First reference curves of waist circumference for German children in comparison to international values: the PEP Family Heart Study

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Background: **Waist circumference (WC) is a sensitive marker for abdominal obesity in the pediatric age group. However, WC is influenced by age, sex, ethnicity and body mass index (BMI), causing difficulties in the selection of the most appropriate cut-off value. Considering the lack of reference values in Germany, we developed age- and gender-specific WC smoothed reference curves in German children, and compared them with reference curves obtained from different countries.**

Methods: **A representative sample of 3531 German children (1788 boys, 1743 girls) aged 3-11 years participating in the Prevention Education Program (PEP) Family Heart Study was studied. WC was measured according to the recommendations of the World Health Organization, then age- and sex-specific WC reference curves were constructed and smoothed using the LMS method and SPSS 14.0 for statistical analysis.**

Results: **WC increased with age in both boys and girls. Boys had higher values of WC than girls at every age and percentile level. 4.1% of the boys and 2.8% of the girls had WC values >97th percentile as compared to 6.3% of the boys and 4.9% of the girls with >97th percentile of BMI (severe obesity). 3.1% of the boys and 2% of the girls had both risk factors. Because 85.3% of the boys and 87.3% of the girls with WC<90th percentile had normal weight, this cut-off point might be appropriate for defining high WC.**

Conclusions: **These first WC reference curves of German children can be added to the existing international curves for children; comparison of different populations demonstrated that the German values are in the middle range of the curves obtained in different countries. Our findings about significant differences between the reference curves obtained in various regions emphasize the necessity of developing population-specific percentiles, and to use them in clinical and epidemiological studies among children.**

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Key words: **children; Germany; international comparison; waist circumference**

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Introduction

Worldwide increase of overweight and obesity in childhood[1-3] is associated with increased risk of overweight/obesity later in life.[4,5] The prevalence of abdominal obesity is increasing among the children and adolescents.[6] Similar to adults, this type of obesity is associated with increased risk of cardiometabolic disorders in children and adolescents.[7-9] Waist circumference (WC) is a highly sensitive and specific measure of abdominal obesity in the pediatric age group,[10-12] whereas indicators based on weight and height measurements, e.g., weight-for-height and/or body mass index (BMI) underestimate obesity in youth.[12] Cross-validation against magnetic resonance imaging confirmed that among children, WC can be considered as a good predictor of visceral adipose tissue.[13]

As there is no universally-accepted cut-off value for WC, and considering the influence of age, gender and ethnicity on this anthropometric index, different countries have provided WC percentile curves in order to define the mean and distribution of WC at each age, such reference curves are mainly computed by using the LMS method.[14] National WC reference curves are developed for children and adolescents in

Cuba,[15] Italy[16,17], Spain,[18] New Zealand,[11] Great Britain,[19] Cyprus,[20] Canada,[21] USA (in US Africans, European-Americans and Mexican-Americans[22] and the Bogalusa Heart Study population[9]), Australia,[23] the Netherlands,[24] Japan,[25] China,[26] Iran[27] Turkey[28] and Mexico.[29] Providing population-specific WC percentile curves from different countries with populations of various ethnicities may result in an international reference standard similar to that for BMI.[30] Considering the lack of such reference curves in Germany, we developed the first age- and sex-specific WC reference curves for German children, and compared them with percentiles obtained in other countries.

Methods

Study population

The Prevention Education Program (PEP) is a 14-year-prospective family study aiming to assess and improve cardiovascular risk factors in children and their families in Nuremberg, Germany. PEP was approved by the Ethical Committee of the Medical Faculty of the Ludwig-Maximilians-University Munich, the Bavarian Ministry of Science and Education and the local school authorities. We have previously described its methodology in details elsewhere[31] and provided it here in brief. Written informed consent was obtained from the parents of the first-grade school students as the target group. Overall, 92% of the elementary school districts in Nuremberg were included in the survey, and their students were invited to participate in this study, along with their siblings. A total number of 2695 first graders and 2682 of their siblings, aged 3-11 years, participated during the recruitment period of the school years between 1994-1995 (1st survey) and 2003-2004 (10th survey). Those children with non-German ethnicity as well as those with an incomplete anthropometric data set were excluded from the 5377 participating children. The current paper reports the cross-sectional data from 3531 German children (1788 boys and 1743 girls) aged 3-11 years, who were freshly recruited each year. Further exclusion criteria were overt cardiovascular, metabolic, endocrine and malignant diseases. There were no significant differences between the yearly mean values of WC in these children participating in the study for the first time during the 10-year-recruitment period.

