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Concordance among diagnostic criteria for metabolic syndrome is inconsistent in Spanish adolescents

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Abstract

Background: The metabolic syndrome (MetS), although more frequent in adults, is a growing health problem in adolescent population. There are different criteria for the diagnosis, however without a consensus of which is the best to be used in this population. The heterogeneity of the different diagnostic criteria makes it necessary to carry out more studies that analyse the degree of agreement among these criteria. The present study was aimed to evaluate the agreement between different criteria for diagnosis of MetS in adolescents.

Materials and methods: A cross-sectional study was performed on 981 adolescents (13.2 ± 1.2 years) randomly recruited from 18 schools in south-east Spain. MetS was diagnosed by eight different criteria.

Results: The criteria proposed by the IDF showed the highest mean values for WC and systolic blood pressure in boys and girls with MetS, and the lowest for glucose and triglycerides in boys. Depending on the diagnostic criteria used, the prevalence of MetS cases in boys ranged from 5.5% to 14.9%, while in girls varied from 3.4% to 32.6%. Both in boys and girls, the criteria proposed by the IDF was the less concordant with the other suggested criteria, while those proposed by Duncan et al, Rodriguez-Moran et al and Cruz and Goran, were very concordant among each other. However, in girls, concordance values were not as high as those found for boys.

Conclusion: The variability observed in the agreement among the existing criteria suggests the need to validate uniform criteria for the diagnosis of MetS in adolescents.

KEYWORDS

adolescents, anthropometric indexes, diagnosis criteria, metabolic syndrome

1 | INTRODUCTION

Metabolic syndrome (MetS) is characterized by a set of three or more metabolic disorders, including abdominal obesity, systemic arterial hypertension, elevated serum triglycerides (TG) and glycaemia and low levels of high-density lipoprotein cholesterol (HDL-c).[1] Adolescents that suffer early changes in the components of MetS are associated with a high risk of developing this condition in adulthood,[2] with an increased risk of developing type 2 diabetes mellitus and cardiovascular diseases (CVD).[3]

On the other hand, the prevalence of MetS in adolescence in many studies is rather divergent, mainly due to the absence of specifically established criteria for its use in non-adult

populations. This situation often involves adapting criteria to define MetS in adults to be used in adolescents.[4] This is the case of the criteria established by the National Cholesterol Education Program - Adult Treatment Panel III,[5] modified by Cook et al,[6] Weiss et al,[7] Duncan et al,[8] and de Ferranti et al[9] The criteria defined by the International Diabetes Federation (IDF)[10] necessarily include the presence of abdominal obesity for the diagnosis of MetS. On the other hand, Cook et al,[6] Cruz & Goran,[11] de Ferranti et al[9] and Rodríguez-Moran et al[12] consider the existence of three or more impaired components of the Mets as compulsory for the diagnosis, regardless the presence of abdominal obesity. Viner et al,[13] based on the World Health Organization (WHO) criteria adapted for children by Alberti & Zimmet,[14] consider that the existence of four or more impaired components is essential for the diagnosis of MetS.

The main reasons for the heterogeneity in these criteria when adapted for the adolescent population is related to changes in growth and development during childhood and adolescence, which give rise to cut-off points without established values.[15,16] The divergence is such that some studies have shown a prevalence of MetS ranging from 20% to 300% in the same population depending on the criteria used.[17,18] The degree of agreement among these criteria is unknown at the moment. Therefore, it is necessary to define a universal criterion for the diagnosis of this condition in adolescents and that facilitates its early screening.[19] In this sense, the present study aims to contrast the degree of agreement among eight diagnostic criteria to define MetS in boys and girls.

2 | METHODS AND MATERIALS

2.1 | Study design and sample

A cross-sectional study was carried out on 981 adolescents (456 boys and 525 girls), 13.2 ± 1.2 years of age (11-16 years old), all of Spanish origin and similar socioeconomic status. The subjects attended 18 high-schools in the provinces of Granada and Almeria (South-East of Spain; 10 public and 8 private). A letter of invitation was sent to the school principals and all centres agreed to participate in the study. Of the 18 schools, two classes per grade of a total of three were randomly selected and invited to participate in the study. To be included in the study, the subjects had to be healthy and not have any type of endocrine dysfunction or physical disorder. All students who did not meet these criteria were not candidates to participate in the study. The flow diagram (Figure 1) summarizes the recruitment process. Reporting of the study conforms to broad EQUATOR guidelines.[20]

The study was previously approved by the Ethics Committee of the University of Granada and also authorized by the school principals. Written informed consent was obtained from all of the parents or legal guardians of the adolescents in accordance with the Declaration of Helsinki. Furthermore, the confidentiality of the personal information was guaranteed by coding the data.

