1.000)	100 (40-100)	99 (98-100)
4	434	63.8	0.993 (0.978-1.000)	100 (16-100)	99 (97-99)
5	433	64.5	0.992 (0.982-1.000)	100 (40-100)	98 (96-99)
6	521	64.6	0.986 (0.973-1.000)	100 (75-100)	92 (89-94)
7	511	72.0	0.990 (0.981-0.998)	100 (59-100)	98 (96-99)
8	479	81.2	0.997 (0.993-1.000)	100 (48-100)	99 (98-100)
9	474	83.3	0.998 (0.993-1.000)	100 (29-100)	99 (98-100)
10	459	78.8	0.987 (0.961-1.000)	100 (48-100)	93 (91-95)
11	371	87.0	0.989 (0.967-1.000)	100 (16-100)	98 (96-99)
12	64			-	-

Results are presented as mean and confidence interval (CI). Values of n represent the absolute number of observations in each category. Total n indicated in each row.

Table IV. Waist circumference values to determine obesity with BMI according to IOTF criteria. Spanish children aged 3-12 years

Age (yrs.)	n	Waist circumference cut-off (cm)	AUC (mean [95 % CI])	Sensitivity (mean [95 % CI])	Specificity (mean [95 % CI])
Boys					
3	349	59.0	0.998 (0.992-1.000)	100 (54-100)	99 (97-100)
4	429	58.9	0.99 (0.993-1.000)	100 (75-100)	98 (96-99)
5	449	60.3	0.863 (0.710-1.000)	77 (46-95)	97 (95-98)
6	508	64.5	0.994 (0.983-1.000)	100 (85-100)	98 (96-99)
7	563	68.0	0.990 (0.982-0.999)	97 (83-100)	96 (94-98)
8	496	72.0	0.994 (0.989-0.999)	100 (87-100)	96 (93-97)
9	492	75.0	0.991 (0.984-0.998)	100 (85-100)	96 (94-98)
10	438	79.0	0.990 (0.982-0.999)	100 (72-100)	97 (95-99)
11	371	87.5	0.993 (0.984-1.000)	100 (54-100)	99 (97-100)
12	55	88.0	0.944 (0.883-1.000)	100 (3-100)	94 (85-99)
Girls					
3	345	55.8	0.981 (0.960-1.000)	100 (63-100)	93 (90-95)
4	434	57.3	0.982 (0.968-0.997)	100 (77-100)	93 (90-95)
5	433	58.5	0.968 (0.944-0.991)	100 (84-100)	84 (81-88)
6	521	61.8	0.974 (0.959-0.989)	97 (85-100)	88 (85-91)
7	511	66.5	0.980 (0.968-0.993)	100 (88-100)	91 (88-93)
8	479	67.0	0.963 (0.936-0.990)	96 (80-100)	83 (79-86)
9	474	73.5	0.987 (0.970-1.000)	100 (72-100)	91 (88-94)
10	459	78.8	0.990 (0.981-0.999)	100 (78-100)	95 (93-97)
11	371	82.5	0.980 (0.964-0.995)	100 (54-100)	96 (94-98)
12	64			-	-

Results are presented as mean and confidence interval (CI). Values of n represent the absolute number of observations in each category. Total n indicated in each row.

DISCUSSION

The purpose of this study was to establish, for the first time, the optimal cut-off values of WC for Spanish children aged 3 to 12 as a prognostic index of childhood abdominal obesity. Moreover, the potential differences between the various national and international diagnostic criteria to define overweight and obesity were evaluated.

According to recently published data, worldwide, in 2016, there were 650 million adults that suffered from obesity and 340 million children and adolescents aged 5-19 years who were overweight or obese (1). Although the prevalence of obesity in children is lower than in adults, the rate at which obesity is increasing during childhood tends to be greater than that witnessed in adulthood (26). In fact, the prevalence of overweight in children under 5 years of age has increased from 4.9 % in 2000 to 5.6 % in 2016 (24). Regarding Spanish data, recently published data revealed an overweight/obesity prevalence of more than 30 % with all the criteria used (IOTF, WHO, OF), with 16 % concomitantly having abdominal obesity (5). Specifically, the data obtained by Aranceta-Bartrina et al. (5) revealed that in the Spanish population aged 3 to 24 years overweight prevalences are 35.9 %, 34.1 %, and 31.9 % according to the WHO, IOTF, and OF criteria, respectively, whereas obesity prevalences are 12.1 %, 10.3 %, and 8.6 % based on these same criteria. These percentages were higher than those obtained in our study, although in both studies the higher prevalences were obtained based on the WHO criteria, followed by the IOTF and OF references. These differences might be attributed to the high education level of the parents, and the high average income, of the present population under study. Of interest, Mediterranean diet promotion seems to be a good strategy for the reduction of overweight, obesity, and abdominal obesity incidences in both children and adolescents (27).

