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Accuracy of body mass index for age to diagnose obesity in Mexican schoolchildren

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Abstract

Objective: **to compare the accuracy of three BMI-for-age references (World Health Organization reference, WHO; the updated International Obesity Task Force reference, IOTF; and Centers for Disease Control and Prevention (CDC) growth charts) to diagnose obesity in Mexican children.**

Methods: **a convenience sample of Mexican schoolchildren (n = 218) was assessed. The gold standard was the percentage of body fat estimated by deuterium dilution technique. Sensitivity and specificity of the classical cutoff point of BMI-for-age to identify obesity (i.e. > 2.00 standard deviation, SD) were estimated. The accuracy (i.e. area under the curve, AUC) of three BMI-for-age references for the diagnosis of obesity was estimated with the receiver operating characteristic (ROC) curves method. The optimal cutoff point (OCP) was determined.**

Results: **the cutoff points to identify obesity had low (WHO reference: 57.6%, CDC: 53.5%) to very low (IOTF reference: 40.4%) sensitivities, but adequate specificities (91.6%, 95.0%, and, 97.5%, respectively). The AUC of the three references were adequate (0.89). For the IOTF reference, the AUC was lower among the older children. The OCP for the CDC reference (1.24 SD) was lower than the OCP for WHO (1.53 SD) and IOTF charts (1.47 SD).**

Conclusions: **the classical cutoff point for obesity has low sensitivity -especially for the IOTF reference. The accuracy of the three references was similar. However, to obtain comparable diagnosis of obesity different cutoff points should be used depending of the reference.**

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Key words: *Obesity. Body fat. Schoolchildren. Accuracy. Diagnosis. Body mass index.*

EXACTITUD DEL ÍNDICE DE MASA CORPORAL PARA LA EDAD PARA DIAGNOSTICAR OBESIDAD EN ESCOLARES MEXICANOS

Resumen

Objetivo: **comparar la exactitud de tres referencias del IMC para la edad (de la Organización Mundial de la Salud, OMS; de la *International Obesity Task Force*, IOTF; y de los Centros para el Control y Prevención de Enfermedades (CDC) de las tablas de crecimiento) para diagnosticar obesidad en niños mexicanos.**

Métodos: **se evaluó una muestra por conveniencia de escolares de la ciudad de México (n = 218). El estándar de oro fue el porcentaje de grasa corporal estimado por la técnica de dilución de deuterio. Se estimaron la sensibilidad y la especificidad del punto de corte clásico del IMC para la edad para identificar obesidad (i.e. > 2.0 desviaciones estándar, DE). La exactitud (i.e., área bajo la curva, ABC) de las tres referencias del IMC para el diagnóstico de la obesidad se estimó con el método de curvas ROC. Se identificó el punto de corte óptimo (PCO).**

Resultados: **los puntos de corte para identificar obesidad tuvieron baja (OMS: 57.6% y CDC: 53.5%) o muy baja (IOTF referencia: 40,4%) sensibilidad, pero especificidades adecuadas (91.6%, 95.0% y 97.5%, respectivamente). El ABC de las tres referencias fueron adecuadas (0.89). Entre los niños mayores la referencia de la IOTF tuvo el menor ABC. El PCO para la referencia de los CDC (1.24 DE) fue menor que el PCO para la de la OMS (1.53 DE) y la de la IOTF (1.47 DE).**

Conclusiones: **el punto de corte clásico para la obesidad tiene baja sensibilidad, especialmente para la referencia de la IOTF. La exactitud de las tres referencias fue similar. Sin embargo, para obtener el diagnóstico comparable de obesidad en diferentes puntos de corte se debe utilizar en función de la referencia seleccionada.**

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Palabras clave: *Obesidad. Grasa corporal. Escolares. Exactitud. Diagnóstico. Índice de masa corporal.*

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Abbreviatiors

BMI: body mass index.
WHO: World Health Organization reference.
IOTF: International Obesity Task Force reference.
CDC: Centers for Disease Control and Prevention growth charts.
SD: standard deviation.
AUC: area under the curve.
ROC: receiver operating characteristic curves method.
OCP: optimal cutoff point.
TBW: total body water.
$^{2}H_2O$: isotope deuterium oxide.
FFM: fat free mas.
%BF: percent of body fat.
W: body weight.