All measurements were performed by trained research assistants, and under standard protocols. Weight and height were measured twice to the nearest 0.1 cm and 0.1 kg, respectively, with children being barefoot and lightly dressed (stadiometer Holtain LTD UK and precision scale SECA, Hamburg, Germany). BMI was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). Waist and hip circumferences were measured to the nearest 0.1 cm according to recommendations of the World Health Organization (WHO).[32] WC was measured at the end of expiration with a flexible inextensible tape (Siber Heger, Swiss) placed directly on the skin horizontal to the floor at the midpoint between the lowest rib and the iliac crest, with the child standing erect with abdomen relaxed and balanced on both feet with the feet touching each other and both arms hanging freely. Hip circumference was measured at the widest part of the hip at the level of the greater trochanter to the nearest 0.1 cm. Waist to hip ratio (WHR) and waist to height ratio (WHtR) were computed by dividing WC by height and hip circumference, respectively.

Statistical analysis

Statistical analysis was performed by using the SPSS for Windows software (version 14.0, SPSS, Chicago, IL), and $P<0.01$ was considered as statistically significant. Smoothed age and gender-specific percentiles for WC were constructed from the raw data and were entered onto a spread sheet separately for boys and girls and imported into the software package LMS Chart Maker Pro, version 2.3, April 2006. The LMS method assumes that the data can be normalized by using power transformation. The percentile curves are the results of smoothing the age specific curves: L for skewness, M for median and S for coefficient of variation.[14,33]

Results

The baseline characteristics of participants are presented in Table 1, showing that in all ages, boys had a significantly higher mean WC than girls, whereas BMI was not different in terms of gender. All anthropometric measures had an increasing trend by increasing age; the exception was for WHR and WHtR which had a continuous decrease.

Table 2 demonstrates the weighted and smoothed gender- and age-specific percentile values at the 3rd, 10th, 25th, 50th, 75th, 90th and 97th percentile, and Fig. 1 presents the corresponding smoothed computed reference curves for WC and BMI in boys and girls. The 97th percentile of BMI and WC was selected for the definition of 'severely obese'. The prevalence of WC>97th percentile was significantly higher in boys than in girls (4.1% vs 2.8%, $P<0.05$); similar significant gender-difference existed for BMI>97th percentile (6.3% vs 4.9%, respectively, $P<0.05$). The increase of

BMI by WC quartiles was nearly identical for boys and girls, i.e., about 1 kg/m² in the first 3 quartiles, but by 3 kg/m² for the 3rd to 4th quartile. This is explained by the increase of mean BMI between the 90th and 97th WC percentile: among boys from 18.4±2.1 to 21.7±3.5 kg/m² and among girls from 18.9±2.6 to 21.9±3.7 kg/m².

As shown in Fig. 2, the combination of both disorders was present in 3.1% of the boys and 2% of the girls. At the 90th percentile low BMI and high WC were more common (3.3%) than high BMI and low WC

Table 1. Weight, height, waist and hip circumference, body mass index (BMI), waist to hip ratio (WHR) and waist to height ratio (WHtR) by age and sex in German boys and girls (mean ± SD)

