Title:

Waist circumference percentiles for Hispanic-American children and comparison with other international references

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Abstract

Introduction: Waist circumference (WC) constitutes an indirect measurement of central obesity in children and adolescents.
Objective: To provide percentiles of WC for Hispanic-American children and adolescents, and compare them with other international references.
Materials and methods: The sample comprised 13 289 healthy children between 6 and 18 years coming from public schools of middle and low socio-economic levels in different parts of Argentina, Cuba, Spain, Mexico, and Venezuela. The LMS method to calculate WC percentiles was applied. Sex and age differences were assessed using Student's t test and ANOVA (SPSS v.21.0). Comparisons were established with references from the United States, Colombia, India, China, Australia, Kuwait, Germany, Tunisia, Greece, and Portugal.
Results: WC increases with age in both sexes. Boys show higher WC in P3, P50, and P97. Comparison of 50th and 90th percentiles among populations from diverse sociocultural and geographical contexts shows high variability, not all justified by the measurement method.

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Introduction

The number of obese children and adolescents in the world has increased tenfold in the last 40 years and, if the trend continues, by 2022 there will be more school population with obesity than with moderate or severe underweight (Garrido-Miguel, Cavero-Redondo, Alvarez-Bueno, & Rodriguez Artalejo, 2019). Lobstein and Jackson-Leach (2016) also estimated high figures of obesity-related co-morbidities by 2025: impaired glucose tolerance (12 million), type 2 diabetes (4 million), hypertension (27 million), and hepatic steatosis (38 million).

These estimates for obesity are based on the body mass index (BMI) which is the most commonly used indicator to evaluate weight excess (Arroyo-Johnson & Mincey, 2016). It is easy to calculate and there is a proved association with lipid metabolism alterations and increased cardiovascular risk factors (Zhang, Zhang, & Li, 2019; Varda, Medved, & Ojsteršek, 2020; Brzezinski, Metelska, My▪ sliwiec, & Szlagatys-Sidorkiewicz, 2020).

However, BMI does show limitations for identifying child overweight and obesity, since the prevalence obtained depends on the criteria, cut-off points, references or standards used (Meyer et al., 2013; Martínez-Alvarez, Villarino Marín, García Alcón, Calle Purón, & Marrodán, 2013; Bergel et al., 2014). BMI is also controversial because it does not distinguish between fat and fat-free mass, and does not provide information on the distribution of body fat. This aspect is essential because the location of excess fat tissue accumulation is more significant than the amount of total fat, as a co-morbidity triggering factor in children and adolescents (Ali et al., 2014; Figueroa Sobrero et al., 2016; Viitasalo et al., 2019). Consistent with adult observations, waist circumference (WC) in children is a predictor independent from insulin resistance, lipid levels, and blood pressure (Zimmet et al., 2007). This measurement is an especially informative parameter for central obesity, where the association with amount of total fat has been confirmed by different methods of body composition, such as skin fold thickness, bioelectric impedance, air-displacement plethysmography, and dual-energy X-ray absorptiometry (Fernández et al., 2017).

Some studies show a positive secular trend of WC seemingly independent of the changes experienced by BMI or weight stabilization (McCarthy, Jarrett, Emmett & Rogers, 2005; Moreno, Sarría, Fleta, Marcos & Bueno, 2005; Fernández et al., 2017). To outweigh ontogenetic variations, some experts suggest the use of WC curves and a 90th percentile cut-off value to define central obesity. They consider that subjects with values higher than such a limit have a significant probability of suffering a cardiovascular disease (Zimmet et al., 2007, Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents; National Heart, Lung, and Blood Institute, EPIC, 2011). Given the population variability of WC during growth (Schwandt & Haas, 2012), it is worth establishing updated normality patterns adapted as far as possible to the anthropobiological composition of the different human groups.