Introduction

The body mass index (BMI=weight kg/stature m^2) is used to identify children with obesity because its convenience (i.e. simple, fast, practical and cheap). Three references for BMI-for-age can be used to asses child adiposity: a) the criteria of the International Obesity Task Force (IOTF), which recently was updated and was derived from data of the population from six countries[1,2]; b) the Centers for Disease Control and Prevention (CDC) growth charts[3], whose BMI values were obtained from the National Health Surveys of the United States of America[2]; and c) the reference of the World Health Organization (WHO)[4], also based on representative samples of the US population.

The majority of the studies validating the BMI-for-age references have been carried out in pediatric populations from Europe[5,6], United States of America[7], Asia[8,9] and Oceania[10]. We are not aware of studies reporting the validity of BMI-for-age in Latin-American populations. Also, while some data are available validating the first IOTF charts[5,6,8,9] and the CDC growth charts[5,7,8], no study about the validity of the updated IOTF reference as adiposity indicator was found. In children from Switzerland[11], Australia[5] and Tobago[12] the CDC reference had better sensitivity than IOTF. Although there are evidence that the WHO reference can identify children at risk of metabolic abnormalities[13]; we did not find some study that assess its capacity to identify body fat excess.

Most studies about the validity of BMI-for-age are also restrictive because only the sensitivity and specificity of pre-defined cutoff points (e.g. percentile 97 or > 2.00 standard deviation, SD) were estimated, leaving unexplored the possibility of increasing the accuracy of the index by use higher or lower cutoff points. This is relevant since some studies have observed very low sensitivities (<50%) with the percentile 95 of CDC growth charts[5] or the cutoff point to obesity (i.e. the equivalent to 30 kg/m^2 in adulthood) of the previous version of the IOTF reference[6,14]. Such sensitivities can be increased modifying the cutoff points. Finally, previous works have used skinfolds[11,14,15] or bioelectric impedance[12,16] as gold standards, which are not the best indicators of adiposity. On another hand, one problem concerning the existence of multiple references is that the estimates of the obesity rates differ according to the reference and the cutoff points utilized, limiting comparisons between studies that applied different criteria.

In this work we compared the accuracy of the three BMI-for-age references (WHO, CDC, and IOTF) and determined the optimal cutoff point to identify obesity by means of these BMI references. A study of diagnostic validity was carried out using the percentage of body fat estimated by deuterium dilution technique as gold standard.

Methods

Sample

Sampling was carried out in two phases. First, with exception of children with plaster cast or motor disabilities, all students (n=1,050) aged 5 to 12 years from two primary schools of Coyoacan County in Mexico City were invited to participate in an assessment of weight and height. Six hundred seven parents consented the participation of their children. With this data, children with normal weight, overweight, and obesity were identified. In the second phase a quota sampling was done aimed to obtain a heterogeneous sample in terms of sex, age, and nutritional status. An exhaustive evaluation of body dimensions and body composition was carried out in the final sample (n=218).

In both phases the written informed consent were obtained from children and their guardians. The Ethics Committee of the Health and Biological Sciences Division from the Metropolitan Autonomous University campus Xochimilco approved the research protocol. The authors declare that they do not have conflicts of interest.

Body fat

The estimation of body fat by means of deuterium dilution have been validated in Mexican children[17]. Measurements of total body water (TBW) were made using hydrometry with stable, non-radioactive, non-toxic isotope deuterium oxide ($^{2}H_2O$). Participants were fasted at the time of dosing. A saliva sample (≈ 2 ml) was collected upon arrival at the elementary school to determine the basal $^{2}H_2O$ concentration. After that, the participants received an accurately weighed oral dose (0.1 g/kg of body weight) of $^{2}H_2O$ (99.9% atom percent excess; Cambridge Isotope Laboratories, Andover, MA, USA). To ensure complete ingestion of the total dose, the container was rinsed with 20 ml of bottled water and given to participants to drink. Following the ^2H_2O dosing, post-dose salivary samples were collected after 3.5-4.0 h of equilibrium time (i.e. the time needed for the tracer to equilibrate with all water spaces)[18]. Due to conditions of the fieldwork (i.e. the children were in the school), only limited restrictions were imposed on dietary or fluid intake on the participants during the equilibrium period, and a light meal was given to all of them 1 h after the deuterium dose was ingested, as has been suggested[19]. The volumes of water in food and beverage were recorded so they could be subtracted from the dilution space. All saliva samples were stored in a freezer at -20ºC in tubes with screw-on caps.

