Waist Circumference and Waist-to-Height Ratio Distributions in Polish and German Schoolchildren: Comparative Analysis

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ABSTRACT

Background: To analyze differences in the distributions of waist circumference (WC) and waist-to-height ratio (WHtR) between Polish (PL) and German (GE) children and adolescents.

Methods: Two samples of children and adolescents aged 7-18 y: From PL (n = 11,326) GE (n = 8,218) participated. The two WC cut-off points (WC1 as central fat distribution and WC2 as central obesity) corresponding at age 18 to the adult criteria were determined. Furthermore, the mean WC cut-off points (WC1m, WC2m) for boys and girls aged 14-18 from both countries were evaluated. For the WHtR, values over 0.5 were used as a definition of central fat distribution. The effect of different WC and WHtR criteria on the prevalence of abdominal obesity in both study groups was evaluated.

Results: The mean and percentile values of WC and WHtR were generally higher in all German children as compared to their peers from Poland. When WC1m is used, the mean (95% CI) prevalence of central fat distribution in the 14-18 y Polish groups was lower (P < 0.05) than those from Germany (boys: 4.4% (3.6-5.2) vs. 8.9% (7.3-10.5); girls: 10.7% (9.0-12.3) vs. 26.4% (23.2-29.6)), whereas, using the WHtR > 0.5, the results were similar for boys - 6.7% (5.9-7.5) vs. 8.5% (8.1-8.9); they were significantly (P < 0.05) lower for Polish and German girls: 5.3% (5.0-5.6) vs. 12.7% (9.7-16.4). The prevalence of central obesity using WC2m as a criterion in the Polish vs. German groups was as follows: (boys - 1.1% (0.8-1.4) vs. 3.1% (2.2-4.0), P < 0.05; girls - 3.1% (2.5-3.7) vs. 10.2% (8.4-12.0), P < 0.05).

Conclusions: The results highlight the greater central obesity associated with the German children, both in terms of WC and WHtR, in comparison to their peers from Poland. The prevalence of AO is significantly associated with the criteria used. The results demonstrate the need for the development of international WC references for pediatric subjects.

Keywords: Abdominal obesity, children and adolescents, waist circumference, waist-to-height ratio
INTRODUCTION

Overweight and obesity have become a public health problem worldwide, both in adults and the pediatric population.\cite{1} Although body mass index (BMI) is routinely used to evaluate weight status and measure generalized obesity, there is now evidence that indices of abdominal obesity (AO) are better predictors for cardio-metabolic complications.\cite{2,3} Recently, anthropometric measures that reflect AO, such as waist circumference (WC) and waist-to-height ratio (WHtR), have been, both in adults and in children, related to an increased risk of all-cause mortality.\cite{4,5} Indices of abdominal obesity (AO) such as waist circumference (WC) and waist-to-height ratio (WHtR) are suggested as being superior to BMI in predicting cardio-metabolic risk and all-cause mortality.\cite{2-6}

Many pediatric studies clearly show a direct relationship between WC and characteristic disorders of metabolic syndrome (MetS) components such as atherogenic dyslipidemia, insulin resistance, hyperglycemia, and hypertension.\cite{6} The current pediatric definition of MetS by the International Diabetes Federation (IDF) recommends using WC as a mandatory diagnostic component.\cite{7}

Although excessive WC or WHtR values have commonly been accepted as measures of central adiposity and precursors of cardio-metabolic disorders, the problem of international reference values, which would be of value in epidemiological comparative examinations of AO prevalence in children and adolescents, still arouses much discussion.

Recently, the criteria for recognizing AO using WC or WHtR at developmental age are subject to particular interest. The identification of children and adolescents in an early phase of AO is important for the effective prevention and control of cardio-metabolic diseases in adult life. For the last 15 years, national WC references have been developed in many European countries.\cite{8-23} (Appendix).

In many countries of Central and Eastern Europe, an increasing prevalence of overweight and obesity and reduced physical activity is being observed as a result of an improved financial situation and so-called westernized lifestyles.\cite{24} Poland and Germany are two large European countries with different economic statuses, in which the problems of obesity, both among the adult and pediatric populations, are more frequently raised.\cite{25,26}

However, a uniform consensus on WC and WHtR cut-off points for youths from different populations has not yet been developed. In the light of the recently observed increasing prevalence of central obesity as measured by WC or WHtR, as opposed to general obesity measured by BMI, the problem of proper epidemiological monitoring of central obesity in adolescents would appear to be of great importance.