Age (y)	Number (*n*)	Weight (kg)	Height (cm)	Waist (cm)	BMI (kg/m^2)	Hip (cm)	WHR	WHtR
Boys								
3	95	15.7±2.19	100.61±4.61	50.93±3.24	15.44±1.35	55.37±3.51	0.92±0.05	0.51±0.03
4	164	17.86±2.14	107.31±4.46	52.85±2.82	15.50±1.51	57.58±3.45	0.92±0.05	0.50±0.03
5	101	19.59±3.11	113.18±5.30	53.57±4.28	15.22±1.58	59.58±4.86	0.90±0.05	0.50±0.03
6	670	23.77±4.17	122.40±5.42	56.55±4.98	15.79±1.96	64.23±5.36	0.88±0.05	0.46±0.04
7	447	25.12±4.37	125.30±5.34	57.81±5.60	15.93±2.10	65.60±5.87	0.88±0.08	0.45±0.04
8	80	29.09±5.23	132.24±6.45	59.79±6.50	16.61±2.86	68.68±6.23	0.87±0.04	0.45±0.05
9	104	31.69±5.55	138.68±6.25	61.13±5.47	16.39±2.09	71.45±5.64	0.86±0.04	0.44±0.03
10	77	37.75±8.18	144.60±5.53	65.69±8.00	17.93±3.04	76.30±7.74	0.86±0.06	0.45±0.05
11	60	38.95±8.37	147.27±6.75	65.67±7.63	17.85±2.88	77.18±7.03	0.85±0.05	0.45±0.04
Total	1788	24.74±7.32	123.33±11.87	57.19±6.66	15.98±2.28	64.84±7.76	0.88±0.06	0.47±0.04
Girls								
3	91	14.58±1.60	99.09±4.56	49.88±2.74	14.84±1.21	54.87±3.07	0.91±0.05	0.50±0.03
4	133	17.23±2.53	106.53±5.61	52.00±4.31	15.16±1.73	57.43±3.64	0.91±0.06	0.49±0.04
5	98	19.64±2.78	112.45±4.70	53.71±3.93	15.60±1.77	60.18±4.12	0.89±0.04	0.48±0.03
6	702	23.10±3.79	121.43±5.40	55.45±4.74	15.60±1.82	64.28±5.38	0.86±0.04	0.46±0.03
7	410	24.82±4.67	124.27±5.25	56.63±5.63	15.99±2.30	66.23±6.13	0.86±0.05	0.46±0.04
8	87	29.29±6.12	132.63±6.69	58.72±6.46	16.54±2.61	69.94±6.74	0.84±0.05	0.44±0.04
9	90	30.93±6.20	137.13±6.57	58.98±6.13	16.32±2.23	71.66±6.38	0.82±0.05	0.43±0.04
10	77	36.86±9.29	143.96±7.11	62.70±8.06	17.65±3.52	76.78±7.92	0.82±0.06	0.44±0.05
11	55	41.18±8.78	149.09±7.69	64.36±7.69	18.41±3.10	81.27±6.88	0.80±0.06	0.43±0.05
Total	1743	24.31±7.21	122.53±12.05	56.02±6.04	15.88±2.23	65.25±7.81	0.86±0.05	0.46±0.04

Table 2. Smoothed age- and sex-specific waist circumference percentile values (cm) for German children of 3-11 years of age in the PEP Family Heart Study

Age	*n*	3rd	10th	25th	50th	75th	90th	97th
Boys								
3	95	45.4	47.2	49.0	50.9	52.9	54.9	57.0
4	154	46.7	48.5	50.4	52.5	54.8	57.2	60.1
5	101	47.9	49.7	51.7	54.0	56.7	59.8	63.6
6	670	49.1	51.0	53.1	55.7	58.8	62.6	67.6
7	447	49.9	51.9	54.2	57.0	60.5	64.9	71.0
8	80	50.9	53.1	55.6	58.6	62.5	67.5	74.6
9	104	52.5	54.7	57.4	60.7	65.0	70.6	79.0
10	77	54.1	56.6	59.4	62.9	67.6	74.0	84.0
11	60	55.5	58.0	61.0	64.8	69.8	77.1	89.2
Girls								
3	91	44.2	45.8	47.5	49.7	52.1	55.0	58.5
4	133	45.4	47.2	49.1	51.4	54.1	57.3	61.3
5	98	46.8	48.7	50.8	53.3	56.2	59.6	64.1
6	702	47.9	49.9	52.2	54.8	58.0	61.8	66.7
7	410	48.6	50.7	53.1	55.9	59.4	63.7	69.2
8	87	49.3	51.5	54.1	57.2	61.0	65.8	72.1
9	90	50.2	52.6	55.4	58.7	62.9	68.2	75.4
10	77	51.5	54.1	57.1	60.7	65.3	71.3	79.7
11	55	52.9	55.6	58.8	62.8	67.9	74.7	84.6