The enrichment of the bottled water, the dose given, and the ^2H_2O in the pre-dose and post-dose samples were measured by chromium reduction of water into hydrogen gas at 850°C using an H/Device system coupled online to an isotope-ratio mass spectrometer (DELTA PLUS, Thermo Finnigan, Bremen, Germany) at the Unit of Medical Research in Nutrition of the *Centro Médico Nacional Siglo XXI*, Mexican Institute of Social Security, in Mexico City. The results were expressed relative to standards measured against V-SMOW and SLAP[20], with a precision of 0.16-0.32 ppm. All assays were performed in triplicate.

The dilution space was calculated by subtracting the pre-dose saliva sample enrichment from that of the post-dose sample, based on the dilution principle, and corrected considering a 4% deuterium exchange with non-aqueous compartment in the body[19]. The fat free mass (FFM, kg) was calculated using Fomon's age and gender specific hydratation values, and was then recalculated as described by Schoeller[19]. For children older than 10 years, FFM was calculated using the hydration factors proposed by Lohman[21]. The percent of body fat (%BF) was subsequently derived from FFM and body weight (W) as follows: %BF = [(W-FFM)/W] x 100. Finally, a child was considered obese when the %BF was equal or higher than 25.0% in boys and 30.0% in girls. In children, higher adiposity than these cutoff points has been associated with an increased cardio-metabolic risk[22,23].

Body mass index for age

Using standardized protocols[24,25], the observers were trained to measure weight and height. The BMI-for-age was estimated using the WHO[4], the CDC[3], and updated IOTF[2] references.

Analysis

The mean and standard deviation of anthropometry and body composition variables were calculated. The rates of obesity were estimated using the classical cutoff point (i.e. Z score > 2.0) of three BMI references. The performance of each BMI-for-age reference to diagnose obesity using the classical cutoff point (> 2.0 SD) was assessed using the following estimates: sensitivity (true positives/[true positives + false negatives]), specificity (true negatives/[true negatives + false positives]), and efficiency ([true positives + true negative]/total population). The 95% confidence interval for every estimate was calculated.

The accuracy of the three BMI-for-age references for the diagnosis of obesity was assessed with the receiver operating characteristic (ROC) curves method[26]. With this method the area under the curve (AUC) is obtained, which is a statistic of the diagnostic tool accuracy, i.e. its capacity to differentiate between cases and no-cases. Values of 0.50 to 0.70, 0.70 to 0.90, and ≥ 0.90 of AUC are considered as low, moderate, and high accuracy, respectively. To determine the optimal cutoff point (i.e. that with maximal specificity and sensitivity) the Youden index was estimated[26]. The estimations were made in total population and by sex and age. The statistical analysis was carried out using SPSS and STATA software. The STATA software allows calculate the Chi-square statistic to determine if there are significant statistical differences between two AUC.

Results

Similar number of girls (n=111) and boys (n=107) participated in the study. Age distribution was: 5 to 7 years old, 21.1%; 8 to 9 years, 31.2%; and 10 to 11 years, 47.17% (see table I). The means of weight, BMI, Z score of BMI-for-age with the three references, and fat free mass (FFM) were higher in boys than girls; but the opposite occurred with height and fat mass (FM). The older children had higher values of weight, height, BMI, FMM, and FM. The 8-9 years old children had higher mean of percentage of body fat and Z score of BMI-for-age with the three references.

Taking into account the body fat percent, almost four out ten schoolchildren had obesity (45.4%) and the rate was higher in boys and older children (10 to 12 years old) (see table II). The highest prevalence of obesity was obtained with the WHO reference (30.7%), whereas the lowest was estimated with the IOTF reference (19.7%). The estimates of obesity rates derived from BMI-for-age references were lower than ones obtained with body fat percent. These differences were similar in both sexes and in the three age groups.