The aim of this study was to analyze differences in WC and WHtR distributions between Polish and German schoolchildren, as well as to evaluate the effect of different WC and WHtR cut-off points on the prevalence of AO in both study groups.

METHODS

Study populations

The analyzed data was obtained from two large cross-sectional surveys of randomly-selected children and adolescents aged 7-18 years. The Polish surveys (n = 11,326; 5,558 boys and 5,768 girls) were conducted between the years 2002 and 2007,\cite{16} while the German surveys (n = 8,218; 4,299 boys and 3,919 girls) were conducted between 2003 and 2007.\cite{17}

The Polish children and adolescents participated in the Prevention Education Program (PEP) Family Heart Study, which is a prospective community–based study consisting of 15 cross-sectional surveys of CVD risk factors and lifestyle behavior in families in Nuremberg (Germany).\cite{17,19} The Polish cross-sectional anthropometric data was obtained from schoolchildren and adolescents who attended primary schools, junior high schools, and high schools in four randomly-selected provinces in Poland: Mazowskie, Wielkopolskie, Łódzkie, and Śląskie. The population was selected for research in a stratified manner. First, towns from these regions were randomly chosen; secondly, schools were randomly chosen within those towns. (Primary schools, junior high schools, and high schools) Finally, classes were randomly chosen within those schools.\cite{16}

For the analysis, we excluded participants with chronic conditions or those who were taking any drugs systematically that might interfere with their growth. In accordance with the principles of the Helsinki Agreement, all parents, as well as their
children, were informed about the purpose of the study, and their written consent was obtained in each case. The Polish survey was approved by the Bioethical Committee of the Medical University of Łódź, and the German PEP study was approved by the Ethical Committee of the Medical Faculty of the Ludwig Maximilian University of Munich.

**Anthropometric measurements**

For the purpose of this study, three anthropometric measurements were taken: Waist circumference (WC), body height, and weight.\[11,21,27\] The same study protocol concerning basic anthropometric parameters was used in both surveys. The methodology of the study has been described previously.\[16,17,19\] The height and weight were measured using standard protocols, without shoes or outerwear. Height was measured to the nearest 0.1 cm on a portable stadiometer and weight to the nearest 0.1 kg. WC was measured in accordance with WHO recommendations: Using a stretch-resistant and flexible anthropometric tape placed horizontally at the midpoint between the edge of the lowest rib and the superior iliac crest, during shallow apnea with the children standing erect with abdomen relaxed.\[27\]

The measurements were performed by properly trained and experienced medical personnel in school consultation rooms in the morning. All measurements were performed twice, and mean values of the analyzed parameters were finally registered. On the basis of standard anthropometric measurements, the waist-to-height ratio (WHtR) was calculated by WC divided by height in all examined subjects.

**Statistical analysis**

The values of WC and WHtR of the Polish and German children were subjected to detailed comparative analysis. The distributions of WC and WHtR were summarized by Lambda (L) Mu (M) Sigma (S) curves that describe the skewness, median, and coefficient of variance of the distribution at each age.\[28\] The LMS method was used for estimating some percentile values of WC and WHtR (the 5th, 25th, 50th, 75th, and 95th percentiles), which normalizes asymmetrical data distribution and optimal curve smoothing.

Based on the two-stage criteria for European adults concerning central fat distribution (WC₁ = 94 cm and 80 cm for males and females, respectively) and central obesity (WC₂ = 102 cm and 88 cm for males and females, respectively), percentile curves forming the same criteria, which link with adult values at the age of 18 (WC₁ and WC₂, respectively), were determined for both the Polish and German populations.\[16,29\] Firstly, the WC z-scores (zWC₁ and zWC₂) that correspond to the adult criteria were defined with the following equations:

\[zWC₁ = \frac{((WC₁/M)^L - 1)}{L \cdot S} \text{ and } zWC₂ = \frac{((WC₂/M)^L - 1)}{L \cdot S}\]

Where: WC₁, WC₂ - the adult WC cut-off points for central fat distribution (WC₁ = 94/80 cm for M/F) and central obesity (WC₂ = 102/88 cm for M/F).