Between 2005 and 2008, a multicenter collaborative project was conducted to collect anthropometric data in children and adolescents from different localities in Spain, Venezuela, Argentina, Cuba, and Mexico. The aim of the present study was to develop age-and sex-smoothed WC reference curves for Hispanic-American children and adolescents. There are some references for WC in the Hispanic-American population derived from samples of the US population. However, these samples include Hispanic residents in the US whose specific origin is unknown. The present study endeavors to provide information based on a large quantity of data from Spain and four Latin American countries. Meanwhile, considering that the 50th percentile represents the value of the median in the population and the 90th percentile is usually taken as the cut-off point for diagnosing abdominal obesity (EPIC, 2011). The intention is also to compare 50th and 90th percentiles in our sample with other references obtained also by the LMS method in different populations.

Materials and Methods

The sample consisted of 13 289 schoolchildren (6575 boys and 6714 girls) between 6 and 18 years old, without obvious pathologies, that were recruited between 2005 and 2011 in public schools at different locations in Argentina (Catamarca and Jujuy), Cuba (Havana), Spain (Madrid), Mexico (Hermosillo and Mexico City), and Venezuela (Caracas and Merida). The study included parental or tutorial informed consent and the ethical ruling of the World Medical Association was respected (WMA, 2008).

Table 1 shows the sample distribution by sex and age and Table 2 shows the sample stratified by country and sex. The participants' date of birth was obtained from their national identity document or the School Registry, and the decimal age was calculated. Data were grouped by sex, in 31 age groups with half-year intervals. Anthropometric measurements were obtained by trained staff with standardized instruments and following techniques recommended by the International Biological Programme (Weiner & Lourie, 1981). WC was measured at umbilical level (centimeter) and waist to height ratio (WtHR) was calculated. Abdominal obesity was diagnosed by cut-off points described by Marrodán et al. (2013).

The dispersion of the raw data was analyzed and outliers were removed using a ± 4 SD cut-off according to the criterion used by Alfaro, Bejarano, Dipierri, Quispe & Cabrera (2004). Normal distribution and homogeneity of the variances were checked for all age groups. Sexual dimorphism of WC was assessed using the Student's t test, and mean differences among age groups of 6 months from 6 to 18 years were established by means of an analysis of variance (ANOVA). For the statistical analysis, SPSS v.21.0 software was used, considering a P-value of less than .05 to be significant in all tests.

The LMS method to calculate percentiles was applied. This method synthesizes the changing distribution of a measurement according to some covariate, often age. The method establishes the changing distribution using the L, M, and S curves representing, respectively, the skewness (lambda), median (mu), and measure of variation (sigma). The LMS method uses the Box-Cox transformation to adapt the distribution of anthropometric data to a normal distribution, essentially minimizing the effects of skewness (Cole & Green, 1992). Age- and sex- specific percentile values (3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th) were calculated and their corresponding curves were smoothed. Data processing was performed using the LMS Chart Maker Pro software (The Institute of Child Health, London). The Q test was used to establish the goodness of fit according to the recommended procedure (Pan & Cole, 2011).

The 90th percentile values in our sample were compared with those of other populations of different ethnic origin that were selected because they computed the WC percentiles using the LMS method and covered a similar age range. The samples used for comparison were from the United States (Fernández et al., 2017), Colombia (Ramírez-Vélez et al., 2017), India (Khadilkar et al., 2014), China (Xiong et al., 2010), Australia (Eisenmann, 2005), Kuwait (Jackson, Al Hamad, Prakash & Al Somaie, 2010), Germany (Schwandt, Kelishadi & Haas, 2008), Greece (Bacopoulou, Efthymiou, Landis, Rentoumis & Chrousos, 2015), Portugal (Sardinha et al., 2012), and Tunisia (Ghouili et al., 2020).

Results

The prevalence of abdominal obesity, as assessed by WtHR (Marrodán et al., 2013), was for the total sample 28.8% in boys and 25.3% in girls. The Mexican series showed the highest values (boys: 36.6%; girls: 40%) while the Cuban series showed the lowest values (boys: 16.7%; girls: 14.2%). Although differences between countries ($P < .05$) were observed in the mean values of WC in some ages (boys: at 11, 13, 15 years; girls: at 8, 10, 14 years) the range of variation and the trend of the growth curve were similar in all datasets. Since the mean is ineffective as a cut-off point, in these circumstances it is legitimate to group the subsamples for the construction of the LMS model (Cole et al, 2000).