Using the cutoff points to identify obesity (i.e. > 2.0 SD), the sensitivity of the WHO and CDC references was low (57.6% and 53.5%, respectively), while with the IOTF reference was very low (40.4%) (see table III). With the three references the specificities (>90%) were adequate, while the efficiencies were moderate (71.5-77.1%). In contrast with the values obtained for boys, in girls the sensitivities

Table I
Descriptive analysis [a] of anthropometry and body composition of a sample of Mexican school children by sex and age

		Sex		Age		
	All, n=218	*Boys, n=107*	*Girls, n=111*	*5-7 yr., n=46*	*8-9 yr., n=68*	*10-12 yr., n=104*
Age, yr.	9.3 (1.8)	9.2 (1.8)	9.3 (1.9)	6.7 (0.6)	8.5 (0.5)	10.9 (0.7)
Weight, kg	39.6 (12.3)	40.3 (13.0)	38.8 (11.6)	28.0 (6.1)	36.3 (9.6)	46.8 (11.1)
Height, cm	138.5 (12.0)	138.2 (12.3)	138.8 (11.8)	123.8 (6.2)	133.6 (6.4)	148.2 (7.3)
BMI, kg/m^2	20.2 (4.0)	20.6 (4.2)	19.8 (3.8)	18.1 (2.9)	20.1 (4.1)	21.1 (4.1)
Z-BMI/WHO	1.2 (1.3)	1.5 (1.3)	1.0 (1.2)	1.2 (1.3)	1.4 (1.4)	1.1 (1.2)
Z-BMI/CDC	0.9 (1.1)	1.1 (1.1)	0.7 (1.0)	0.9 (1.1)	1.0 (1.1)	0.8 (1.0)
Z-BMI/IOTF	1.3 (1.2)	1.5 (1.2)	1.1 (1.1)	1.2 (1.2)	1.4 (1.3)	1.2 (1.1)
FFM, kg	28.6 (7.8)	29.8 (8.2)	27.4 (7.2)	20.8 (3.0)	25.9 (4.8)	33.8 (7.0)
FM, kg	11.0 (6.5)	10.5 (7.1)	11.4 (6.0)	7.2 (3.6)	10.4 (6.2)	13.0 (7.0)
FM, %	26.2 (9.6)	24.2 (10.1)	28.1 (8.6)	24.3 (8.7)	26.8 (10.1)	26.6 (9.6)

[a] Mean and standard deviation (in parenthesis) are reported.
Abbreviators: BMI, body mass index; Z-BMI/WHO, Z score of BMI-for-age according to World Health Organization reference (de Onis et al., 2007); Z-BMI/CDC, Z score of BMI-for-age according to Centers for Disease Control and Prevention reference (Kuczmarski et al., 2002); BMI/IOTF, Z score of BMI-for-age according to the International Obesity Task Force reference (Cole and Lobstein, 2012). FFM, fat free mass; FM, fat mass.

Table II
Overweight and obesity rates according to different criteria among a sample of Mexican schoolchildren

	Total		*Sex*		*Age (years)*		
			Boys	*Girls*	*5-7*	*8-9*	*10-12*
	n	*%*	*%*	*%*	*%*	*%*	*%*
Body fat percent [a]							
Normal	119	54.6	50.5	58.6	63.0	52.9	51.9
Obesity	99	45.4	49.5	41.4	37.0	47.1	48.1
Z-BMI/WHO							
Normal	151	69.3	58.0	80.2	67.4	66.2	72.1
Obesity	67	30.7	42.0	19.8	32.6	33.8	27.9
Z-BMI/CDC							
Normal	159	72.9	62.6	82.9	67.4	67.6	78.9
Obesity	59	27.1	37.4	17.1	32.6	32.4	21.2
Z-BMI/IOTF							
Normal	175	80.3	73.8	86.5	80.4	75.0	83.6
Obesity	43	19.7	26.2	13.5	19.6	25.0	16.4

[a] Estimated through isotopic dilution and using the cutoff point of 25% in boys and 30% in girls.
Abbreviators: Z-BMI/WHO, Z score of BMI-for-age according to World Health Organization reference (de Onis et al., 2007); Z-BMI/CDC, Z score of BMI-for-age according to Centers for Disease Control and Prevention reference (Kuczmarski et al., 2002); BMI/IOTF, Z score of BMI-for-age according to the International Obesity Task Force reference (Cole and Lobstein, 2012).