Despite the high prevalence values reported to date, it is important to note that data should be analyzed with caution since the results of studies in terms of overweight and obesity prevalences are largely dependent on the criteria used (10,11). Thus, the results of our study indicate that overweight prevalence according to WHO criteria was three and seven points higher than according to IOTF and the Spanish national standard (OF), respectively. Regarding the prevalence of obesity, the data obtained based on the WHO criteria was eight points higher than the data obtained according to the OF criteria, whereas that calculated using the IOTF standards doubled OF values. Therefore, there is a strong need to define appropriate standard criteria to determine obesity risk in the Spanish children population. The degree of agreement (κ coefficient) between the three diagnostic criteria (OF, IOTF, WHO) analyzed in the present study indicated that it was "substan-

Table V. Waist circumference values to determine obesity with BMI according to WHO criteria. Spanish children aged 3-12 years

Age (yrs.)	n	Waist circumference cut-off (cm)	AUC (mean [95 % CI])	Sensitivity (mean [95 % CI])	Specificity (mean [95 % CI])
Boys					
3	349	54.5	0.943 (0.897-0.989)	89 (71-98)	91 (87-94)
4	429	54.5	0.959 (0.934-0.984)	100 (88-100)	80 (76-84)
5	449	57.6	0.897 (0.828-0.966)	82 (65-93)	88 (85-91)
6	508	59.9	0.977 (0.964-0.990)	96 (85-99)	90 (87-93)
7	563	63.0	0.978 (0.967-0.989)	92 (84-97)	92 (89-94)
8	496	65.8	0.975 (0.960-0.991)	95 (87-99)	92 (89-94)
9	492	70.0	0.977 (0.961-0.994)	92 (83-97)	95 (93-97)
10	438	73.8	0.973 (0.955-0.991)	90 (76-97)	93 (91-96)
11	371	76.8	0.951 (0.914-0.989)	91 (76-98)	88 (84-91)
12	55	76.8	0.973 (0.932-1.000)	100 (59-100)	88 (75-95)
Girls					
3	345	55.2	0.970 (0.941-0.998)	95 (74-100)	94 (91-96)
4	434	56.5	0.935 (0.889-0.980)	84 (64-95)	90 (86-92)
5	433	58.0	0.954 (0.931-0.978)	97 (84-100)	85 (81-88)
6	521	60.8	0.969 (0.954-0.95)	96 (87-100)	87 (83-90)
7	511	63.5	0.9664 (0.949-0.983)	96 (87-100)	86 (82-89)
8	479	67.0	0.968 (0.952-0.985)	96 (86-99)	87 (83-90)
9	474	69.0	0.941 (0.916-0.966)	95 (83-99)	83 (79-86)
10	459	74.0	0.972 (0.958-0.986)	100 (91-100)	90 (87-93)
11	371	75.0	0.966 (0.943-0.989)	95 (76-100)	89 (85-92)
12	64	76.0	0.762 (0.445-1.000)	67 (9-99)	87 (76-94)

Results are presented as mean and confidence interval (CI). Values of n represent the absolute number of observations in each category. Total n indicated in each row.

tial" for the overweight and obesity category between the Spanish OF and the IOTF criteria. However, the agreement for overweight between the Spanish OF and the WHO criteria was only "slight" or "fair" in case of obesity. These differences are consistent with other international studies that revealed that the WHO criteria generally resulted in a higher prevalence estimation than the one calculated using the IOTF standards (10,28). Therefore, studies tend to use the IOTF criteria as first choice (28,29), since it can be used for comparative purposes due to its extensive use in Europe and worldwide (30). However, it should be noted that the methodologies used to establish the different reference criteria must be carefully considered when interpreting the results obtained (9).

Currently, the most commonly used screening tool for the diagnosis of overweight/obesity in children is the pBMI for age. However, this rate is unable to provide information on fat distribution, a limitation that has been largely missed (31). A good marker of obesity indicative of central body fat distribution is WC. In fact, it has been recently considered as an important 'vital sign' in clinical practice (18). To date, the published research has been focused on the establishment of waist to height cut-off points for abdominal obesity measurement in different populations (namely Turkish, Korean, Polish, and Chinese children and adolescents) (32-34), none of them in the Mediterranean area. Likewise, some other studies aimed at the development of WC, WHR, and waist to height reference curves and percentiles (35,36). However, WHR seems to be a poor predictor of abdominal obesity in children since this ratio is highly dependent on age (15). In our study, WC was selected since it contributes more strongly to the variation in BMI according to gender and age (37). As expected, the calculated cut-off values of WC, for both males and females, increased with age. Furthermore, it is important to note that the high AUCs obtained by the ROC curve analysis indicate a high sensitivity and specificity for obesity discrimination in children using BMI according to different diagnostic criteria.

Finally, it should be highlighted that the obtained results indicate that WC measurement is not only an easy-to-apply, low-cost, and fast method but also of interest in clinical practice due to its potential use in the evaluation of central adiposity in children. The main strengths of our study are that similar studies have not been previously performed in a Spanish children population, and that the measurements and anthropometric data were collected by accredited anthropometrists (level I and II, ISAK). Furthermore, the rather large sample size (n = 8,241) provides more reliable results with great precision and power. However, the study also shows some limitations. For example, more precise methodologies should be used (such as Dual X-ray Absorptiometry (DEXA) or doubly labeled water) to analyze the percentage of body fat.

CONCLUSIONS

The results of this study demonstrate that the proposed gender- and age-specific cut-off values of WC represent a single and simple methodology with potential applications not only in both community and clinical practice but also in research studies as a prognostic index for abdominal obesity in Spain.

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