Tables 3 and 4 show values for 3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th WC percentiles and L, M, S parameters for boys and girls from 6 to 18 years old, classified by periods of 6 months. The corresponding growth curves are represented in Figure 1 (boys) and Figure 2 (girls). An increase in WC with age is found in both sexes ($P < .001$). Generally, boys show higher WC than girls in P3, P50, and P97, especially in the latter, where differences average 4.6 cm, compared with 1.5 cm in P3, and 0.9 cm in P50. However, sexual differences in P50 were significant at 4, 14, and 16 years ($P < .001$; $P < .05$; $P < .001$, respectively).

Tables 5A and 5B shows the 90th percentile value obtained by the LMS method in the present study and in the compared populations. In general, in both the male and female series, the comparison between countries shows that there is more similarity between the values at the 50th percentiles than at the 90th percentiles. Similarly, for both the 50th and 90th percentiles, the similarities between all of the samples are greater at younger ages, while the differences are more pronounced at pubertal ages, from 12.5 or 13.5 years of age. Values of 50th and 90th percentiles obtained in the present study are higher than those in Australia, Germany, Tunisia, Greece, Colombia, and China. Meanwhile, they are slightly higher than those of India and Kuwait up to 13.5 years, while above that age the trend is reversed, so that Indians and Kuwaitis show higher values for both percentiles. Comparison of our data with both series obtained from 2009 to 2014 National Health and Nutrition Examination Survey data (NHANES) published by Fernández et al. (2017), for subjects between 6.5 and 12.5 years, shows a greater similarity to the 50th percentiles of the combined series (CS, all ethnics groups) than to the Mexican American (MA) series. From age 12.5 onwards, the differences are more pronounced with the MA, which always presents higher values than those in the present study. The 90th percentile of both the CS and the MA series were higher than those of the present study at all ages, but dramatically so from the age of 12.5 years.

Discussion

The main purpose of this study was to provide reference WC percentile values for Hispanic-American children and adolescents aged 6 to 18 years old, specific for age and sex, obtained through the LMS method.

The results evidence the ontogenetic and sexual variation expressed by WC, a feature already verified in prior studies in populations of different ethnic origin (Lek, Yan, Zhang, Wang & Cheung, 2016; Schwandt & Haas, 2012). Since there is no standard recommended by the international health agencies, and taking into account that central fat distribution constitutes a risk factor in child and youth populations, the preparation of patterns that reflect central adiposity changes with age, according to sex, constitute a priority for its application in epidemiologic studies. This necessity, in addition to the fact that inter-ethnic variations affecting this central obesity measurement have been identified, explains the generation of WC percentile curves for populations from diverse sociocultural and geographical contexts.

The comparison among country WC references shows remarkable variability. Specifically, the 90th percentile, which is recommended by the International Diabetes Federation (Zimmet et al.,

2007) as the cut-off point for the diagnosis of abdominal obesity. All the chosen studies have used the LMS method to generate the percentile values. In addition, these are surveys with a high number of participants. In the present study, the sample was composed of 13 389 individuals and the rest of the comparative samples ranged from N = 2038 (Tunisia) to 9593 (Kuwait).

One factor to take into account in the comparison of WC values may be the technique and the anatomical site of measurement. A systematic review of 120 studies (236 samples) carried out by Ross et al. (2008) identified eight different protocols for WC measurement. The authors did not find differences between all sites of WC measurement and morbidity or mortality, but discrepancies were observed in the absolute dimension values that may affect risk cut-off points. Bosy-Westphal et al. (2010) compare the associations between WC measured at three different sites with total visceral adipose tissue (VAT) volume, analyzed by computerized axial tomography. Their study verified that WC measured at the level just above the uppermost lateral border of the iliac crest (WC iliac crest), WC measured just below the lowest rib (WC rib) and WC taken midway between both sites (WC middle), had similar relations with VAT and cardiometabolic risk factors. However, the absolute value of the measure was WC iliac crest > WC middle > WC rib ($P < .001$).