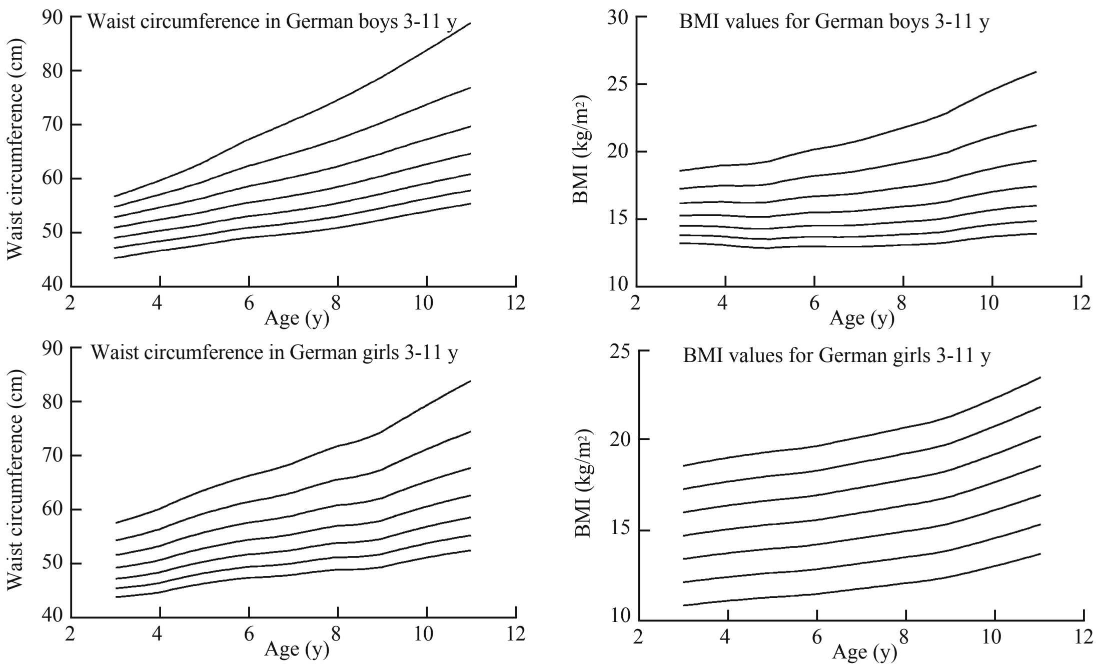

Fig. 1. Smoothed reference curves for the 3rd, 10th, 25th, 50th, 75th and 97th percentiles for waist and body mass index in 3 to 11-year-old German boys and girls. BMI: body mass index.

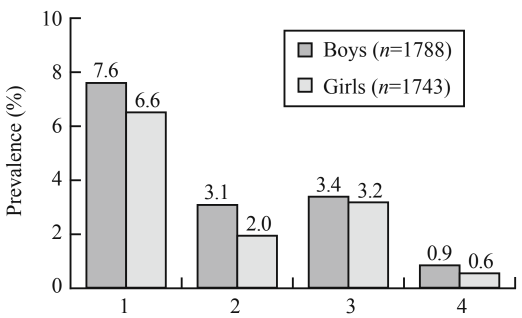

Fig. 2. Prevalence of combined waist circumference and body mass index at different percentiles in 3 to 11-year-old German children: the PEP Family Heart Study (1: BMI and WC>90th percentile; 2: BMI and WC>97th percentile; 3: BMI<90 and WC>90 percentile; 4: BMI>90 and WC<90 percentile).

(0.8%) among children, possibly reflecting the higher prevalence of abdominal overweight. However, 85% of the boys and 87% of the girls had WC and BMI values below the <90th percentile.

Fig. 3 shows the 90th percentile curves for WC in boys and girls from 10 countries in Europe, North America, Australia, Japan, China, Iran and Turkey. WC curves of both boys and girls are higher in Italian,[16] Iranian,[27] European-American[22] and Cypriot[20] children than in German children and lower in British,[19] Japanese,[25] Turkish,[28] Canadian[21] and Australian[23] children.

As presented in Table 3, the comparison of the 90th percentile values from 12 different countries demonstrates that 6- and 11-year-old children from Japan and UK have the lowest WC values, and that Italian and Mexican boys and girls (except the 11-year-old Mexican girls) have the highest WC values. The difference between the lowest and the highest WC values was higher in girls than in boys, i.e., respectively, 15 cm and 17 cm in 6-year-old boys and girls; and 21 cm and 25 cm in 11-year-old boys and girls.

Discussion

This study presents for the first time, the age- and gender-specific percentile curves for a representative sample of 3 to 11-year-old German children based on the yearly new recruitment of the cross-sectional surveys 1994-2003. These data complement the existing set of WC reference values obtained in some other countries. As emphasized recently, evaluation of cardiometabolic disorders in children is feasible only when specific references for the association of age, gender and ethnic origin to health risks would become available.[34] Comparison of our reference curves with those of other countries would be useful for such evaluation. Our selection criterion of these 12 countries was their different geographical location and their population of different ethnicities. The major differences of the percentile curves between various regions underscore the need for providing population-specific WC reference curves for children.

