Original Article (short paper)

Waist circumference percentile in children from municipalities of developed and developing countries

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Abstract — Aims: to design reference percentile curves of waist circumference (WC) in children aged 6–10 from municipalities of developed (Portugal) and developing (Brazil) countries and to compare these results with other international references. **Methods**: this cross-sectional study enrolled a 6–10-year-old probability sampling. Univariate analysis of covariance adjusted by height was carried out to test the main effects of age, sex, countries, and interactions. WC percentile curves were performed with the LMS Chart Maker. **Results:** The sample comprised 6,475 children. Portuguese children presented a curvilinear increase in WC curves and Brazilian WC curves have shown a linear increase with age both for boys and girls. Overweight and obesity prevalence was 15.9 % and 4.7 % for Portuguese children and 12.9 % 4.5% for Brazilian children, respectively. There was a main effect ($p<0.0001$) for age and countries, and an interaction effect for sex*age ($p=0.001$) and countries*age ($p<0.0001$). Portuguese boys and girls have shown higher values for the 50th, 75th, and 95th percentiles than Brazilian boys and girls. **Conclusions:** WC reference percentile curves were drawn for 6–10-year-old Portuguese and Brazilian children. Portuguese children have higher WC values than Brazilian children and other children from developed countries.

Keywords: abdominal obesity. child. reference values. anthropometry. methods.

Introduction

An obesity epidemic affects developed[1] and developing countries[2,3]. The paradox between obesity and poverty has been discussing the obesity rate growth in developed countries, especially in poor areas[1]. On the other hand, Olaya et al.[4] showed that children in higher income countries (Western Europe) had lower risk of overweight and obesity. Political-economic transitions and socio-demographic changes in Eastern European countries might explain the increased risk of obesity. However, Wabitsh et al.[5] pointed out an unexpected stabilization or reduction of childhood obesity rates in developed countries and suggested urgent public health programs in developing countries to minimize children's obesity rates, including increases in physical activity and decline in screen time and consumption of sugar-sweetened soft drinks.

Anthropometric measures have been widely used to quantify and classify the obesity status among children according to sex, age, and race-ethnicity.Waist circumference (WC) has been considered one of the most commonly used anthropometric index to define abdominal obesity[6], to predict cardiovascular risk factors[7] (CVRF), including hypertension[6,8], abdominal aortic intima-media thickness[9], elevated levels of HOMA-IR and fasting insulin[10], and altered left ventricular diastolic function[11]. Thereby, abdominal obesity has also become a serious health problem in children and should be managed carefully[6].

The development of reference values for anthropometric measures based on national data is necessary to monitor obesity over time at an individual and population level. In this sense, developed[12–14] and developing[15–18] countries have established WC percentile reference curves for their children. Portuguese and Brazilian 6–10-year-old children do not have a percentile curves with normative parameters according to the national and international comparisons. Reference curves are an important public healthy tool to the early identification of possible risk of abdominal obesity. Moreover, some studies have showed changes in the children's adiposity over time. Freedman et al.[19] observed that the secular increases in WC among boys (3.7 cm) and girls (6 cm) from 1988–1994 compared to 2011–2012 reduced about 75% for boys and 50% for girls after BMI adjustment. Other studies revealed that there was no BMI increase after WC increases over time[20,21],suggesting that BMI might be a less sensitive tool to detect changes in the children's central obesity. This methodological approach is key for the government's decision making regarding prevention and control in childhood obesity.

In summary, there is need to develop reference values and comparisons between the data from different countries to update the information on abdominal obesity proportion in children and establish consistent trends in developed and developing countries. Therefore, this study aims (a) to design reference percentile curves of waist circumference in 6–10-year-old children from municipalities of developed (Portugal) and developing (Brazil) countries; and (b) to compare these results with other international references.

Methods

Study design

This cross-sectional study used a 6-10-year-old sampling from Portugal and Brazil. Portuguese data were collected in the metropolitan area of Porto, in the North of Portugal (10 schools), and the Autonomous Region of Madeira (50 schools). In Brazil, data were collected in both Uberaba (15 schools) and Viçosa (8 schools), located in the South-Eastern region of the country. The required sample size was estimated based on the number of children enrolled in primary education of each city, prevalence of 50% abdominal obesity (unknown prevalence in the municipality), tolerance error of 5%, and a confidence level of 95%. In the first stage, the eligible schools were randomly selected. In the second stage, the classrooms were selected and all children were invited and had the same chance to participate in this study.