As indicated in the methodology, WC was measured at umbilical level. It should be noted that Wang et al. (2003) reported that percentage body fat is more highly correlated with WC iliac crest values than with other WC values (WC rib, WC middle, and narrowest WC) but is more difficult to measure. Nevertheless, WC at umbilical level practically coincides with the border of the superior iliac crest but is more intuitive and easy to identify (Brown et al., 2018). The same exact point (umbilicus) was used in the Australian study (Eisenmann, 2005). In the comparative international series from the United States (Fernández et al., 2017), India (Khadilkar et al., 2014), China (Xiong et al., 2010), and Greece (Bacopoulou et al., 2015) WC iliac crest was used. In Kuwait (Jackson et al., 2010), Colombia (Ramírez-Vélez et al., 2017), Germany (Schwand et al., 2008), Portugal (Sardinha et al., 2012), and Tunisia (Ghouili et al., 2020) WC middle was the protocol applied.

Values of 50th and 90th percentiles obtained in the present study are higher than those in references for Germany, Tunisia, Greece, and Colombia. This fact could be partly attributed to the measurement site, since as reported by Ross et al. (2008) the WC iliac crest (practically the same as umbilical WC) gives higher values than the WC middle. However, the differences observed are much larger than what would be expected from the technique effect, which in the study of Wang et al. (2003) was quantified in a maximum range of 1.63 cm for the same individual. On the other hand, and contrary to what would be expected from the measurement protocol, the references for Portuguese and Kuwaities, using the middle WC, show values up to 10 cm higher than the Spanish-American ones in the present study.

Since the Australian, American, Indian, and Chinese references used a very similar WC measure, there is less room for placing the responsibility for the contrast on the methodology. The Australian references come from the Australian Health and Fitness Study carried out in 1985 (the oldest data of all the series compared) and show the lowest values. This fact should be interpreted with caution in the context of the secular increase in abdominal obesity worldwide. The Chinese references were produced with data taken between 2003 and 2004 and the North American ones with data taken between 2009 and 2014. Neither the measurement technique nor the temporality of the samples can justify the large differences observed, particularly from adolescence onwards. The greatest differences with the sample of the present study are observed precisely with the NHANES MA series Since the measurement protocol is similar and the ethnic composition of the population is closer to that of Hispanic-Americans, it is worth considering whether the P90 values in particular are not reflecting the effect of the obesogenic environment.

Another factor to consider is what happens when creating growth patterns from contemporary samples (in obesity environment). Perhaps in that case the highest values should not be used as cut-off points. Working with a sample of 124 643 adolescents aged 15, Jiunshiou et al. (2016) found that the optimal WC cutoff point in predicting high cardiovascular risk was the 77th percentile. In the opinion of Monzani et al. (2016), percentile-charts are strongly influenced by the nutritional status of the sample used in a particular moment.

The unequal sample size by country (ranging from N = 1974 in Cuba to N = 3283 in Argentina) as well as a smaller sample size in the extreme ages (6-7 years and 16-18 years) constitutes a limitation of this work. However, the present study has two strengths. It has been conducted with a large number of participants (13 289) that exceeds that of most national studies, including the NHANES 2014 (Fernández al. 2017), and the individuals have been measured by the same research team. Moreover, these references complement those already published for subcutaneous fat skinfolds for the same population (Marrodán et al., 2015; Marrodán et al., 2017).

Conclusion

We have developed WC percentile reference curves for Hispanic-American children aged 6 to 18 years. These can be used to evaluate more accurately the abdominal obesity status in populations with that ancestry. The findings derived from the comparison with other international samples emphasize the suitability of using WC references adapted to the ethnic composition of each population.

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Conflict of interest

The authors declare no conflict of interest.

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Table 1

Sample distribution by sex and age

	Boys (N = 6575)		Girls (N = 6714)	
Age (years)	N	(%)	N	(%)
6	238	3.6	224	3.3
7	352	5.4	309	4.6
8	514	7.8	546	8.1
9	565	8.6	631	9.4
10	643	9.8	680	10.1
11	737	11.2	733	10.9
12	581	8.8	713	10.6
13	688	10.5	761	11.3
14	889	13.5	857	12.8
15	688	10.5	622	9.3
16	350	5.3	290	4.3
17	195	3.0	192	2.9
18	135	2.1	156	2.3
Total	6575		6714	