Data about WC at the 97th percentile might be of

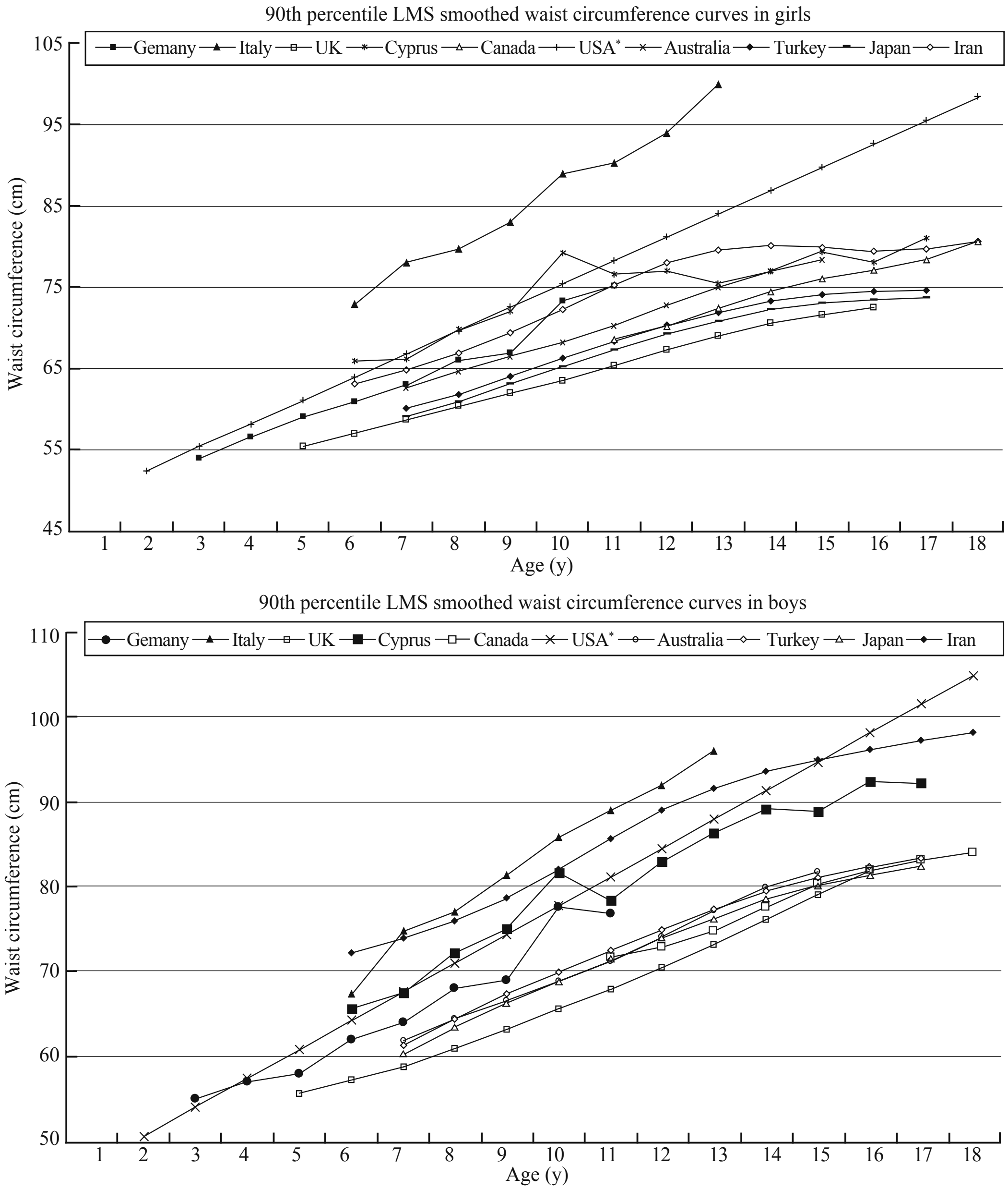

Fig. 3. Comparison of the 90th percentile LMS smoothed waist circumference reference curves of youths in 10 countries.

Table 3. Comparison of 90th percentile values for waist circumference (cm) among 6- and 11-year-old boys and girls from 12 countries*

Boys				Girls			
6 years		11 years		6 years		11 years	
Japan	55	UK	67.9	Japan	56	UK	65.4
UK	57.1	Japan	70	UK	57.0	Japan	66
China	60	Australia	71.3	China	58	Turkey	68.4
Turkey	61.3	Canada	71.7	Turkey	60.1	Canada	68.7
Australia	61.9	Turkey	72.5	Germany	61.8	China	69
Germany	62.6	China	75	Australia	62.7	Australia	70.4
USA	64.2	Iran	75.5	Iran	63.5	Germany	74.7
Iran	65.0	Germany	77.1	USA	64.0	Iran	75.0
Cyprus	65.6	Cyprus	78.4	Cyprus	65.9	Mexico	75.2
Italy	67.4	USA	81.1	Mexico	68.0	Cyprus	76.6
Mexico	70.3	Mexico	87.4	Italy	73.0	USA	78.3
		Italy	89.0			Italy	90.3