(49.1-71.7% versus 30.4-41.3%) and efficiencies (72.9-79.4% versus 70.3-73.9%) were lower, but the specificities (87.0-96.3% versus 95.4-98.5%) were higher. The sensitivity, specificity, and efficiency values in the older group tended to be lower than in the younger groups.

In the total sample, the accuracy of three references was moderate (AUC=0.89) (see table IV). The optimal

Table III
Validity of BMI references as indicators of obesity[a] by sex and age group in a sample of Mexican children

		Z-BMI / WHO[b]	*Z-BMI / CDC[c]*	*Z-BMI / IOTF[d]*
Total	Se	57.6 (47.2-67.5)	53.5 (43.2-63.6)	40.4 (30.7-50.7)
	Sp	91.6 (85.1-95.9)	95.0 (89.3-98.1)	97.5 (92.8-99.5)
	Ef	76.1 (69.9-81.6)	77.1 (70.9-82.5)	71.5 (65.1-77.4)
Sex				
Boys	Se	71.7 (57.7-83.2)	66.0 (51.7-78.5)	49.1 (35.1-63.2)
	Sp	87.0 (75.1-94.6)	90.7 (79.7-96.9)	96.3 (87.3-99.5)
	Ef	79.4 (70.5-86.6)	78.5 (69.5-85.8)	72.9 (63.4-81.0)
Girls	Se	41.3 (27.0-56.8)	39.1 (25.1-54.6)	30.4 (17.7-45.8)
	Sp	95.4 (87.1-99.0)	98.5 (91.7-100.0)	98.5 (91.7-100.0)
	Ef	73.0 (63.7-81.0)	73.9 (64.7-81.7)	70.3 (60.8-78.6)
Age				
5-7 yr.	Se	76.5 (50.1-93.2)	76.5 (50.1-93.2)	52.9 (27.8-77.0)
	Sp	93.1 (77.2-99.2)	93.1 (77.2-99.2)	100.0 (88.1-100.0)
	Ef	87.0 (73.7-95.0)	87.0 (73.7-95.0)	82.6 (68.6-92.2)
8-9 yr.	Se	65.6 (46.8-81.4)	65.6 (46.8-81.4)	50.0 (31.9-68.1)
	Sp	94.4 (81.3-99.3)	97.2 (85.5-99.9)	97.2 (85.5-99.9)
	Ef	80.8 (69.5-89.4)	82.3 (71.2-90.5)	75.0 (63.0-84.7)
10-12 yr.	Se	46.0 (31.8-60.7)	38.0 (24.7-52.8)	30.0 (17.9-44.6)
	Sp	88.9 (77.4-95.8)	94.4 (84.6-98.8)	96.3 (87.3-99.5)
	Ef	68.2 (58.4-77.0)	67.3 (57.3-76.2)	64.4 (54.4-73.6)

[a]Estimated through isotopic dilution and using the cutoff point of 25% in boys and 30% in girls. [b]Z-BMI / WHO, Z score of BMI-for-age according to World Health Organization reference (de Onis et al., 2007); [c]Z-BMI / CDC, Z score of BMI-for-age according to Centers for Disease Control and Prevention reference (Kuczmarski et al., 2002); [c]Z-BMI / IOTF, Z-score of BMI-for-age according to the International Obesity Task Force reference (Cole and Lobstein, 2012).
For the three BMI references the sensitivity (Se), specificity (Sp), and efficiency (Ef) with their respective confidence intervals (in parenthesis) were estimated. In the three cases the cutoff point to define obesity was > 2.00 standard deviation.

cutoff point (OCP) for the CDC reference (1.24) was lower that the OCP for WHO (1.53) and IOTF references (1.47). The sensitivity (77.8-83.8%), specificity (80.7-84.%), and efficiency (81.2-86.1%) of the OCP for each reference were moderate.

There were not differences among sexes respect the AUC of references. The OCP for the CDC and IOTF references were higher in girls than in boys. For the three references, the AUC and the OCP were lower in oldest children than in youngest ones. For example, for the IOTF reference the AUC was 0.97 among children aged 5-7 years and 0.85 in those aged 10-12 years ($p<0.050$). The sensitivities, specificities, and efficiencies were lower in older children.