Table 2

Sample distribution by country and sex

	Argentina	Cuba	México	Spain	Venezuela	Total
Sex	(N)	(N)	(N)	(N)	(N)	(N)
Boys	1635	894	1232	1532	1282	6575
Girls	1648	1080	1351	1370	1265	6714
Total	3283	1974	2583	2902	2547	13289

Table 3

Smoothed percentiles, and L, M, and S values for WC (cm) in boys

Age (years)	L	M	S	P3	P5	P10	P25	P50	P75	P90	P95	P97
6.0	-3.3	56.8	0.0	49.2	49.9	51.1	53.5	56.8	61.2	66.8	71.5	75.4
6.5	-3.2	57.9	0.1	49.9	50.6	51.9	54.4	57.9	62.5	68.5	73.5	77.7
7.0	-3.1	59.0	0.1	50.6	51.4	52.7	55.3	59.0	63.9	70.2	75.5	80.0
7.5	-3.0	60.1	0.1	51.3	52.2	53.6	56.3	60.1	65.3	71.9	77.5	82.4
8.0	-2.9	61.2	0.1	52.1	52.9	54.4	57.2	61.2	66.6	73.6	79.6	84.6
8.5	-2.9	62.4	0.1	52.8	53.7	55.2	58.2	62.4	68.0	75.3	81.5	86.8
9.0	-2.8	63.5	0.1	53.5	54.5	56.0	59.1	63.5	69.4	76.9	83.3	88.8
9.5	-2.7	64.6	0.1	54.2	55.2	56.9	60.1	64.6	70.7	78.5	85.0	90.6
10.0	-2.6	65.7	0.1	55.0	56.0	57.7	61.0	65.7	71.9	79.9	86.6	92.1
10.5	-2.5	66.8	0.1	55.8	56.8	58.6	62.0	66.8	73.1	81.2	87.9	93.5
11.0	-2.4	67.9	0.1	56.6	57.7	59.5	63.0	67.9	74.3	82.4	89.1	94.6
11.5	-2.4	69.0	0.1	57.5	58.6	60.4	64.0	69.0	75.5	83.6	90.1	95.4
12.0	-2.3	70.1	0.1	58.4	59.6	61.4	65.1	70.1	76.6	84.7	91.1	96.2
12.5	-2.2	71.2	0.1	59.4	60.6	62.5	66.1	71.2	77.7	85.6	91.9	96.8
13.0	-2.2	72.2	0.1	60.4	61.6	63.5	67.2	72.2	78.7	86.5	92.6	97.3
13.5	-2.1	73.2	0.1	61.3	62.5	64.5	68.2	73.2	79.7	87.3	93.1	97.7
14.0	-2.1	74.2	0.1	62.2	63.4	65.4	69.1	74.2	80.5	88.0	93.6	97.9
14.5	-2.0	75.0	0.1	63.1	64.3	66.3	70.0	75.0	81.3	88.6	94.0	98.1
15.0	-2.0	75.8	0.1	63.9	65.1	67.1	70.8	75.8	82.0	89.1	94.3	98.3
15.5	-1.9	76.5	0.1	64.6	65.8	67.8	71.6	76.5	82.6	89.6	94.6	98.4
16.0	-1.9	77.2	0.1	65.3	66.5	68.5	72.2	77.2	83.2	90.0	94.9	98.5
16.5	-1.8	77.7	0.1	65.9	67.1	69.1	72.8	77.7	83.7	90.3	95.1	98.6
17.0	-1.8	78.2	0.1	66.4	67.6	69.6	73.4	78.2	84.1	90.6	95.3	98.6
17.5	-1.7	78.7	0.0	66.9	68.1	70.1	73.9	78.7	84.5	90.9	95.4	98.7
18.0	-1.7	79.1	0.0	67.4	68.6	70.6	74.3	79.1	84.9	91.1	95.5	98.7