Procedures

After approval by the Ethics Committee (CEP/UFTM 1710, CEP/UFV 095/2011), the schools' principals were contacted to obtain authorization and to schedule data collection. Students who met the inclusion criteria and were interested in participate in the study received an Informed Consent Statement for their parents' acknowledgement and signing. Anthropometric measurements were performed at the schools by following specific protocols.

Anthropometry

Body mass (BM) was obtained by digital electronic scale with a 150 kg maximum capacity and 100 g accuracy, the height (H) was obtained using a portable stadiometer with a 2 meter length and a scale of 0.1 cm, and the children were wearing light clothing and no shoes, according to the standard techniques[22] . Body mass index (BMI) was calculated by dividing body mass by squared height (m). Children were classified as overweight and obese based on the International Obesity Task Force (IOTF) criteria[23].

Waist circumference (WC) measurements were taken at midpoint between the iliac crest and the lower rib, after normal expiration using a flexible and non-elastic 2 m tape, as recommended by the World Health Organization[24].

Comparisons between countries

The Word Bank method has been used to classify developed and developing countries (Gross National Income per capta ≥ US$12,736 was considered developed country). A literature review was performed and data on the 50th and 75th WC percentiles was obtained for comparisons between countries. Comparison was limited to studies that had used the LMS methodology and the same WC benchmark. The following countries were considered developed (High Income): Chile[25], Venezuela[26], Germany[13], Kwait[27], Poland[28], and Portugal. Brazil, Bulgaria[29], China[30], Malaysia[31], Thailand[18], Turkey[15] and Peru[17] were classified as developing countries (Upper Middle Income).

Statistical analysis

An univariate analysis of covariance (ANCOVA) was carried out to test the main effects of age (6 to 10 years old), sex (girls and boys), countries (Portugal and Brazil) and interactions (age*sex, age*countries, sex*countries and age*sex*countries). Height was entered as covariate. The effect size (ES) was calculated as recommended by Cohen[32]. The Chi-square test was performed to verify the association between the frequency of high waist circumference (WC $>75^{th}$) and countries. Statistical analyses were performed using the SPSS software version 21 for Windows (SPSS, Inc, Chicago, Illinois).

Waist circumference percentile curves were performed with the LMS Chart Maker Pro version 2.54 software[33]. The LMS method assumes that data can be normalized by using power transformation. Percentile curves were designed to smooth specific age and sex curves: L for skewness, M for median and S for coefficient of variation. Further comparisons should hold 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles as benchmarks[34].

Results

The sample comprised 6,475 children, 4,052 from Portugal (BM=30.91 ± 8.95 kg; H=1.29 ± 0.10 m; BMI=18.05 ± 3.22 kg/m^2; 51.50 % boys) and 2,423 from Brazil (BM= 30.95 ± 9.13 kg; H= 1.31± 0.09 m; BMI=17.53 ± 3.50 kg/m^2; 54.40% girls). Overweight and obesity prevalence was 15.9% and 4.7% in Portuguese children and 12.9 % and 4.5% in Brazilian children, respectively.

Waist circumference descriptive statistics is in Table 1. ANCOVA with WC as the dependent variable, height as covariate, and age, sex, and countries as fixed factors, showed significant effects for age [$F_{(4,5604)} = 4.639$; $p<0.0001$; ES= 0.006], countries [$F_{(1,5604)} = 1084.459$; $p<0.0001$; ES= 0.162], and interactions sex*age [$F_{(4,5604)} = 8.600$; $p=0.001$; ES = 0.003] and countries*age [$F_{(4,5604)} = 66.926$; $p<0.0001$; ES= 0.046].

Table 1: Waist circumference in Portuguese and Brazilian children according to age and sex

Age (years)	Waist circumference								ANCOVA p-value	
	Portugal*				Brazil*				sex*age	countries*age
	n	Girls	n	Boys	n	Girls	n	Boys		
6	500	59.20 ± 7.09	476	58.94 ± 6.90	191	56.94 ± 7.64	166	56.47 ± 7.00	0.001	<0.001
7	405	61.11 ± 7.86	453	60.90 ± 7.81	276	59.19 ± 8.36	251	59.27 ± 8.73		
8	319	65.32 ± 8.87	364	64.00 ± 8.94	270	59.99 ± 8.06	210	60.09 ± 8.41		
9**	400	67.31 ± 9.23	457	68.01 ± 10.32	292	61.57 ± 8.97	256	61.46 ± 9.31		
10**	327	66.87 ± 8.56	351	68.62 ± 10.33	289	61.29 ± 9.52	222	62.79 ± 9.73		
Total	1951	63.55 ± 8.92	2101	63.83 ± 9.67	1318	60.01 ± 8.73	1105	60.22 ± 8.99		