Discussion

Among Mexican school children, the classical cutoff point for references of BMI-for-age (> 2 SD) did not provided an estimation of obesity prevalence closer to that one derivate by deuterium dilution technique. The classical cutoff point to identify obesity with the three references had low (CDC and WHO charts) or very low (IOTF) sensitivities. With the ROC curves approach a cutoff point for each reference was identified and better balance between sensitivity and specificity was obtained. The accuracy of these references was lower in older children.

In our study, the "gold standard" was the %BF estimated through deuterium isotopic dilution, which has been validated previously in Mexican children[17]. With this method, four out of ten children had obesity. Referred to this estimates, those obtained with the classical cutoff point to diagnose obesity with BMI-for-age were lower: from -14.7 (difference respect to the prevalence derived from WHO reference) to -25.7 (difference respect to the rate estimated from IOTF reference). This shows that the references based in more contemporary American populations (i.e. the CDC charts were made with data collected from 1963 to 1980) produced lower figures of obesity rates than

Table IV
Accuracy and optimal cutoff point of BMI to diagnostic obesity[a] in a sample of Mexican schoolchildren. Differences between reference populations and by sex and age

	AUC	*OCP*	*Se*	*Sp*	*Ef*
Z-BMI / WHO					
Total	0.89 (0.85-0.93)	1.53	77.8 (68.3-85.5)	84.0 (76.2-90.1)	81.2 (75.4-86.1)
Sex					
Boys	0.91 (0.86-0.96)	1.64	86.8 (74.7-94.5)	81.5 (68.6-90.7)	84.1 (75.8-90.5)
Girls	0.86 (0.79-0.93)	1.53	67.4 (52.0-80.5)	89.2 (79.1-95.6)	80.2 (71.5-87.1)
Age group					
5-7 yr.	0.95[b] (0.90-1.00)	1.75	88.2 (63.6-98.5)	93.1 (77.2-99.2)	91.3 (79.2-97.6)
8-9 yr.	0.92 (0.86-0.98)	1.22	100.0 (89.1-100.0)	66.7 (49.0-81.4)	82.3 (71.2-90.5)
10-12 yr.	0.84[b] (0.77-0.92)	1.13	82.0 (68.6-91.4)	74.1 (60.3-85.0)	77.9 (68.7-85.4)
Z-BMI / CDC					
Total	0.89 (0.84-0.93)	1.24	78.8 (69.4-86.4)	84.0 (76.2-90.1)	86.1 (75.9-86.5)
Sex					
Boys	0.91 (0.85-0.96)	0.88	96.2 (87.0-99.5)	70.4 (56.4-82.0)	83.2 (74.7-89.7)
Girls	0.86 (0.79-0.93)	1.24	69.6 (54.2-82.3)	89.2 (79.1-95.6)	81.1 (72.5-87.9)
Age group					
5-7 yr.	0.97[b] (0.92-1.00)	1.33	94.1 (71.3-99.9)	93.1 (77.2-99.2)	93.5 (82.1-98.6)
8-9 yr.	0.92 (0.85-0.98)	0.96	100.0 (89.1-100.0)	66.7 (49.0-81.4)	82.3 (71.2-90.5)
10-12 yr.	0.84[b] (0.77-0.92)	1.00	78.0 (64.0-84.5)	77.8 (64.4-88.0)	77.9 (68.7-85.4)
Z-BMI / IOTF					
Total	0.89 (0.85-0.93)	1.47	83.8 (75.1-90.5)	80.7 (72.4-87.3)	82.1 (76.4-86.9)
Sex					
Boys	0.91 (0.86-0.96)	1.09	96.2 (87.0-99.5)	70.4 (56.4-82.0)	83.2 (74.7-89.7)
Girls	0.86 (0.80-0.93)	1.48	80.4 (66.1-90.6)	83.1 (71.7-91.2)	82.0 (73.5-88.6)
Age group					
5-7 yr.	0.97[b] (0.93-1.00)	1.88	88.2 (63.6-98.5)	93.1 (77.2-99.2)	91.3 (79.2-97.6)
8-9 yr.	0.91 (0.85-0.98)	1.80	78.1 (60.0-90.7)	88.9 (73.9-96.9)	83.8 (72.9-91.6)
10-12 yr.	0.85[b] (0.77-0.92)	1.04	86.0 (73.3-94.2)	72.2 (58.4-83.5)	78.8 (69.7-86.2)