*: obtained from the curves.

special interest because they can reflect 'abdominal obesity'. Comparison of the published 97th percentile values from different countries demonstrates that at the age of 6 years, boys from Japan[25] and UK[12] had the lowest WC values (60 cm) followed by China[26] and Turkey[28] (65 cm each), Germany (68 cm), Iran[27] (70 cm) and Mexico[29] (74 cm); whereas compared to boys, the ranking of 6-year-old girls does not show major differences in the WC values. However, at the age of 11 years, only Mexican boys had higher WC values (94 cm) than the German boys (89 cm), moreover German girls had WC values higher than in the other 5 countries. Overall, in different countries the increasing trend of WC from age 6 to age 11 years is greater in boys (12 to 22 cm) than in girls (6 to 18 cm). The rapid increase of WC at the 97th percentile by 14% between the ages of 8-11 years in German children (from 67.5 cm to 77.1 in boys, and from 65.8 to 74.7 cm in girls) indicates that this age group appears to be uniquely at increased risk for extreme overweight. Similar findings are reported from Japan[25] and Iran.[27]

Children with a WC>90th percentile are at higher risk of having multiple cardiometabolic risk factors than those with lower WC percentiles.[8] The 90th percentile values of WC in boys and girls with 6 and 11 years of age are included among the 12 existing national reference curves. These two age groups are of special interest because 6-year-old children mainly represent first graders and beyond age 11 adolescence begins. Comparison of the 90th percentile values reported from 12 different countries reveals large differences between various populations, i.e., 6- and 11-year-old children from Japan and UK have the lowest value of WC 90th percentile, whereas Italian and Mexican boys and girls (except 11-year-old Mexican girls) have the highest values. The difference between the lowest and the highest WC values was higher in girls than in boys.

Thus, optimal WC cut-off values will likely vary according to the population studied and should be validated according to ethnicity, as well as gender- and age-specificity. The ethnic differences in body fat patterning and the genetic tendency of some ethnic groups to abdominal obesity should be considered as well.[35,36] Although the year of data collection varies in different countries, e.g., 1981 in Canada,[21] 1988 in UK,[19] 1988-1994 in USA,[22] 1992-1994 in Japan,[25] 1994-2003 in Germany,[31] 1999-2000 in Cyprus,[20] the range of age (2 to 18 years) and the sites of WC measurement differ between studies, as all the four commonly used sites are almost equally associated with total body fat and truncal fat in each sex and are highly reproducible.[37] Our findings confirm that WC percentiles may serve as a simple and valid epidemiological marker for assessment of childhood obesity and its related health consequences.

Still, there is no universally accepted cut-off value of WC related to cardiometabolic disorders in children. Some studies considered the cut-off value of the 75th percentile,[38-40] whereas some other studies considered the 90th percentile as the cut-off for high WC.[41] Maffeis et al[8] proposed that children with a WC greater than the 90th percentile are more likely to have multiple risk factors, Katzmarzyk[21] suggested a cut-off point based on the age- and sex-specific 90th or 95th percentile, Fredriks[24] and colleagues proposed a cut-off point of 1.3 standard deviations to screen for increased abdominal fat in youths. According to Janssen et al,[42] elevated health risk in children and adolescents is best detected by the combination of BMI and WC, because in their study, the mean WC values differed by 4.0 to 9.7 cm, whereas the mean BMI values have been similar in the low and high-WC groups. Our findings propose that for 3 to 11-year-old German children, the 90th percentile is the appropriate cut off value because more than 85% of the children below this percentile had a BMI in the normal range.

There are strengths and limitations in this study. A limitation of our study is the unequal number of subjects in the nine age groups. This is due to the study design postulating first graders as index subjects resulting in the highest numbers in the age groups of 6 and 7 years. The Tanner stage was not assessed because it could not be included in the written informed consent of this large epidemiological study. We also wish to acknowledge that our data are compared to the data obtained in different periods of time and the data have been subjected to change with the recent global rise in the prevalence of childhood obesity. Moreover, data of some countries reflect the data of urban and rural areas, while some of them are restricted to urban areas. The strengths of our study are the novelty in German children, the large sample size of children studied during a long period of time with a constantly reproducible study procedure, as well as comparison of our results with data obtained from children of Western and non-Western countries.