Note: Adjusted by height; *difference between groups; **no difference between ages;

We developed and smoothed the sex and age-specific WC percentile values at the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles of Portuguese (Table 2) and Brazilian (Table 3) by the LMS method, Figure 1. The Portuguese children presented a curvilinear increase in WC curves and Brazilian WC curves have shown a linear increase in age both for boys and girls.

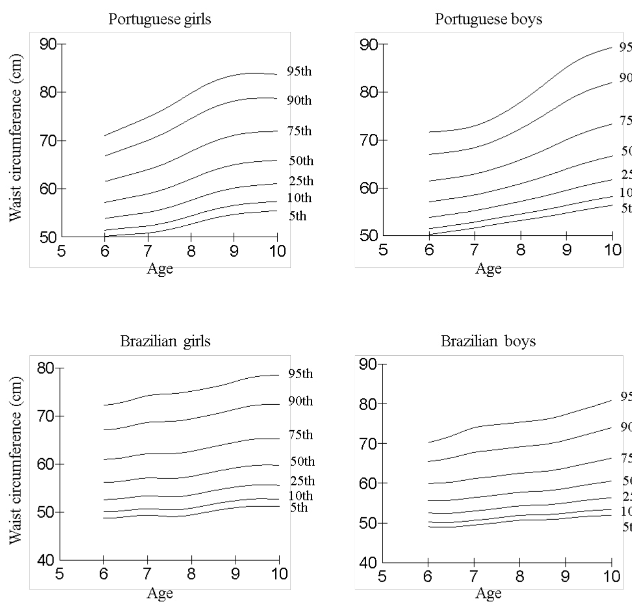
Table 2: Smoothed age-specific percentile values of waist circumference in Portuguese girls and boys

Age (Years)	L	M	S	WC percentile (cm)						
				5th	10th	25th	50th	75th	90th	95th
Girls										
6	−2.971	57.190	0.097	50.18	51.44	53.86	57.19	61.52	66.81	71.04
7	−2.504	58.992	0.109	50.87	52.33	55.14	58.99	63.99	70.07	74.86
8	−2.118	62.069	0.119	52.72	54.40	57.65	62.07	67.76	74.57	79.84
9	−1.798	65.003	0.123	54.72	56.59	60.17	65.00	71.10	78.20	83.54
10	−1.585	65.927	0.121	55.47	57.41	61.07	65.93	71.93	78.73	83.68
Boys										
6	−3.348	57.086	0.097	50.25	51.46	53.81	57.09	61.45	67.01	71.67
7	−3.331	58.550	0.095	51.63	52.87	55.25	58.55	62.92	68.43	72.99
8	−3.256	60.905	0.103	53.20	54.56	57.20	60.90	65.91	72.42	77.99
9	−2.858	63.970	0.119	54.75	56.36	59.51	63.97	70.08	78.17	85.25
10	−2.492	66.672	0.126	56.38	58.19	61.71	66.67	73.38	82.05	89.38

Table3: Smoothed age-specific percentile values of waist circumference in Brazilian girls and boys

Age (years)	L	M	S	WC percentile (cm)						
				5th	10th	25th	50th	75th	90th	95th
Girls										
6	−3.007	56.161	0.107	48.74	50.05	52.60	56.16	60.94	67.07	72.24
7	−2.960	57.085	0.111	49.34	50.70	53.35	57.08	62.12	68.65	74.21
8	−2.859	57.424	0.114	49.41	50.82	53.57	57.42	62.64	69.39	75.15
9	−2.786	59.198	0.114	50.91	52.37	55.21	59.20	64.55	71.41	77.17
10	−2.715	59.714	0.117	51.13	52.64	55.58	59.71	65.28	72.45	78.50
Boys										
6	−3.516	55.632	0.097	49.03	50.19	52.46	55.63	59.91	65.47	70.23
7	−3.752	56.393	0.104	49.44	50.64	53.00	56.39	61.15	67.76	73.98
8	−3.769	57.700	0.102	50.65	51.87	54.27	57.70	62.50	69.14	75.36
9	−3.480	58.705	0.108	51.14	52.45	55.02	58.70	63.83	70.85	77.31
10	−2.940	60.516	0.118	51.88	53.38	56.32	60.52	66.29	74.00	80.82