[a]The gold standard was the body fat estimated through isotopic dilution and using the cutoff point of 25% in boys and 30% in girls.
[b]Differences among age groups $p < 0.050$ using the same reference.
Area under the curve (AUC) of each BMI-for-age reference is reported. For each optimal cutoff point (OCP) the sensitivity (Se), specificity (Sp), efficiency (Ef) with their respective confidence intervals (in parenthesis) were estimated.
Abbreviators: Z-BMI / WHO, Z score of BMI-for-age according to World Health Organization reference (de Onis et al., 2007); Z-BMI / CDC, Z score of BMI-for-age according to Centers for Disease Control and Prevention reference (Kuczmarski et al., 2002); Z-BMI / IOTF, Z score of BMI-for-age according to the International Obesity Task Force reference (Cole et al., 2012).

those based in surveys carried out previously (i.e. the WHO reference is based in data collected between 1963 and 1974). This difference can be attributed to the increasing obesity rate experienced in American contemporary populations in the last decades[27]. Although the IOTF reference was built in with populations from six countries (including American participants), it produces a lower rate of obesity. Again, the time when the fieldwork was done should be considered: the data for the IOTF reference was collected in the decades of sixties-to-nineties[28].

With respect the results of the accuracy assessment, when the classical cutoff point (> 2 SD) was used, the sensitivities of the references tending to be low (CDC and WHO) or very low (IOTF). In other populations the IOTF reference has had low sensitivity[6,9] and some studies have showed that the CDC reference is more accurate than the IOTF[5,11,12]. These results showed that in order to assess adiposity, it is necessary to identify a cutoff point for each reference to yield estimations closer to a more precise method.

For clinical practice and population studies, a diagnostic tool to identify obesity with highest accuracy is required. If the diagnostic tool will be used in the clinical practice, it should have high specificity to avoid negative consequences in children after wrongful positive diagnosis, such as stigma, excessive concern due their body weight or body image, and parental pressure. Likewise, is convenient to avoid low sensitivity, otherwise the children that can be beneficiated by any treatment would not be identified. On the other hand, when the diagnostic tool is used in epidemiologic research (i.e. prevalence rate estimation) a balance is necessary because low sensitivity yields sub-estimation of the outcome, while the opposite occurs with low specificity; in other words, higher efficiency is recommendable. Although in our sample the CDC, IOTF, and WHO references had similar accuracy to diagnose obesity (AUC=0.89), the cutoff point that maximizes sensitivity and specificity was lower in the first one (1.24, 1.47, and 1.53, respectively). In this respect, de Onis[29] noticed that the CDC reference has upward skewness, therefore its use could imply that American children who have gained weight in the context of obesity epidemic were to considered normal. To avoid this situation, lower cutoff point should be used when the CDC reference is utilized.

In general terms, among older children the accuracy of the three references was lower. This might be a reflection of the onset of puberty spurt among older girls. Due to differences of timing of the puberty, an increase of the variability of the BMI occurs during the adolescence and the association of the body fat with the BMI changes[30]. In future studies the role of sexual maturity on accuracy of BMI-for-age references should be examined.

Our study has several limitations. The sampling was by convenience; therefore the representativeness of our sample is restricted. The small size of sample precluded us to verify if there were differences in validity of the BMI-for-age references according to age within each sex group. In addition, the small sample size produces wider confidence intervals in the stratified analysis. Finally, although our gold standard was an adiposity measure, we did not include any clinical outcome to assess the capacity of BMI-for-age references to identify higher risks for health.

In summary, when in this sample of Mexican children the classical cutoff for the three references under evaluation were used, the results were not comparable because they produced divergent estimations of obesity rate and they have low to very low sensitivity. But, when the full range of values of three references was examined, the three references had adequate accuracy. Our results suggest that to obtain comparable results is needed to use different cutoff for each reference; also is not convenient to use the classical cutoff point for obesity, especially for the IOTF reference. Although is necessary to confirm if our results are replicated in a larger and representative sample, our data suggest that in epidemiological studies –in which often only the weight and height are assessed– the obesity in Mexican children could be diagnosed using as criteria ≥ 1.53 SD of the WHO reference ≥ 1.47 SD of IOTF reference, or ≥ 1.53 SD of the WHO reference. The use of these cutoff points could enable the comparison among studies that use different references.

Conflict of Interest statement

We claim no conflict of interest related to our research.

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