2.2 | Anthropometric measurements

Each participant underwent an anthropometric evaluation performed by a level 2 anthropometrist certified by the International Society for the Advancement of Kinanthropometry (ISAK), in accordance with the ISAK guidelines.[21] We performed the anthropometric measurements in the morning after a 12-hour fast and a 24-hour abstention from exercise. The anthropometric assessment was carried out individually in a classroom provided by each school, in order guarantee the privacy of the participants. We measured body weight (kg) twice (with participants wearing no shoes and in light clothes) using a self-calibrating Seca 861 class (III) digital floor scale (Saint Paul, USA) with a precision of up to 100 g. We measured height with a Seca 214* portable stadiometer, asking participants to remove their shoes and stand erect with their backs, buttocks and heels in continuous contact with the vertical height rod of the stadiometer and head oriented in the Frankfurt plane. We then placed the horizontal headpiece on top of the participants' heads to measure their height. We took height measurements twice to the nearest 0.5 cm. We used the average of the two values for weight and height in the analysis. We calculated body mass index (BMI) as weight divided by height squared (kg/m^2). We measured waist circumference (WC) with a Seca automatic roll-up measuring tape (precision of 1 mm) using the horizontal plane midway between the lowest rib and the upper border of the iliac crest at the end of a normal inspiration/expiration. Also measured were the triceps, biceps, subscapular and suprailiac skinfolds. The instrument used for this purpose was a Holtain skinfold calliper (Holtain Ltd.), with an accuracy of 0.1-0.2 mm. The percentage of body fat was based on these skinfold measurements. Previously, the Brook equation was used to calculate body density.[22] Once the body density value had been obtained, the body fat percentage was determined with the Siri Equation [23] A trained member of the research team collected anthropometric measures in a classroom enabled for this purpose by the principal of each school.

2.3 | Serum biochemical examination

Blood collection was performed after a previous 12-hour fast. At 8:00 AM, 10 mL of blood was extracted by venipuncture in the antecubital fossa of the right arm with a disposable vacuum blood collection tube. In the 4 hours after the extraction,