Table 4

Smoothed percentiles, and L, M, and S values for WC (cm) in girls

Age (years)	L	M	S	P3	P5	P10	P25	P50	P75	P90	P95	P97
6.0	-2.4	56.3	0.1	47.7	48.6	50.0	52.7	56.3	61.0	66.5	70.8	74.2
6.5	-2.3	57.3	0.1	48.4	49.3	50.7	53.5	57.3	62.1	67.9	72.3	75.8
7.0	-2.2	58.3	0.1	49.1	50.0	51.5	54.4	58.3	63.4	69.3	73.9	77.5
7.5	-2.1	59.4	0.1	49.8	50.8	52.3	55.3	59.4	64.6	70.8	75.5	79.2
8.0	-2.1	60.5	0.1	50.6	51.6	53.2	56.3	60.5	65.9	72.3	77.2	80.9
8.5	-2.0	61.7	0.1	51.4	52.4	54.1	57.4	61.7	67.3	73.9	78.8	82.7
9.0	-1.9	63.0	0.1	52.3	53.4	55.1	58.5	63.0	68.8	75.5	80.6	84.5
9.5	-1.9	64.4	0.1	53.3	54.4	56.2	59.7	64.4	70.3	77.1	82.3	86.2
10.0	-1.8	65.8	0.1	54.4	55.5	57.4	61.0	65.8	71.8	78.7	83.9	87.9
10.5	-1.7	67.1	0.1	55.4	56.6	58.5	62.2	67.1	73.2	80.2	85.4	89.3
11.0	-1.6	68.3	0.1	56.4	57.6	59.6	63.4	68.3	74.5	81.5	86.6	90.4
11.5	-1.6	69.4	0.1	57.4	58.6	60.6	64.4	69.4	75.6	82.6	87.6	91.3
12.0	-1.5	70.4	0.1	58.2	59.4	61.5	65.3	70.4	76.6	83.4	88.3	91.8
12.5	-1.4	71.2	0.1	58.9	60.2	62.3	66.2	71.2	77.4	84.0	88.7	92.2
13.0	-1.3	72.0	0.1	59.6	60.9	63.0	66.9	72.0	78.0	84.5	89.1	92.3
13.5	-1.2	72.5	0.1	60.2	61.5	63.6	67.5	72.5	78.5	84.8	89.2	92.3
14.0	-1.1	73.0	0.1	60.7	62.0	64.1	68.0	73.0	78.9	85.1	89.3	92.3
14.5	-1.0	73.5	0.1	61.1	62.5	64.6	68.5	73.5	79.3	85.3	89.4	92.2
15.0	-0.9	74.0	0.1	61.6	62.9	65.1	69.0	74.0	79.6	85.5	89.4	92.2
15.5	-0.8	74.4	0.1	62.1	63.4	65.6	69.5	74.4	80.0	85.8	89.6	92.2
16.0	-0.8	74.9	0.1	62.6	63.9	66.1	70.0	74.9	80.4	86.1	89.7	92.3
16.5	-0.7	75.4	0.1	63.1	64.4	66.6	70.6	75.4	80.9	86.4	90.0	92.5
17.0	-0.6	76.0	0.0	63.6	65.0	67.2	71.1	76.0	81.4	86.8	90.3	92.7
17.5	-0.5	76.5	0.0	64.2	65.6	67.8	71.7	76.5	81.9	87.2	90.6	93.0
18.0	-0.5	77.1	0.0	64.8	66.2	68.4	72.3	77.1	82.4	87.7	91.0	93.3

Table 5

Comparison of WC 90th percentile between present study and other international samples