Figure 1: Smoothed reference curves for the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentiles of waist circumference in Portuguese and Brazilian girls and boys aged 6–10 years



The comparisons of the age and sex-specific 50th and 75th WC percentiles between children from developed countries and Portugal, and Brazilian children and developing countries are in Figure 2. The frequency of WC >75th was of 35.9% for Portuguese children and 22.9 % for Brazilians, and there was a significant difference between countries (p<0.001; Chi-square test). Chile showed the highest WC values in the 50th and 75th percentiles among developed countries and Polish children had the lowest WC values. Brazilian girls aged 6–8 showed the highest values for the 50th and 75th percentiles, while Chinese boys aged 8–10 showed the highest values for the 75th percentile. Overall, Malaysia presented the lowest values for the 50th percentile of all ages and both sexes, as well as when compared to girls in the 75th percentile. The values for the 75th percentile in Malaysian boys were closer to Peruvian boys, which showed to be the lowest values. Portuguese boys and girls have been shown higher values for 50th, 75th, and 95th percentiles than Brazilian boys and girls (Figure 3).

Figure 2: Comparisons of age and sex in the 50th percentile **(A)** and 75th percentile **(B)** values of waist circumference between Portugal and other developed countries and Brazil and other developing countries.

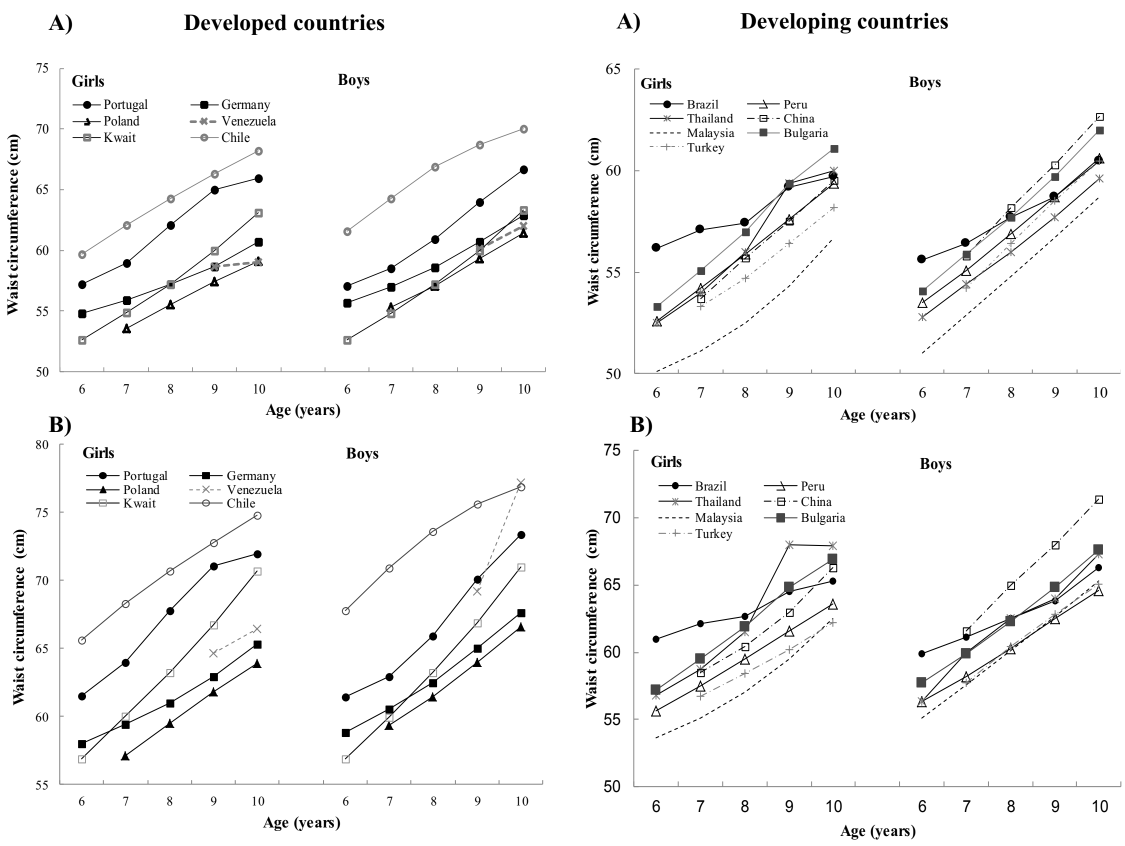
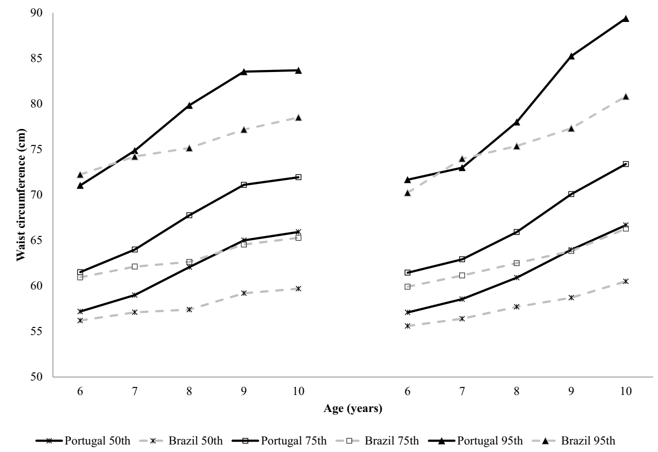