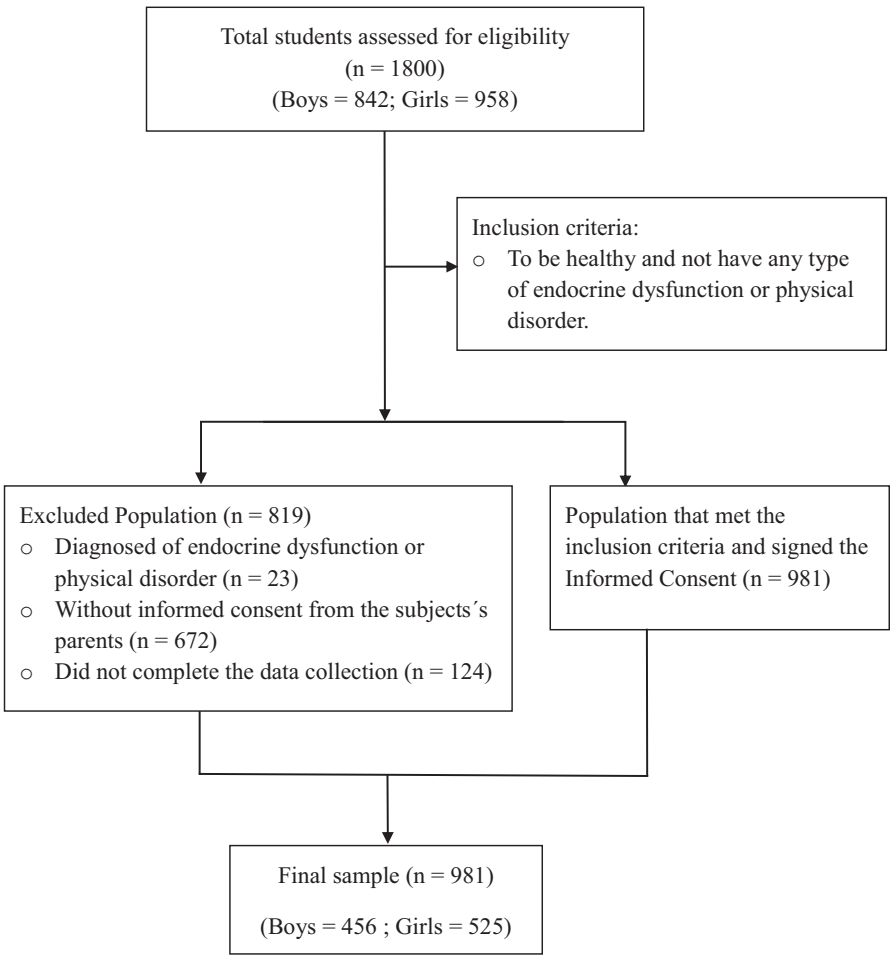

FIGURE 1 Flow diagram of the recruitment progress

all samples were centrifuged at 1300 *g* for 15 minutes (Z400 K; Hermle). The red blood cells were thus separated and the serum was finally frozen at −80°C for its subsequent analysis. Immediately after collection and before centrifugation, however, we measured glucose concentration using an enzymatic colorimetric method (glucose oxidase-phenol aminophenazone [GOD-PAP] method; Human Diagnostics) as well as the concentrations of HDL-C, total cholesterol and triglycerides by means of enzymatic colorimetric methods using an Olympus analyser. Low-density lipoprotein cholesterol (LDL-C) was estimated using the Friedewald equation ([LDLC] = [Total Cholesterol] − [HDL-C] − ([TG]/5)), where TG = concentration of triglycerides. Serum insulin was determined by radioimmunoanalysis (Insulin Kit; DPC, Los Angeles, EEUU). Insulin resistance was quantified with HOMA (Homeostasis Model Assessment)[24] by applying the following formula: fasting glucose (mmol/L) × fasting insulin (mU/L)/22.5.

2.4 | Blood pressure determination

We measured blood pressure (BP) levels using a previously calibrated aneroid sphygmomanometer and a Littmann® stethoscope, following the recommendations for blood pressure measurement of the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research.[25] Systolic BP ≥130 and/or diastolic BP ≥85 mm Hg were regarded as a risk factor of MetS.

2.5 | Diagnostic criteria of metabolic syndrome in adolescents

Eight different criteria were used to diagnose MetS in the adolescent sample studied: Cook et al,[6] Weiss et al,[7] Duncan et al,[8] de Ferranti et al,[9] Cruz & Goran,[11] Rodríguez-Moran et al[12] and Viner et al,[13] as well as the IDF criteria as published by Zimmet et al[10] The details of the criteria employed may be consulted in Table S1.

2.6 | Statistical analysis

The Kolmogorov-Smirnov test was used to assess the normality of the distribution. Results were reported as

mean ± SD, except for the number of girls and boys with or without MetS, which was expressed as number. Mean differences between boys and girls were assessed using Student's *t* test. Kappa for agreement was calculated for the childhood MetS definitions. Comparisons of means were assessed by ANOVA, followed by Tukey's test. There were no missing data. Statistical analyses were performed using SPSS v24.0 (IBM, Armonk, USA). Statistical significance was defined as $P < .05$.

3 | RESULTS

3.1 | Baseline characteristics of the participants

Baseline biochemical and anthropometric measurements of participants are shown in Table 1. All measured variables were within normal limits. In general terms, differences between boys and girls were not observed. However, a significant lower WC, body weight and systolic blood pressure (SBP) and a significant higher fat content was found in girls compared to boys.

TABLE 1 Characteristics of participants

	Boys (n = 456)		Girls (n = 525)	
	Mean	SD	Mean	SD
Age (y)	13.2	1.2	13.3	1.2
Weight (kg)	57.1	14.1	53.1***	11.0
Fat (%)	27.3	8.3	29.6***	7.8
BMI (kg/m^2)	21.5	4.0	21.1	3.6
WC (cm)	73.7	11.8	71.3***	9.6
Glucose (mg/dL)	86.2	31.2	85.2	28.7
Triglycerides (mg/dL)	129.2	59.3	125.0	46.2
Cholesterol (mg/dL)	81.8	17.3	81.4	15.7
LDL-c (mg/dL)	93.4	23.6	92.9	22.5
HDL-c (mg/dL)	40.1	2.8	40.0	3.1
SBP (mm Hg)	119.6	15.7	116.9**	15.1
DBP (mm Hg)	64.5	9.2	63.9	8.8
Insulina (mU/mL)	21.0	10.2	20.2	9.0
HOMA-IR	4.5	2.9	4.3	3.1

Note: Differences between means were assessed by an unpaired Student's *t* test.

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; Fat (%), body fat percentage; HDL-c, high-density lipoprotein cholesterol; HOMA-IR, homeostatic model assessment of insulin resistance; LDL-c, low-density lipoprotein cholesterol; SBP, systolic blood pressure; TG, triglycerides; WC, waist circumference.