In conclusion, the large differences in the values obtained from various countries underscore the necessity of providing population-specific WC reference curves from different populations, which in turn may result in an international reference standard similar to that provided for BMI.

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Contributors: Schwandt P proposed the study and wrote the first draft. Haas GM analyzed the data. All authors contributed to the design and interpretation of the study and to further drafts. Schwandt P is the guarantor.

References

1 Ebbeling CB, Pawlak DB, Ludwig DS. Childhood obesity: public-health crisis, common sense cure. Lancet 2002;360:473-482.
2 Lobstein T, Baur L, Uauy R, IASO International Obesity TaskForce. Obesity in children and young people: a crisis in public health. Obes Rev 2004;5 Suppl 1:4-104.
3 Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. JAMA 2006;295:1549-1555.
4 Reilly JJ, Methven E, McDowell ZC, Hacking B, Alexander D, Stewart L, et al. Health consequences of obesity. Arch Dis Child 2003;88:748-752.
5 Dietz WH. Health consequences of obesity in youth: childhood predictors of adult disease. Pediatrics 1998;101(3 Pt 2):518-525.
6 Li C, Ford ES, Mokdad AH, Cook S. Recent trends in waist circumference and waist-height ratio among US children and adolescents. Pediatrics 2006;118:e1390-e1398.
7 Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. Pediatrics 1999;103(6 Pt 1):1175-1182.
8 Maffeis C, Grezzani A, Pietrobelli A, Provera S, Tatò L. Waist circumference and cardiovascular risk factors in prepubertal children. Obes Res 2001;9:179-187.
9 Katzmarzyk PT, Srinivasan SR, Chen W, Malina RM, Bouchard C, Berenson GS. Body mass index, waist circumference, and clustering of cardiovascular disease risk factors in a biracial sample of children and adolescents. Pediatrics 2004;114:e198-e205.
10 Savva SC, Tornaritis M, Savva ME, Kourides Y, Panagi A, Silikiotou N, et al. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. Int J Obes Relat Metab Disord 2000;24:1453-1458.
11 Taylor RW, Jones IE, Williams SM, Goulding A. Evaluation of waist circumference, waist-to-hip ratio, and the conicity index as screening tools for high trunk fat mass, as measured by dual-energy X-ray absorptiometry, in children aged 3-19 y. Am J Clin Nutr 2000;72:490-495.
12 McCarthy HD, Ellis SM, Cole TJ. Central overweight and obesity in British youth aged 11-16 years: cross sectional surveys of waist circumference. BMJ 2003;326:624.
13 Brambilla P, Bedogni G, Moreno LA, Goran MI, Gutin B, Fox KR, et al. Crossvalidation of anthropometry against magnetic resonance imaging for the assessment of visceral and subcutaneous adipose tissue in children. Int J Obes (Lond) 2006;30:23-30.
14 Cole TJ, Green PJ. Smoothing reference centile curves: the LMS method and penalized likelihood. Stat Med 1992;11:1305-1319.
15 Martinez E, Devesa M, Bacallao J, Amador M. Percentiles of the waist-hip ratio in Cuban scholars aged 4.5 to 20.5 years. Int J Obes Relat Metab Disord 1994;18:557-560.
16 Zannolli R, Morgese G. Waist percentiles: a simple test for atherogenic disease? Acta Paediatr 1996;85:1368-1369.
17 Barba G, Troiano E, Russo P, Strazzullo P, Siani A. Body mass, fat distribution and blood pressure in Southern Italian children: results of the ARCA project. Nutr Metab Cardiovasc Dis 2006;16:239-248.
18 Moreno LA, Fleta J, Mur L, Rodríquez G, Sarría A, Bueno M. Waist circumference values in Spanish children—gender related differences. Eur J Clin Nutr 1999;53:429-433.
19 McCarthy HD, Jarrett KV, Crawley HF. The development of waist circumference percentiles in British children aged 5.0-16.9 y. Eur J Clin Nutr 2001;55:902-907.
20 Savva SC, Kourides Y, Tornaritis M, Epiphaniou-Savva M, Tafouna P, Kafatos A. Reference growth curves for cypriot children 6 to 17 years of age. Obes Res 2001;9:754-762.
21 Katzmarzyk PT. Waist circumference percentiles for Canadian youth 11-18y of age. Eur J Clin Nutr 2004;58:1011-1015.
22 Fernández JR, Redden DT, Pietrobelli A, Allison DB. Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. J Pediatr 2004; 145:439-444.
23 Eisenmann JC. Waist circumference percentiles for 7- to 15-year-old Australian children. Acta Paediatr 2005;94: 1182-1185.
24 Fredriks AM, van Buuren S, Fekkes M, Verloove-Vanhorick SP, Wit JM. Are age references for waist circumference, hip circumference and waist-hip ratio in Dutch children useful in clinical practice? Eur J Pediatr 2005;164:216-222.
25 Inokuchi M, Matsuo N, Anzo M, Takayama JI, Hasegawa T. Age-dependent percentile for waist circumference for Japanese children based on the 1992-1994 cross-sectional national survey data. Eur J Pediatr 2007;166:655-661.
26 Sung RY, Yu CC, Choi KC, McManus A, Li AM, Xu SL, et al. Waist circumference and body mass index in Chinese children: cutoff values for predicting cardiovascular risk factors. Int J Obes (Lond) 2007;31:550-558.