Boys	present study		US NHANES CS (1)		US NHANES MA (2)		COLOMBIA (3)		INDIA (4)		CHINA (5)		AUSTRALIA (6)		KUWAIT (7)		GERMANY (8)		TUNISIA (9)		GREECE (10)		PORTUGAL (11)	
Age	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**
6.5	57.9	68.5	56.8	67.4	58.2	72.0	-	-	56.1	64.0	55.7	65.8	-	-	52.6	62.9	-	-	54.2	60.5	-	-	-	-
7.5	60.1	71.9	59.1	71.4	60.7	76.3	-	-	58.7	67.4	56.9	67.9	55.4	61.9	54.8	67.0	55.7	62.6	56.0	62.9	-	-	-	-
8.5	62.4	75.3	61.3	75.4	63.2	80.7	-	-	61.3	70.9	57.9	69.7	57.1	64.4	57.2	71.7	57.0	64.9	58.0	65.6	-	-	-	-
9.5	64.6	78.5	63.6	79.3	65.8	85.0	59.4	69.9	64.2	74.6	59.3	72.0	58.6	66.6	60.0	76.8	58.6	67.5	59.9	68.0	-	-	-	-
10.5	66.8	81.2	65.9	83.3	68.3	89.3	60.3	72.4	67.3	78.4	61.0	74.6	60.1	68.8	63.3	82.1	60.7	70.6	61.9	70.6	-	-	-	-
11.5	69.0	83.6	68.2	87.3	70.8	93.6	62.0	75.5	70.4	82.3	62.8	77.0	61.8	71.3	66.7	87.1	62.9	74.0	64.1	73.3	-	-	-	-
12.5	71.2	85.6	70.4	91.3	73.3	98.0	63.3	75.7	73.3	85.8	64.6	79.1	63.8	74.1	69.9	91.5	64.8	77.1	66.3	75.8	69.7	83.8	-	-
13.5	73.2	87.3	72.7	95.2	75.8	102.3	64.6	75.3	75.8	88.8	66.9	81.2	66.6	77.2	72.5	93.5	-	-	68.6	78.4	71.0	84.8	-	-
14.5	75.0	88.6	75.0	99.2	78.3	106.6	65.7	76.7	78.0	91.2	69.7	84.0	69.4	79.9	74.9	98.5	-	-	70.6	80.6	72.1	85.0	-	-
15.5	76.5	89.6	77.3	103.2	80.8	110.9	68.1	78.3	79.8	93.2	71.3	85.3	71.6	81.7	76.8	101.1	-	-	72.3	82.5	73.0	85.3	76.4	92.2
16.5	77.7	90.3	79.5	107.2	83.3	115.3	70.0	78.6	81.3	94.9	71.6	85.4	-	-	78.5	103.3	-	-	74.5	84.8	74.2	86.1	78.1	92.8
17.5	78.7	90.9	81.8	111.2	85.8	119.6	71.2	82.3	82.7	96.3	71.3	84.9	-	-	79.9	105.2	-	-	76.9	87.6	73.8	85.1	79.2	94.0
18.0	79.1	91.1	84.1	115.1	88.3	123.9	-	-	-	-	-	-	-	-	81.1	106.7	-	-	79.3	90.4	-	-	80.9	95.9
Girls	**present study**		**US NHANES CS (1)**		**US NHANES MA (2)**		**COLOMBIA (3)**		**INDIA (4)**		**CHINA (5)**		**AUSTRALIA (6)**		**KUWAIT (7)**		**GERMANY (8)**		**TUNISIA (9)**		**GREECE (10)**		**PORTUGAL (11)**	
Age	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**	**P50**	**P90**
6.5	57.3	67.9	56.8	68.4	58.3	71.0	-	-	56.1	64.9	52.5	60.2	-	-	52.6	63.0	54.8	61.8	53.06	58.56	-	-	-	-
7.5	59.4	70.8	59.1	72.4	60.7	74.7	-	-	58.7	68.1	53.3	62.0	54.9	62.7	54.9	67.2	55.9	59.4	54.68	60.87	-	-	-	-
8.5	61.7	73.9	61.5	76.4	63.2	78.4	-	-	61.2	71.3	54.3	63.8	56.3	64.7	57.2	71.7	57.2	65.8	56.95	64.0	-	-	-	-
9.5	64.4	77.1	63.8	80.4	65.6	82.2	58.0	68.8	64.0	74.6	55.7	65.8	57.6	66.5	60.0	76.5	58.7	68.2	59.76	67.84	-	-	-	-
10.5	67.1	80.2	66.1	84.5	68.0	85.9	59.6	71.0	67.2	78.3	57.7	68.1	59.0	68.3	63.1	81.6	60.7	71.3	62.44	71.60	-	-	-	-
11.5	69.4	82.6	68.4	88.5	70.5	89.6	60.8	71.0	70.5	82.1	60.1	70.6	60.6	70.4	66.6	86.7	62.8	74.7	64.84	74.98	-	-	-	-
12.5	71.2	84.0	70.8	92.5	72.9	93.3	61.9	72.5	73.5	85.5	62.6	73.3	62.7	72.8	69.9	91.3	-	-	67.14	78.12	66.2	78.6	-	-
13.5	72.5	84.8	73.1	96.5	75.4	97.0	64.3	74.3	76.1	88.3	65.1	75.7	64.9	75.0	72.5	95.2	-	-	69.30	80.95	67.2	79.0	-	-
14.5	73.5	85.3	75.4	100.5	77.8	100.8	72.0	77.0	78.0	90.3	67.1	77.5	66.8	77.0	74.9	98.5	-	-	71.14	83.20	67.6	78.7	-	-
15.5	74.4	85.8	77.7	104.5	80.3	104.5	72.3	77.0	79.3	91.6	67.9	78.0	68.2	78.4	76.9	101.3	-	-	72.54	84.73	67.5	77.8	78.1	92.6
16.5	75.4	86.4	80.1	108.5	82.7	108.2	72.9	78.3	80.3	92.5	67.8	77.3	-	-	78.6	103.6	-	-	73.65	85.85	67.7	77.6	77.7	91.8
17.5	76.5	87.2	82.4	112.5	85.1	111.9	73.3	79.4	81.1	93.3	67.5	76.4	-	-	80.0	105.4	-	-	74.54	86.70	67.5	77.3	79.0	93.4
18.0	77.1	87.7	84.7	116.5	87.0	115.6	-	-	-	-	-	-	-	-	81.1	107.0	-	-	75.50	87.62	-	-	81.8	96.5