**$P < .05$;

***$P < .001$.

3.2 | Values for components of MetS in subjects with MetS according to different diagnostic criteria

Tables 2 shows the values for components of MetS in boys and girls with MetS according to the different diagnostic criteria assessed. In boys, depending on the diagnostic criteria employed, the number of MetS diagnoses ranged from 25 to 68. The highest mean values for WC, HDL-c, SBP and diastolic blood pressure (DBP) were found when the IDF criteria was employed. In contrast, the lowest mean values for WC and SBP were found with the Cook et al[6] criteria, and the lowest mean value for HDL-c were found with the Viner et al[13] criteria. The criteria proposed by Viner et al[13] showed the highest mean levels of glucose and triglycerides. The lowest mean levels for glucose and triglycerides were found with the IDF criteria.

A greater variability in the number of diagnosed girls was observed. In these subjects, the highest mean values for WC, SBP and DBP were found when the IDF criteria was employed. The lowest mean values of WC, SBP and DBP were found when the Cook et al[6] criteria were employed. In regard to the biochemical parameters, the highest and the lowest mean values for HDL-c were found when the Cruz and Goran[11] and Weiss et al[7] criteria were employed, respectively. The highest and the lowest mean values for glucose and triglycerides were found when the Weiss et al[7] and the Cruz and Goran[11] criteria were employed. No significant differences were observed in DBP among girls with MetS regardless the criteria used.

3.3 | Prevalence of components of MetS according to the different diagnostic criteria in adolescents with Mets

Table 3 shows the prevalence of components of MetS in participants with MetS according to the different diagnostic criteria. Depending on the diagnostic criteria used, the prevalence of MetS cases in boys ranged from 5.5% to 14.9%, while in girls varied from 3.4% to 32.6%. The highest MetS prevalence in boys was observed with the Duncan et al,[8] Rodriguez-Moran et al[12] and Cruz and Goran[11] criteria. In girls, the highest MetS prevalence was observed with the Cruz and Goran[11] criteria. Girls had higher MetS prevalence than boys by all definitions except when the IDF, Weiss[7] and Viner[13] criteria were employed.

The most frequently MetS component observed in boys with MetS was hypertriglyceridemia by all criteria, except for IDF, Weiss et al[7] and Viner et al[13] criteria. A greater variability on the most frequent MetS component was observed in girls. Interestingly, in girls, the same prevalence for hyperglycaemia and low HDL-c concentration, 6.3% and 18.1%

TABLE 2 Values for components of MetS in subjects with MetS according to diagnostic criteria

	IDF		Cook		De Ferranti		Weiss		Viner		Duncan		Rodríguez-Moran		Cruz & Goran	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Boys																
MS (number)	41		39		63		32		25		68		68		68	
WC (cm)	86.0^{a}	9.9	74.6^{b}	11.7	80.2^{ab}	12.7	76.9^{b}	14.0	77.8^{ab}	13.5	79.5^{ab}	12.4	79.5^{ab}	12.4	79.5^{ab}	12.4
Glucose (mg/dL)	128.4^{a}	53.5	172.9^{b}	47.4	139.5^{a}	56.9	191.4^{b}	27.7	193.7^{b}	24.4	136.0^{a}	56.2	136.0^{a}	56.2	136.0^{a}	56.2
Triglycerides (mg/dL)	193.0^{a}	120.1	257.9^{a}	146.4	210.1^{ac}	133.9	295.0^{bc}	143.9	338.9^{b}	132.5	204.0^{a}	130.6	204.0^{a}	130.6	204.0^{a}	130.6
HDL-c (mg/dL)	35.7^{a}	3.4	33.1^{bc}	2.2	35.0^{a}	3.4	32.3^{c}	1.6	32.4^{c}	1.8	34.9^{ab}	3.2	34.9^{ab}	3.2	34.9^{ab}	3.2
SBP (mm Hg)	137.2^{a}	14.7	121.6^{b}	17.0	123.5^{b}	17.3	122.9^{b}	17.9	123.4^{b}	18.8	124.0^{b}	16.6	124.0^{b}	16.6	124.0^{b}	16.6
DBP mm Hg)	74.1^{a}	11.4	64.6^{b}	8.6	65.5^{b}	9.0	65.1^{b}	9.0	63.9^{b}	9.2	66.3^{b}	8.7	66.3^{b}	8.7	66.3^{b}	8.7
Girls																
MS (number)	32		58		97		18		21		134		86		171	
WC (cm)	83.2^{a}	7.5	70.5^{b}	10.4	75.2^{bc}	10.3	73.7^{bc}	14.8	75.5^{ab}	13.3	73.6^{b}	9.1	79.5^{ac}	12.4	73.7^{b}	9.5
Glucose (mg/dL)	131.9^{abc}	52.2	148.3^{b}	51.8	121.1^{a}	52.3	194.4^{d}	7.1	188.2^{d}	22.5	110.0^{c}	48.2	139.2^{ab}	50.7	104.5^{c}	43.5
Triglycerides (mg/dL)	196.2^{ab}	120.9	191.6^{ab}	114.9	164.5^{ab}	98.1	329.8^{c}	121.9	312.9^{c}	128.1	151.9^{a}	85.9	204.0^{b}	130.6	145.5^{a}	77.0
HDL-c (mg/dL)	35.3^{ab}	2.6	33.7^{a}	4.5	36.1^{b}	4.8	32.8^{a}	1.3	33.1^{a}	1.3	37.2^{c}	4.6	34.9^{a}	3.2	38.0^{c}	4.3
SBP (mm Hg)	132.3^{a}	10.2	113.4^{b}	17.1	117.7^{bc}	17.0	116.4^{bc}	20.8^{a}	118.8^{ab}	19.5	117.2^{b}	15.5	124.0^{ac}	16.6	117.5^{b}	15.3
DBP mm Hg)	70.7^{a}	8.8	62.1^{a}	8.8	62.6^{a}	9.5	64.4^{a}	10.2	64.4^{a}	10.1	63.0^{a}	9.0	66.3^{a}	8.7	63.7^{a}	8.9