Figure 3: Comparisons of age and sex in the 50th, 75th and 95th percentiles for waist circumference of Portuguese and Brazilian children.



Discussion

This study presents the age and gender specific percentiles of 6–10-year-old children on WC designed for developed and developing countries. The main findings of this study are the new reference values for Portuguese and Brazilian children that establish percentile curves of normative parameters, according to national and international reference values. This data can be added to the existing international WC reference for children and comparisons can be made for national and international control in public health. Reference curves are an important tool to an early identification of possible risk of abdominal obesity in children and should be used in clinical practice and programs for weight control and obesity prevention.

To the best of our knowledge, no national reference curves have been published for 6–10-year-old Portuguese children using WC as recommended by WHO. There are reference curves published for Azorean adolescents (15–18 years)[35], Portuguese children and adolescents (10–18years) in different benchmarks[36], but no studies for children under 10 years old, which is filled by this study.

Portugal showed high WC percentile values, and several studies demonstrated that Portuguese obesity rates in children and adolescents are an important public health problem[37–39]. Furthermore, obesity was associated with several cardiovascular risk factors in Portuguese children[40]. A Portuguese study comprising 1,433 children (6–12 yrs) highlighted that the overweight and obese prevalence was 22.3% and 10.7%, respectively, and abdominal obesity prevalence (WC ≥ 90th) was 7.8%[41]. Moreira et al.[42] described the food pattern in 1,976 Portuguese children aged 5 - 10 years old and obese children presented a positive association with yoghurt, cheese, and ice cream intakes, which might be consumed as a part of the family's snacks or desserts, and the overweight/obese prevalence was 38.8% in girls and 38.6% in boys. A meta-analysis involving exclusively Portuguese children concluded that, in most studies, the higher prevalence of overweight/obesity was for boys compared to girls; the prevalence of overweight/obesity ranged from 19% to 35% and did not increase significantly in prevalence rates from 2002 to 2010[38].

Since the last century, Brazil and other developing countries experience an epidemiological and nutritional transition characterized by a decrease in communicable diseases, malnutrition, and an increase in chronic diseases and obesity[43,44]. Significant changes in Brazilian food consumption patterns occurred between 2002 and 2008; there was a 30% increase in the number of meals eaten out, 37.0% in the acquisition of ready-made meals, 20.0% in soft drinks intake, while vegetable (19.4%) and cereals (20.5%) consumption decreased[45]. Data from the last Brazilian National Survey[45,46] showed that since 1989–2009, 5–9-year-old children increased overweight prevalence from 15% to 34.8% and obesity increased from 4.1% to 16.6% among boys. Girls increased the overweight from 11.9% to 32% and obesity 2.4% to 11.8%.

Previous studies associated WC with CVRF and metabolic syndrome in Brazilian children, and specific WC values could predict several cardiometabolic risks[7, 47, 48]. Rocco et al.[48] suggested WC cutoff values to detect a cluster of CVRF (WC = 80.5 cm for boys; WC= 83.0 cm for girls) in Brazilian children and adolescents. Obesity in Brazilian children was associated with the duration of the breast-feeding period, the legal guardian's weight excess, sedentarism, physical activity level, and rapid chewing[49].