L, M, S are the gender- and country-specific values of WC distribution parameters (skewness, median, and coefficient of variability, respectively) at 18 years.

Next, the WC cut-off points (WC₁ and WC₂) at each age were evaluated by regressing the previously defined zWC₁ and zWC₂ backward into adolescence as follows:

\[WC₁ = M \cdot L \cdot S \cdot zWC₁^{1/L} \text{ and } WC₂ = M \cdot L \cdot S \cdot zWC₂^{1/L}\]

Where: L, M, S are the respective age- and gender-country-specific values of WC distribution (in our case at 14-18 years).

Following this, using similar methodology as that used in determining international BMI IOTF cut-off points, the mean values of the country–specific WC cut-off points (WC₁m and WC₂m) for boys and girls from both countries aged 14-18 years were evaluated.

According to recent suggestions related to the WHtR index, WHtR > 0.5 is defined as a measure of central fat distribution.\[29\]

The effects of different definitions of the WC cut-off points on the prevalence of AO (WC₁, WC₁m, and WHtR > 0.5 as measures of central fat distribution and WC₂, WC₂m as measures of central obesity) in both study groups were analyzed.

All comparisons regarding differences in WC and WHtR for groups of both Polish and German boys and girls, for each age studied, were made using the Mann-Whitney U-test. The prevalence of central fat distribution and central obesity were estimated, and the proportions were compared using the \(\chi^2\) test. Results were considered significant at \(P < 0.05\). Statistical analysis was performed using the Statistica v. 9.0 package (StatSoft.pl) and LMS.
RESULTS

The study population comprised \( n = 11,326 \) Polish children and adolescents (5,558 boys and 5,768 girls) and \( n = 8,218 \) German children (4,299 boys and 3,919 girls) aged 7-18 years. The number of subjects in each study group and essential anthropometric parameters (body weight, height, BMI, WC, and WHtR) of the analyzed Polish and German boys and girls are presented in Table 1.

### WC and WHtR distributions

Mean and selected percentile (5\(^{th}\), 25\(^{th}\), 50\(^{th}\), 75\(^{th}\), and 95\(^{th}\)) WC values for Polish and German boys and girls, by sex and age, are presented in Table 2. Graphical presentation of the WC-smoothed curves for the 5\(^{th}\), 50\(^{th}\), and 95\(^{th}\) percentiles of WC for boys and girls from two study groups are demonstrated in Figure 1. As expected, both in boys and girls the WC increased with age, and boys prevailed in both the analyzed groups.

In general, the WC values in both boys and girls from Germany were significantly higher compared to their peers from Poland, and all analyzed WC

| Table 1: Basic characteristics of PL and GE boys and girls |
|-----------------------------------------------------------|
| **Parameter**                                             | **Boys**               | **Girls**              |
|                                                          | Mean (SD) | Range  | Mean (SD) | Range        |
| Number                                                  |           |        |           |              |
| PL                                                      | 5,558     |        | 5,768     |              |
| GE                                                      | 4,299     |        | 3,919     |              |
| Age [y]                                                 |           |        |           |              |
| PL                                                      | 13.0 (3.3)| 6.4-19.0 | 13.2 (3.4)| 6.4-19.0    |
| GE                                                      | 10.8 (3.2)| 7.1-18.0| 10.7 (3.1)| 7.1-18.0    |
| Height [cm]                                             |           |        |           |              |
| PL                                                      | 158.1 (18.5)| 106.5-204.0 | 154.0 (14.6)| 101.0-192.0 |
| GE                                                      | 153.2 (18.1)| 112.0-206.0 | 149.6 (15.1)| 112.0-206.0 |
| Body weight [kg]                                        |           |        |           |              |
| PL                                                      | 50.8 (18.1)| 15.5-142.4 | 47.2 (14.4)| 15.0-122.0 |
| GE                                                      | 46.4 (16.8)| 16.9-119.9 | 43.1 (14.4)| 17.1-152.9 |
| BMI [kg/m\(^2\)]                                        |           |        |           |              |
| PL                                                      | 19.6 (3.7)| 10.4-41.3 | 19.4 (3.5)| 9.9-41.5    |
| GE                                                      | 18.9 (3.3)| 10.9-35.8 | 18.7 (3.5)| 11.7-51.1  |
| WC [cm]                                                 |           |        |           |              |
| PL                                                      | 68.8 (10.3)| 40.0-125.0 | 65.2 (8.7)| 43.0-119.0 |
| GE                                                      | 68.2 (10.1)| 45.0-117.0 | 66.0 (10.7)| 45.0-149.0 |
| WHtR                                                    |           |        |           |              |
| PL                                                      | 0.436 (0.047)| 0.294-0.701 | 0.424 (0.045) | 0.304-0.735 |
| GE                                                      | 0.446 (0.044)| 0.309-0.719 | 0.441 (0.489)| 0.313-0.861 |