Note: Values with the same supperscript letters are not significantly different.

Differences between means that share a letter are not statistically significant ($P < .05$).

Abbreviations: DBP, diastolic blood pressure; HDL-c, high-density lipoprotein cholesterol; SBP, systolic blood pressure; WC, waist circumference.

TABLE 3 Prevalence (%) of components of MetS according to the different diagnostic criteria in adolescents with MetS

	Abdominal obesity	Hiperglycaemia	Hypertriglyceridemia	Low HDL-c	Hypertension	MetS
Boys						
IDF	48.0	6.8	3.9	18.0	39.5	9.0
Cook	48.0	6.8	99.3	18.0	17.1	8.6
De Ferranti	24.3	6.8	100.0	18.0	17.1	13.8
Weiss	5.5	6.8	11.0	13.6	1.3	7.0
Viner	48.0	6.8	3.9	18.0	1.3	5.5
Duncan	33.8	6.8	99.3	18.0	17.1	14.9
Rodriguez-Moran	33.8	6.8	99.8	18.0	17.1	14.9
Cruz & Goran	33.8	6.8	99.8	18.0	17.1	14.9
Girls						
IDF	37.0	6.3	2.7	18.1	34.7	6.1
Cook	37.0	6.3	99.0	18.1	40.8	11.0
De Ferranti	28.0	6.3	100.0	18.1	40.8	18.5
Weiss	4.6	6.3	3.2	18.1	3.0	3.4
Viner	37.0	6.3	2.7	18.1	3.0	4.0
Duncan	55.2	6.3	99.0	18.1	40.8	25.5
Rodriguez-Moran	55.2	6.3	28.6	18.1	40.8	16.4
Cruz & Goran	55.2	6.3	28.6	18.1	40.8	32.6

TABLE 4 Number of concordant cases of boys with MetS according to Kappa after crossing diagnostic criteria

	IDF	Cook	De Ferranti	Weiss	Viner	Duncan	Rodriguez-Moran	Cruz & Goran
IDF	**41**							
Cook	19	**39**						
De Ferranti	29	39	**63**					
Weiss	18	30	32	**32**				
Viner	17	24	25	25	**25**			
Duncan	31	39	60	32	25	**68**		
Rodriguez-Moran	31	39	60	32	25	68	**68**	
Cruz & Goran	31	39	60	32	25	68	68	**68**

Values in bold show the total of subjects diagnosed of MetS with the criteria of the cited authors.

respectively, was observed in all diagnostic criteria. In boys, the prevalence for hyperglycaemia was 6.8% by all criteria, while the prevalence for low HDL-c was 18.0% by all criteria except for those proposed by Weiss et al.[7]

3.4 | Agreement cases of adolescents with MetS according to Kappa after crossing diagnostic criteria