Notes for Table 5:
1: Fernandez et al. 2017 NHANES Complete sample
2: Fernandez et al. 2017 NHANES Mexican American sample
3: Ramírez-Velez et al. 2017
4: Kadhilcar et al. 2014
5: Xiong et al. 2010
6: Eisenman et al. 2005
7: Jackson et al. 2010
8: Schwandt et al. 2008
9: Ghouilli et al. 2020
10: Bocupoulou et al. 2015
11: Sardinha et al. 2012

Figure 1

Smoothed curves of WC percentile values for boys

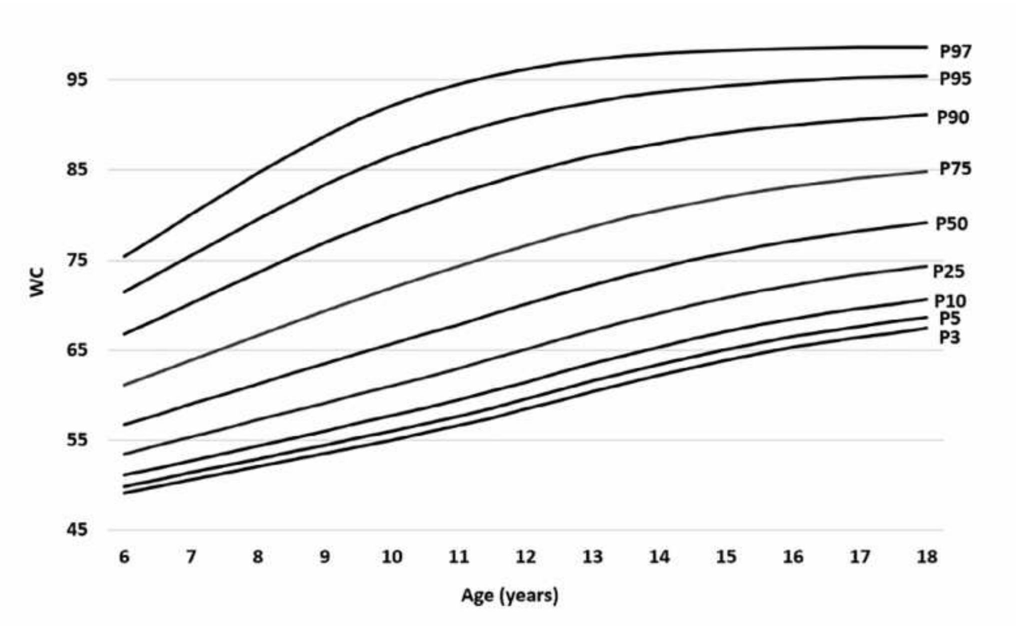

Figure 2

Smoothed curves of WC percentile values for girls