BMI=Body mass index, WC=Waist circumference, WHtR=Waist-to-height ratio, PL=Polish, GE=German

**Figure 1**: Smoothed LMS curves for the 5\(^{th}\), 50\(^{th}\), and 95\(^{th}\) percentiles of waist circumference (WC) for Polish (PL) and the German (GE) boys (left) and girls (right)
percentile curves for Polish boys and girls ran below the adequate curves for German peers. These differences increased with age, and their maximal values were observed at the age of 18 years. The 18-year-old boys and girls from GE had higher WC values at the level of 50th and 95th percentiles compared to their Polish peers (Δ WC = 3.4 cm and 8.1 cm for boys and Δ WC = 4.2 cm and 12 cm for girls) [Figure 1].

Mean and selected percentile (5th, 25th, 50th, 75th, and 95th) WHtR values for Polish and German boys and girls by sex and age are given in Table 3, and selected WHtR percentile (5th, 50th, and 95th) curves are presented in Figure 2. Similar to WC,
both in boys and girls from Poland and German, exceeded the WHtR ≥ 0.5 value in all analyzed age groups [Table 3].

**WC Cut-Off values linked with adults criteria**
Table 4 shows absolute values of different WC cut-off points by gender and age for central

### Table 3: Mean and selected percentile (5th, 25th, 50th, 75th, and 95th) WHtR values for PL and GE boys and girls

| Age [y] | n   | Mean (SD) | Boys | n   | Mean (SD) | Girls |
|---------|-----|-----------|------|-----|-----------|-------|
|         |     |           | 5    | 25  | 50        | 75    | 95    |
|         |     |           |      |     |           |       |       |
| 7       | PL  | 416       | 0.449 (0.04) | 0.393 | 0.421 | 0.445 | 0.473 | 0.525 |
|         | GE  | 872       | 0.454 (0.033) | 0.407 | 0.432 | 0.453 | 0.478 | 0.525 |
| 8       | PL  | 440       | 0.448 (0.044) | 0.388 | 0.417 | 0.442 | 0.472 | 0.528 |
|         | GE  | 422       | 0.449 (0.039) | 0.400 | 0.425 | 0.447 | 0.473 | 0.523 |
| 9       | PL  | 490       | 0.447 (0.047) | 0.384 | 0.413 | 0.439 | 0.470 | 0.531 |
|         | GE  | 459       | 0.448 (0.039) | 0.395 | 0.421 | 0.443 | 0.470 | 0.524 |
| 10      | PL  | 482       | 0.442 (0.047) | 0.379 | 0.409 | 0.435 | 0.468 | 0.532 |
|         | GE  | 456       | 0.452 (0.044) | 0.391 | 0.417 | 0.440 | 0.468 | 0.526 |
| 11      | PL  | 468       | 0.44 (0.05)   | 0.376 | 0.406 | 0.432 | 0.465 | 0.532 |
|         | GE  | 452       | 0.442 (0.048) | 0.387 | 0.414 | 0.437 | 0.467 | 0.527 |
| 12      | PL  | 496       | 0.442 (0.052) | 0.374 | 0.404 | 0.430 | 0.463 | 0.532 |
|         | GE  | 361       | 0.446 (0.047) | 0.383 | 0.411 | 0.434 | 0.465 | 0.528 |
| 13      | PL  | 514       | 0.436 (0.052) | 0.372 | 0.400 | 0.425 | 0.458 | 0.525 |
|         | GE  | 317       | 0.44 (0.048)  | 0.380 | 0.408 | 0.432 | 0.463 | 0.528 |
| 14      | PL  | 498       | 0.426 (0.044) | 0.368 | 0.396 | 0.420 | 0.451 | 0.515 |
|         | GE  | 277       | 0.437 (0.048) | 0.378 | 0.406 | 0.430 | 0.462 | 0.528 |
| 15      | PL  | 488       | 0.421 (0.042) | 0.367 | 0.394 | 0.418 | 0.447 | 0.508 |
|         | GE  | 222       | 0.436 (0.048) | 0.377 | 0.405 | 0.430 | 0.462 | 0.529 |
| 16      | PL  | 456       | 0.43 (0.047)  | 0.370 | 0.397 | 0.420 | 0.450 | 0.507 |
|         | GE  | 186       | 0.436 (0.045) | 0.378 | 0.406 | 0.431 | 0.463 | 0.531 |
| 17      | PL  | 416       | 0.429 (0.04)  | 0.373 | 0.401 | 0.425 | 0.454 | 0.509 |
|         | GE  | 161       | 0.443 (0.046) | 0.379 | 0.408 | 0.433 | 0.466 | 0.534 |
| 18      | PL  | 394       | 0.436 (0.042) | 0.377 | 0.406 | 0.431 | 0.460 | 0.512 |
|         | GE  | 114       | 0.447 (0.045) | 0.381 | 0.410 | 0.436 | 0.469 | 0.538 |