Tables 4 and 5 show the number of concordant cases of boys and girls with MetS according to Kappa values after crossing the different diagnostic criteria. Both in boys and girls, the criteria proposed by the IDF was the less concordant with the other suggested criteria, while those proposed by Viner et al,[13] Duncan et al,[8] Rodriguez-Moran et al[12] and Cruz and Goran,[11] were very concordant among each other. In fact, the highest number of MetS diagnosed boys were observed with the criteria by Duncan et al,[8] Rodriguez-Moran[12] et al and Cruz and Goran,[11] showing kappa values above .999 (Figure 2). All boys diagnosed of MetS with the criteria published by Weiss et al[7] ($\kappa = .602$), Viner et al[13] ($\kappa = .497$) and Cook et al[6] ($\kappa = .696$), also presented MetS according to the criteria proposed by Duncan et al,[8] Rodriguez-Moran et al[12] and Cruz and Goran.[11]

TABLE 5 Number of concordant cases of girls with MetS according to Kappa after crossing diagnostic criteria

	IDF	Cook	De Ferranti	Weiss	Viner	Duncan	Rodriguez-Moran	Cruz & Goran
IDF	**32**							
Cook	21	**58**						
De Ferranti	28	58	**97**					
Weiss	9	18	18	**18**				
Viner	14	20	21	16	**21**			
Duncan	29	58	92	18	21	**134**		
Rodriguez-Moran	29	56	70	18	21	86	**86**	
Cruz & Goran	30	56	90	18	21	130	86	**171**

Values in bold show the total of subjects diagnosed of MetS with the criteria of the cited authors.

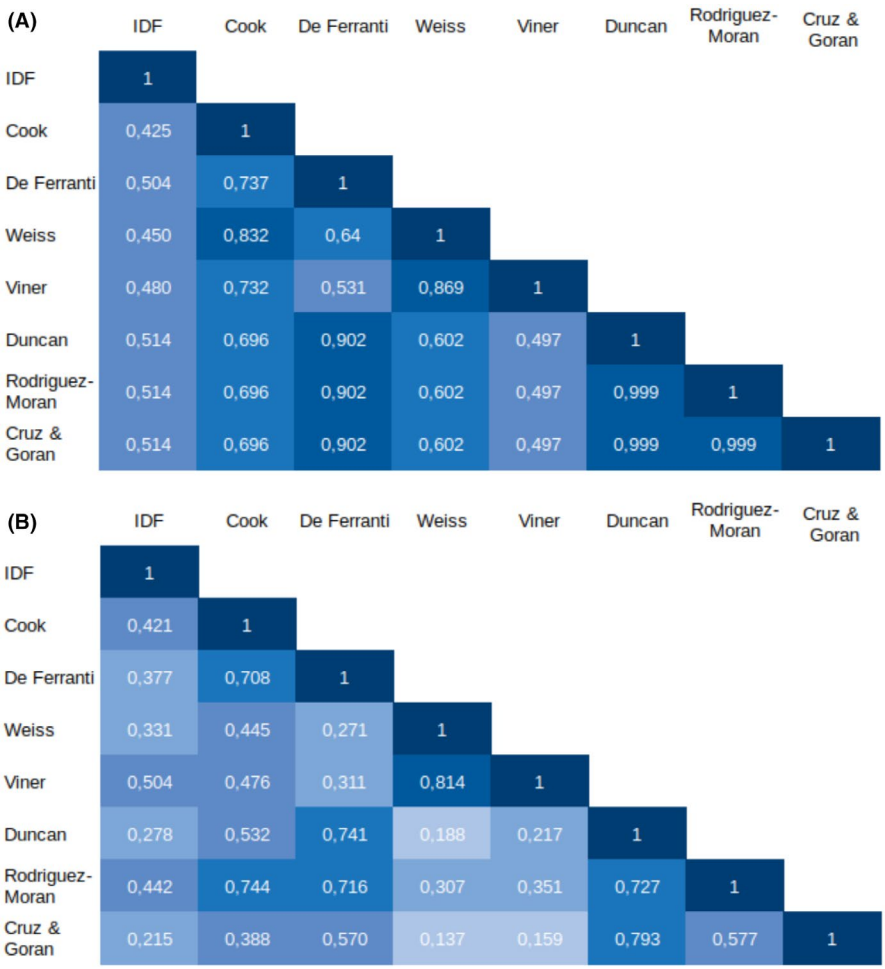

FIGURE 2 Kappa values for agreement for the diagnosis of metabolic syndrome in adolescents according to the eight criteria employed

95.2% of boys with MetS, as diagnosed with criteria by De Ferranti et al,[9] were also diagnosed of Mets with the criteria by Duncan et al,[8] Rodriguez-Moran et al[12] and Cruz and Goran[11] criteria ($\kappa = .902$). Good percentages of concordance were not observed between the cases diagnosed with the IDF criteria and each of the rest of the criteria.