27 Kelishadi R, Gouya MM, Ardalan G, Hosseini M, Motaghian M, Delavari A, et al. First reference curves of waist and hip circumferences in an Asian population of youths: CASPIAN study. J Trop Pediatr 2007;53:158-164.
28 Hatipoglu N, Ozturk A, Mazicioglu MM, Kurtoglu S, Seyhan S, Lokoglu F. Waist circumference percentiles for 7- to 17-year-old Turkish children and adolescents. Eur J Pediatr 2008;167:383-389.
29 Gómez-Díaz RA, Martínez-Hernández AJ, Aguilar-Salinas CA, Violante R, Alarcón ML, Villarruel MJ, et al. Percentile distribution of the waist circumference among Mexican pre-adolescents of a primary school in Mexico City. Diabetes Obes Metab 2005;7:716-721.
30 Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 2000;320:1240-1243.
31 Schwandt P, Geiss HC, Ritter MM, Ublacker C, Parhofer KG, Otto C, et al. The Prevention Education Program (PEP). A prospective study of the efficacy of family-oriented lifestyle modification: design and baseline data. J Clin Epidemiol 1999;52:791-800.
32 Lean MEJ, Han Thang S, Deurenberg P. Predicting body composition by densitometry from simple anthropometric measurements. Am J Clin Nutr 1996;63:4-14.
33 Cole TJ. The LMS method for constructing normalized growth standards. Eur J Clin Nutr 1990;44:45-60.
34 Brambilla P, Lissau I, Flodmark CE, Moreno LA, Widhalm K, Wabitsch M, et al. Metabolic risk-factor clustering estimation in children: to draw a line across pediatric metabolic syndrome. Int J Obes (Lond) 2007;31:591-600.
35 Al-Shaer MH, Abusabha H. The impact of ethnicity on the lifetime risk of the metabolic syndrome and diabetes mellitus. Am J Cardiol 2005;95:819-820.
36 Banerjee D, Misra A. Does using ethnic specific criteria improve the usefulness of the term metabolic syndrome? Controversies and suggestions. Int J Obes (Lond) 2007;31:1340-1349.
37 Wang J, Thornton JC, Bari S, Williamson B, Gallagher D, Heymsfield SB, et al. Comparisons of waist circumferences measured at 4 sites. Am J Clin Nutr 2003;77:379-384.
38 de Ferranti SD, Gauvreau K, Ludwig DS, Neufeld EJ, Newburger JW, Rifai N. Prevalence of the metabolic syndrome in American adolescents: findings from the Third National Health and Nutrition Examination Survey. Circulation 2004;110:2494-2497.
39 Katzmarzyk PT, Srinivasan SR, Chen W, Malina RM, Bouchard C, Berenson GS. Body mass index, waist circumference, and clustering of cardiovascular disease risk factors in a biracial sample of children and adolescents. Pediatrics 2004;114:e198-e205.
40 Moreno LA, Pineda I, Rodriguez G, Fleta J, Sarria A, Bueno M. Waist circumference for the screening of the metabolic syndrome in children. Acta Paediatr 2002;91:1307-1312.
41 Cook S, Weitzman M, Auinger P, Nguyen M, Dietz WH. Prevalence of a metabolic syndrome phenotype in adolescents: findings from the third National Health and Nutrition Examination Survey, 1988-1994. Arch Pediatr Adolesc Med 2003;157:821-827.
42 Janssen I, Katzmarzyk PT, Srinivasan SR, Chen W, Malina RM, Bouchard C, et al. Combined influence of body mass index and waist circumference on coronary artery disease risk factors among children and adolescents. Pediatrics 2005;115:1623-1630.

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