**WHtR ≥ 0.5, All differences were significant (P<0.05) between countries (without *) and between genders (without †), PL=Polish, GE=German, WHtR=Waist-to-height ratio**
fat distribution (P90, WC1, WC1m) and central obesity (WC2, WC2m) for adolescents aged 14-18 years from both countries studied. Percentile levels of WC cut-off points for central fat distribution (WC1) were higher in the case of Polish boys (P96.5), while in the case of Polish girls, they were similar to P90 (P91): The frequently used level defining the central fat distribution.

Table 4: Absolute values of WC cut-off points for 14-18 y old PL and GE boys and girls for central fat distribution and central obesity

| Age [y] | Central fat distribution | Central obesity |
|---------|--------------------------|-----------------|
|         | WC (P90) | WC1 | WC1m | WC2 | WC2m |
|         | PL | GE | PL | GE | PL | GE | PL | GE |
| Boys    |     |    |     |    |     |    |     |    |
| 14      | 82.4 | 84.7 | (P96.5) | (P89.4) | 89.8 | 84.2 | 87.0 | 101.1 | 91.6 | 96.4 |
| 15      | 84.0 | 87.3 | 91.0 | 86.8 | 88.9 | 101.6 | 94.4 | 98.0 |
| 16      | 85.5 | 89.7 | 92.2 | 89.3 | 90.7 | 101.9 | 97.0 | 99.5 |
| 17      | 86.8 | 92.1 | 93.1 | 91.6 | 92.4 | 101.9 | 99.5 | 100.7 |
| 18      | 88.1 | 94.5 | 94.0 | 94.0 | 94.0 | 102 | 102 | 102 |
| Girls   |     |    |     |    |     |    |     |    |
| 14      | 77.2 | 82.2 | 77.9 | 73.9 | 75.9 | 86.1 | 80.8 | 83.4 |
| 15      | 78.0 | 84.2 | 78.7 | 75.5 | 77.1 | 86.8 | 82.8 | 84.8 |
| 16      | 78.6 | 86.1 | 79.2 | 77.1 | 78.2 | 87.3 | 84.6 | 85.9 |
| 17      | 79.0 | 87.8 | 79.7 | 78.6 | 79.1 | 87.7 | 86.3 | 87.0 |
| 18      | 79.3 | 89.6 | 80.0 | 80.0 | 80.0 | 88 | 88 | 88 |

WC (P90)-WC values correspond to the 90th percentiles, WC1. WC2-WC values linked with adult criteria at 18 y old, WC1m. WC2m-mean values of WC1 and WC2 for Polish and German subjects, PL=Polish, GE=German, WC=Waist circumference

Figure 2: Smoothed LMS curves for the 5th, 50th, and 95th percentiles of waist-to-height ratio (WHtR) for Polish (PL) and the German (GE) boys (left) and girls (right)

Figure 3: The WC cut-off percentile curves for the Polish (PL) and the German (GE) boys (left) and girls (right) that are linked at age 18 years with the adults criteria. (Dashed curves - represents average values)
DISCUSSION

The results of this study show that German children and adolescents are characterized by significantly higher WC values in comparison with their peers from Poland.