In girls, those published by Duncan et al[8] and Cruz and Goran[11] were the criteria that diagnosed a higher number of MetS cases, 134 and 171, respectively. However, concordance values were not as high as those found for boys. Indeed, the highest kappa value observed in girls corresponded to the concordance of the criteria proposed by Weiss et al[7] and Viner et al,[13] and was .814. All girls diagnosed of Mets with the criteria of Cook et al[6] ($\kappa = .532$), Weiss et al[7] ($\kappa = .188$), Viner et al[13] ($\kappa = .217$) and Rodriguez-Moran et al[12] ($\kappa = .727$), also presented MetS

according to the criteria proposed by Duncan et al[8] In this line, all girls diagnosed of MetS with the criteria proposed by Weiss et al[7] (κ = .137), Viner et al[13] (κ = .159) and Rodriguez-Moran et al[12] (κ = .577) criteria were also diagnosed of Mets with the criteria by Cruz and Goran.[11]

4 | DISCUSSION

In the present study, we had the possibility for the first time to contrast the degree of agreement among eight diagnostic criteria to define MetS in boys and girls. The main findings of this study were the low degree of concordance observed between the IDF with the remaining diagnostic criteria, and a great agreement among the diagnostic criteria of Duncan et al,[8] Rodriguez-Moran et al[12] and Cruz and Goran.[11] To our knowledge, this is the first study of analysing the concordance between eight different criteria for the diagnostic of the MetS in adolescents.

Our results show significantly lower values of WC, body weight and SBP in girls, along with significantly higher fat content in girls compared to boys. These differences among boys and girls could be explained, in part, by the variations in the body composition of the human species at that age, in particular due to a higher fat content in girls.[26]

With regard to the MetS components, in boys the highest mean values for WC, HDL-c, SBP and DBP were found after applying the criteria proposed by the IDF; in girls, applying these same criteria, higher mean values were also obtained for WC, SBP and DBP. These results partially differ from those obtained in other studies, such as the one developed by Peña-Espinoza et al,[27] with a Mexican adolescent population, who found higher WC and HDL-c values, when the criteria proposed by Ferranti et al[9] were used. In our study, the lowest mean values for WC, HDL-c and SBP were found in boys after applying the criteria of Cook et al[6] and Viner et al,[13] while in girls the lowest mean values for WC, SBP and DBP were found after applying the criteria of Cook et al,[6] followed by the lowest HDL-c values after applying the criteria of Weiss et al[7] These results partially differ from those reported by Peña-Espinoza et al,[27] who regardless of sex obtained lower WC and HDL-c values when using the criteria proposed by Weiss et al[7] On the other hand, in our study, after applying the criteria of Viner et al,[13] the highest mean levels of glucose and triglycerides were obtained in boys, while the lowest were found applying the criteria proposed by the IDF. These results differ from those observed by Reuter et al,[19] who in their study with an adolescent population from 10 to 17 years of age in southern Brazil found lower mean glucose levels when applying the criteria of Cook et al[6] and Ferranti et al,[9] regardless of sex. These differences observed in the values for the components of MetS with other authors might be explained by the variability in the ethnicity of the participants or the distinct number of participants diagnosed by the different diagnostic criteria.

On the other hand, our results show a high variability in the prevalence of MetS between both sexes according to the different criteria used. In boys, the prevalence ranges between 5.5% using the criteria of Viner et al[13] and 14.9% applying the criteria of Duncan et al,[8] Rodriguez-Moran et al[12] and Cruz and Goran.[11] In girls, a maximum prevalence of 32.6% was observed after applying the criteria of Cruz and Goran[11] and 3.4% when the criteria established by Weiss et al[7] are applied. According to Valdés-Villalpando et al,[28] these differences can be explained at the different cut-off points established in each criterion to assess body composition by means of WC or BMI using both percentiles and Z-scores, together with different criteria for dyslipidemia values for TG and HDL-c, using cut-off points in percentiles or mg/dL, as well as different cut-off points to define blood pressure levels. According to Weihe et al,[29] this great variability justifies the urgent need to validate criteria to allow uniformity for the diagnosis of MetS in the adolescent population. Our results differ from those described by Reuter et al[19] with Brazilian adolescents, in which they found a MetS prevalence of 1.9, 5.0 and 2.1% using the criteria of Cook et al,[6] Ferranti et al[9] and the IDF. Other international studies have shown dissimilar prevalences according to the diagnostic criteria used. For instance, Kim et al,[30] in a representative study of the Korean adolescent population, obtained a MetS prevalence of 2.1% using the criteria defined by the National Cholesterol Education Program, Adult Treatment Panel III and IDF. Using the same criteria, in the study by Galera-Martínez et al,[31] which was carried out with adolescents from Southern Spain, a prevalence of MetS of 3.8% was reported. Another study developed in Turkey found a prevalence of MetS of 6.3% among adolescents using the criteria proposed by the IDF.[32] Therefore, a great variability in the prevalence of MetS in adolescents is observed, depending on the diagnostic criteria used and their cut-off points. Taking into account that the best prevention and treatment of MetS depends on an early diagnosis, the choice of criteria to diagnose MetS in adolescents can compromise the clinical care of these subjects.