Obesity seems to have a different behavior in developed and developing countries. In developing countries, especially in Latin America, the overweight in preschoolers was associated with the area of residence, the high level of maternal education, and the female sex[50], and the authors speculate that overweight may become a greater problem in a higher number of countries in school-age children. Studies have found significant differences in obesity prevalence among European children from the East (6.5%) and West (1.6%) regions, being associated to boys, low maternal education level, younger parents, and children living in developing countries (Upper Middle Income) such as Romania or Bulgaria[4].

Brazilian and Portuguese municipalities presented similar rates of overweight and obesity; however, there was a signicant difference revelead by ANCOVA for WC values. Portugal had the highest WC values for all ages, regardless of sex, compared to Brazil and higher WC > 75th frequency. In addition to the differences in nutritional transition, it is worth to highlight that physical activity (PA) have been considered a factor associated with central obesity in children[51].

The Global Alliance of Healthy and Active Children organized reports on children's and young people's physical activity (PA) from 38 countries, representing 60% of the world's population. Low-income countries generally had better scores on global physical activity compared to higher-income countries[52]. The 2016 Brazilian Physical Activity Report Card[53] shows that, overall, PA levels are low among Brazilian children and young people (grade "C"). The cards estimated that 41.7% of 6–19-year-old Brazilians meet the PA guidelines (≥ 300 minutes/week). The results for Portuguese children[54] conclude that they did not achieve enough PA levels according to the recommendations (grade "D"). Physical activity levels in both countries are similar and insufficient to meet the recommendation for children. There is need to promote PA practice in the young population from both countries.

After comparing the data from developed countries, one country considered as "developing" and recently classified as "developed" showed the highest WC values. If Chile had not entered the group of developed countries, Portugal would have shown the highest WC percentile values. This data might suggest that countries that have experienced economic growth (from Middle to High Income) have a late epidemiological and nutritional transition. Gomez-Campos et al.[25] have showed significant differences between CDC-2012 references and Chilean children. Chilean 6–9-year-old boys showed a higher WC when compared to American children (CDC, 2012, $p< 0.05$); WC values were similar between Chilean girls and CDC-2012 reference values in females aged 6–12, but this WC comparison was measured with a different benchmark. When these authors[25] compared Chilean WC to Malaysian and Bulgarian children, Chilean children had the highest values for the 50th percentile compared to other international references for both sexes and the same WC benchmark. Regardless of the methodology, it is expected that children from different ethnic groups have different growth and development patterns.

Nawarycz et al.[55] compared WC distributions between children from Poland and Germany; WC values in German boys and girls were significantly higher compared to Polish children, and the authors pointed out the need for a consensus on WC measurements and suggested the benchmark recommended by WHO.

Bustamante et al.[17] compared WC reference values of Peruvian children with other international references. The WC Peruvian children values (4–17 yrs) were lower than the ones for North-Americans and Argentinean children of all ages.They have found that WC differences between Peruvian and North-American children were of ~5.4 cm in boys and ~6.6 cm in girls, while for Peruvian and Argentinean children were it was of ~2.8 cm in boys and ~3.9 cm in girls aged between 6 and 13. However, the found differences can be partly explained by the use of different benchmarks to measure WC; however, it is not recommended to compare different WC measurement points.

This study has several limitations and strengths. Data were representative for both municipalities/regions, but not for both countries. Variations in the data collection period were found in the different municipalities (Brazil: 2009–2011, and Portugal: 2009–2015) because of logistical problems and partnerships. Researchers should be aware of the importance of WC comparisons using different benchmarks. In this study, we limited the comparisons to studies that used the same benchmark and LMS methodology. This research presented the age and gender specific percentiles of 6–10-year-old children WC designs for developed and developing countries. Moreover, we presented new reference values for Portuguese and Brazilian children, thus establishing percentile curves with normative parameters according to the national and international references. We believe future research need to compare the reference values and more accurate methods of body composition measurement and prediction cardiovascular risk factors.

Conclusion

This study has designed new WC reference values for Portuguese and Brazilian children. Reference percentile curves are an important tool when assessing abdominal obesity or central obesity in children. This data might be used on clinical practice and on national or international comparison.

A serious public health problem among Portuguese and Brazilian children could be prevented with efforts regarding this age group. Special attention should be given to Portuguese children, considering they have shown high WC values compared to other countries.

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