Waist circumference and waist-to-height ratio were generally higher in all German children as compared to their peers from Poland. In terms of increased WHtR, Polish and German girls had significantly lower values compared with boys from both countries. The higher prevalence of central obesity in German youths indicates that national growth charts should be developed. Furthermore, risk scores of CVD in Polish and German youths might be helpful investigating causes of these anthropometric differences by analyzing lifestyle behavior.

A novel approach taken by this paper is that it demonstrates the first use of the same, averaged WC cut-off points for both countries. This approach was chosen as a proposal to initiate a discussion regarding the use of international WC cut-off points as epidemiological measures of AO. The average prevalence of central fat distribution with average WC values for boys and girls from both countries (PL vs. GE) was respectively: 4.4% vs. 8.9% for boys and 10.7% vs. 26.4% for girls, whereas the average prevalence of central fat was respectively: 1.1% vs. 3.1% for boys and 3.1% vs. 10.2% for girls. All differences were statistically significant \( (P < 0.05) \) [Figure 4].

**Figure 4:** Prevalence of AO for Polish (PL) and German (GE) adolescents aged 14-18 y using different criteria. WC1, WC2 - WC values linked with adults criteria at 18 y old, WC1m, WC2m - mean values of WC for Polish and German adolescents linked with adults criteria at 18 y old, WHtR \( \geq 0.5 \) - waist to height ratio over 0.5

**Prevalence of central fat distribution and central obesity**

The prevalence of central fat distribution and central obesity was found to be significantly higher in German boys and girls as compared with Polish peers. This prevalence in adolescents from Poland and Germany aged 14-18 years, based on different definitions (P90, WC1/WC2, WC1m/WC2m, WHtR>0.5), by age and sex are presented in Figure 4.

When WC1m is used as a WC cut-off point, the mean (95% CI) prevalence of central fat distribution in the Polish adolescent groups (14-18 y) was lower \( (P < 0.05) \) as compared to peers from Germany (boys: 4.4% (3.6-5.2) vs. 8.9% (7.3-10.5); girls: 10.7% (9.0-12.3) vs. 26.4% (23.2-29.6)), whereas using WHtR > 0.5 as the criterion of central fat distribution, the results were similar only for boys - 6.7% (5.9-7.5) vs. 8.5% (8.1-8.9), but for Polish and German girls, they were significantly \( (P < 0.05) \) lower: 5.3% (5.0-5.6) vs. 12.7% (9.7-16.4).

However, when WC2m is used as a criterion, the prevalence of central obesity in the Polish vs. German groups was thus: (boys - 1.1% (0.8-1.4) vs. 3.1% (2.2-4.0), \( P < 0.05 \); girls - 3.1% (2.5-3.7) vs. 10.2% (8.4-12.0), \( P < 0.05 \) [Figure 4].
indirect screening markers for AO in adults and for children and have been applied in epidemiological studies along with the body mass index (BMI).

Different approaches have been used to evaluate WC cut-off values for children and adolescents, including extrapolations from adult cut-offs, ROC analysis or specific arbitrary percentiles. In practice, the individual AO diagnosis in children and adolescents is usually performed based on representative national reference systems with the WC 90\textsuperscript{th} percentile as the cutoff point. Jelliffe et Janssen\cite{31} suggested percentile levels corresponding at age 18 with the adult criteria as cut-off points for all MetS risk factors. This approach eliminates the arbitrary choice of cut-off points and ensures their continuity with the stable, legitimate criteria associated with adults.

Compared with general fatness, AO much more strongly correlated with an increased risk of cardio-metabolic complications on what already has pointed out by Vague in 1947 y.\cite{32} Since then, many studies have confirmed the adverse role of central obesity and the usual accompanying insulin resistance in the pathogenesis of cardio-metabolic disturbances, which led the creation in 1988 by Raven\cite{33} concept of X syndrome (metabolic syndrome: MetS).