Regarding the degree of agreement between the different criteria applied for the diagnosis of MetS, the IDF criteria showed the lowest agreement in both boys and girls with the other criteria studied (κ < .550). These results are similar to the findings reported by Reuter et al[19] and Agudelo et al[33] who showed kappa values of .532 and .390 between the IDF vs Cook et al[6] criteria, and .382 and .14 between the IDF vs de Ferranti et al[9] criteria, respectively. Tavares Giannini et al[34] also reported confirmed a low kappa value (κ = .48) for the agreement between the IDF and Ferranti et al[9] criteria. However, the study carried out by Guilherme et al[4] in Brazilian adolescents reported good agreement between the IDF criteria with the criteria proposed by Cook et al[6] and Ferranti et al,[9] κ = .950 and κ = .670, respectively. This

variability on the degree of agreement in the aforementioned studies was also observed in the study by Peña-Espinoza et al,[27] where kappa values were .700 and .353 between the IDF criteria and the criteria of Cook et al[6] and De Ferranti et al,[9] respectively.

In boys, the criteria proposed by Duncan et al,[8] Rodriguez-Moran et al[12] and Cruz and Goran[11] were very concordant among each other, with kappa values above .999. However, in girls concordance values between these criteria were good but not as high as those found for boys. In this regard, the study carried out by Mirmiran et al[35] showed a kappa value of .359 between the Duncan et al[8] and Cruz and Goran[11] criteria, which differs from our results. Our findings also showed a great concordance between the criteria proposed by Duncan et al,[8] Rodriguez-Moran et al[12] and Cruz and Goran[11] and the criteria of De Ferranti et al[9] ($\kappa = .902$) in boys. These results partially differ from those obtained by Mirmiran et al,[35] who in adolescent population and regardless of sex, reported kappa values of .616 and .178 between the criteria proposed by de Ferranti et al[9] and Duncan et al[8] and Cruz and Goran[11] respectively. Furthermore, Seo et al[36] reported a kappa value of .407 in the Korean adolescent population between the criteria of Cruz and Goran[11] and Ferranti et al,[9] regardless of sex.

The present study has some strengths and limitations. This study is the first, to our knowledge, that was employed eight different criteria for the diagnosis of MetS in Spanish adolescents and that includes an analysis of concordance between the different diagnostic criteria for MetS. In addition, we would like to emphasize the usefulness of the large sample size, which contributes to obtaining solid results that will improve comparability in future studies. In addition, all participants were of the same geographical region, with similar culture, lifestyle and eating habits, making the sample more homogeneous. The most important limitation of the present study is its cross-sectional design.

5 | CONCLUSIONS

Our results showed a great concordance between the criteria proposed by Duncan et al,[8] Rodríguez-Moran et al[12] and Cruz and Goran,[11] and also between these criteria and the criteria proposed by de Ferranti et al[9] We also report a lower degree of agreement between the IDF criteria and the remaining 7 criteria used to diagnose MetS. However, our results differ from that reported by previous studies with similar characteristics, highlighting the differences between the different criteria for diagnosing MetS. The discrepancies observed in the agreement among the eight criteria employed in our study, and also in comparison with other authors, suggest the need to validate criteria that allow a uniformity in the diagnosis of MetS in adolescents, which is crucial for their usefulness in the clinical practice and for public health authorities in the management of this important public health problem.

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CONFLICT OF INTEREST

No conflict of interest, financial or otherwise is declared by the authors.

AUTHOR CONTRIBUTIONS

EGJ and JSP conceived and designed the study. AFA collected and analysed the data. JSR interpreted the data. EGJ, JSP and AFA drafted the manuscript. All authors have revised and approved the submitted manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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