A precise measurement of the visceral adipose tissue demands the use of complicated and expensive imaging techniques such as dual-energy X-ray absorptiometry (DEXA), computer tomography, or magnetic resonance.\cite{34} In 1995, Lean \textit{et al}.\cite{35} proposed that the WC alone could be used as a measure for indicating need for weight management and to define suitable values for risk groups. They suggested Action Level One (WC\textsubscript{1}) for a WC $\geq$ 94 cm for men and $\geq$ 80 cm for women and Action Level Two (WC\textsubscript{2}) for a WC of $\geq$ 102 cm for men and $\geq$ 88 cm for women. American experts (NCEP-ATP III – Third Report of the National Program of Cholesterol Education) defined WC cut-off values as 102 cm for male adults and 88 cm for female adults.\cite{36} The cut-off values for adult men and women that have been proposed by the International Diabetes Federation are significantly lower, i.e., 94 cm and 80 cm, respectively.\cite{37}

It should be emphasized that in studying WC, the results are strongly influenced by the methodology used for taking measurements. Hence, there is a strong need for an international consensus in this regard to allow comparisons to be made between studies.\cite{38} To this end, reference systems developed recently in many European countries often differentiate WC measurement site, although it must be emphasized that the most commonly used reference point, and the one used in this study, is that proposed by the WHO, i.e., for WC to be measured midway between the edge of the lowest rib and the superior iliac crest (Appendix).

According to McCarthy and Ashwell,\cite{39} WHtR values during the past 20 years have increased greatly in British children, showing a radical rise in the number of children with central obesity. A similar tendency is noted by Li \textit{et al}.\cite{40} regarding mean WC and WHtR among US subjects aged 18 to 19. In Poland, the trend towards increasing prevalence of AO in children and adolescents are not as intensive as in other European countries, but it requires future monitoring.\cite{41} While this study gives a clear picture of the relationship between AO in German and Polish children, further research is needed to incorporate studies from a range of countries, with the aim of building a more complete international AO criterion for pediatric subjects. Furthermore, risk scores of CVD in Polish and German youths might be helpful investigating causes of these anthropometric differences by analyzing lifestyle behavior.\cite{42}

**CONCLUSIONS**

The results indicate the significant predominance of the German boys and girls, especially adolescents, in terms of central obesity measured by both WC and WHtR in comparison to their peers from Poland. The prevalence of AO is significantly associated with the used criteria. Using the analyzed criteria of central fat distribution for adolescents (WC\textsubscript{1} and WHtR > 0.5), the AO prevalence was comparable only in the case of boys. The results demonstrate also the need for development of the international WC references for the pediatric subjects.

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Appendix: A summary of population studies on European children’s WC

| Countries | Sample size F/M | Age range | Data collection | Authors/publication year/references |
|-----------|----------------|-----------|----------------|-----------------------------------|
| Italyb    | 1418/1440      | 6-14      | 1993           | Zannoli et al., 1996[8]           |
| Spaina    | 659/701        | 6-14     | 1996           | Moreno et al., 1999[9]           |
| Cyprusb   | 1214/1258      | 6-17     | 1999-2000      | Savva et al., 2001[10]           |
| UKc       | 3585/4770      | 5-16.9   | 1988           | McCarthy et al. 2001[11]         |
| Netherlandsa | 7018/7482  | 0-21     | 1996-1997      | Fredriks et al., 2005[12]        |
| Turkeya   | 2433/2337      | 7-17     | 2005           | Hatipoglu et al., 2008[13]       |
| Swedisha  | 568/517        | 9-15     | 1998-1999      | Ortega et al., 2008[14]          |
| Bulgariab | 1758/2052      | 6-18     | 2006-2007      | Galcheva et al., 2009[15]        |
| Polanda   | 2884/2779      | 7-18     | 2002-2005      | Ostrowska-Nawarycz et al., 2010[16] |
| Germanya  | 1743/1788      | 3-11     | 2003-2004      | Schwandt et al., 2008[17]        |
| Germanya,b | 3321/3492    | 11-18    | 2003-2006      | Kromeier-Hauschild K et al., 2010[18] |
| Germanya  | 1391/1633      | 12-18    | 2000-2007      | Haas G-M et al., 2011[19]        |
| Norwaya   | 2780/2945      | 4-18     | 2003-2006      | Brannsether B et al., 2011[20]   |
| Switzerlanda | 1175/1128    | 6-13     | 2007           | Aeberli I et al., 2011[21]       |
| Greecea   | 1551/1589      | 6-12     | 2003           | Tzotzas et al., 2011[22]         |
| Portugala | 10,657/11,346  | 10-18    | 2008           | Sardinha LB et al., 2012[23]     |

WC measurements sits=a midway between the lowest rib and the top of the iliac crest (WHO recommendation), bAt the umbilicus level, WC=Waist circumference