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SUPPLEMENT ARTICLE

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Waist circumference and waist-to-height ratio in 7-year-old children—WHO Childhood Obesity Surveillance Initiative

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Abbreviations: BAZ, BMI-for-age Z scores; BMI, body mass index; BUL, Bulgaria; COSI, Childhood Obesity Surveillance Initiative; CZH, Czechia; DXA, dual X-ray absorptiometry; ESP, Spain; GRE, Greece; HAZ, height-for-age Z scores; IDEFICS, Identification and prevention of Dietary- and lifestyle-induced health EFfects In Children and infantS; IOTF, International Obesity Task Force; IRL, Ireland; LTU, Lithuania; LVA, Latvia; MKD, North Macedonia; NOR, Norway; OR, odds ratio; SD, standard deviation; SWE, Sweden; UK, United Kingdom; USA, United States of America; WAZ, weight-for-age Z scores; WC, waist circumference; WHO, World Health Organization; WHtR, waist-to-height ratio.

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Summary

Childhood obesity is a serious global health problem. Waist circumference (WC) and waist-to-height ratio (WHtR) reflect body fat distribution in children. The objectives of this study were to assess WC and WHtR in 7-year-old children and to determine body mass index (BMI), WC, and WHtR differences in children from 10 selected countries across Europe (Bulgaria, Czechia, Greece, Ireland, Latvia, Lithuania, North Macedonia, Norway, Spain, and Sweden) participating in the World Health Organization (WHO) Europe Childhood Obesity Surveillance Initiative (COSI). The 50th and 90th percentile of WC (according to COSI and "Identification and prevention of Dietary- and lifestyle-induced health EFfects In Children and infantS" (IDEFICS) cutoff values) and WHtR above 0.5 were used as measures of abdominal obesity in a unique sample of 38,975 children aged 7.00–7.99 years. Southern European countries, including Greece and Spain, showed significantly higher BMI, WC, and WHtRin both genders ($p < 0.0001$) than Eastern and Northern Europe. The highest values for WC were observed in Greece (60.8 ± 7.36 cm boys; 60.3 ± 7.48 cm girls), North Macedonia (60.4 ± 7.91 cm boys; 59.0 ± 8.01 cm girls), and Spain (59.7 ± 6.96 cm boys; 58.9 ± 6.77 cm girls). WC and WHtRin may add an information about the occurrence of central obesity in children.

KEYWORDS
childhood obesity, COSI, waist circumference, waist-to-height ratio

1 | INTRODUCTION

Childhood obesity is a major contributor to the global burden of disease[1] and is a major risk factor for obesity in adulthood.[2,3] The usual measure used for obesity assessment is body mass index (BMI), defined as weight in kilograms divided by the square of the height in meters. BMI is a simple and inexpensive measure of body adiposity, but it does not reflect body fat distribution. In the WHO European Childhood Obesity Surveillance Initiative (COSI), overweight and obesity prevalence of primary-school children aged 6–9 years is routinely assessed.[4] Concurrently, in some countries, waist circumference (WC) was measured. Intercountry comparison of the differences in the waist and waist/height ratio between the countries with waist measurement accessible is an important output of the project. Moreover, Vanderwall et al,[5] who measured body composition by dual X-ray absorptiometry (DXA) in 663 female and male children and adolescents with overweight/obesity aged 4–18 years, found that BMI in children younger than 9 years was a moderate-to-poor predictor of both total and relative fat mass. A simple indicator that would help identify children with health compromising abdominal fat would thus be of value. WC may serve as such an indicator and has been identified as a good predictor of visceral adipose tissue in adults[6] and children.[7,8] However, different cutoffs for WC are applied in different countries, and there is thus a need for agreed standards for WC cutoffs to define central obesity in children.[9]

Both visceral and subcutaneous abdominal fat determined by computed tomography are significantly correlated with WC percentile and WHtR in youth aged 6–18 years.[10] WC cannot distinguish visceral from subcutaneous abdominal adiposity, but this distinction may not be clinically important. Kelly et al.[10] demonstrated in a cohort of children and adolescents that both visceral fat and subcutaneous abdominal fat were associated with serum lipids profile, insulin resistance, and systolic blood pressure.

Using WHtR as a measure for central adiposity, McCarthy and Ashwell[11] found in representative cross-sectional surveys of British children aged 5–16 years that WHtR had significantly increased from 1977 to 1997 in boys and from 1987 to 1997 in girls.

Precise measurement of WC in children is difficult. The need for trained personnel using a strict protocol and standardized equipment[12,13] represents a major limiting factor for determining central adiposity using this method. Currently, a major problem in comparing both national and international data has been a lack of consistency in data collection methods. Study collaborations, such as the World Health Organization (WHO) Europe COSI, which uses a standardized protocol for data collection, make valid intracountry and intercountry comparisons possible.

The aim of this study was to evaluate WC and WHtR, measured in 7-year-old children from 10 countries participating in the COSI project, and to describe any intercountry differences in WC and WHtR.

2 | METHODS

COSI is a population-based survey that was launched by WHO Europe in 2006 (with data collection starting in 2007) to establish an international system for monitoring childhood obesity in the WHO European Region. Its aim is to fill the gap in reliable and valid information on anthropometry in primary-school children by routinely measuring their body weight and body height. Monitoring this population group complements existing cross-sectional, nationally representative surveys carried out in the European Region that mainly target preschool children aged 0–5 years or adolescents aged 11–15 years.[14] COSI measures levels of thinness, overweight, and obesity among children aged 6–9 years at regular intervals following a common protocol.[12,15–17] Of the 22 countries participating in the first three rounds of COSI data collection, which took place in 2007–2008, 2009–2010, and 2012–2013, our study evaluated cross-sectional data from the 10 countries that had measured WC.

2.1 | Data collection

The data collection process has been described previously.[16,18,19] For WC analysis, the WHO dataset was obtained from the WHO Regional Office for Europe after being cleaned in a standardized manner. The dataset included data on age, sex, country code, weight, height, WC, and BMI. In addition, the round indicates the year of measurement (first round 2007–2008, second round 2009–2010, and third round 2012–2013).

2.2 | Anthropometric measurements

All examiners of the COSI project were trained in measuring weight, height, and WC using WHO standardized techniques.[19] The monitoring of data quality procedures was stressed throughout the measurement process.[18] Body height was measured standing upright and recorded to the nearest 0.1 cm. Body weight was measured to the nearest 0.1 kg and then adjusted for the estimated weight of the clothes worn.[20] The WC was measured at midway between the lowest border of the rib cage and the upper iliac crest to the nearest 0.1 cm. Anthropometric measurements were conducted before lunch time if possible. The WHtR was calculated as WC (cm) divided by height (cm).

For thinness, normal weight, overweight (excluding obesity), and obesity and overweight (including obesity) prevalence, the WHO criteria BMI for age[21] were used. Thinness was defined as BMI-for-age value below −2 *Z* scores. Normal weight was defined as between −2 and +1 *Z* scores. Overweight (excluding obesity) and obesity were defined as BMI-for-age value between +1 and +2 *Z* scores and above +2 *Z* scores, respectively. The proportion of children meeting these criteria in the studied population was determined.

2.3 | Final data set

Children from 10 European countries in which WC was measured were included in the analysis (BUL, Bulgaria; CZH, Czechia; ESP, Spain; GRE, Greece; IRL, Ireland; LVA, Latvia; LTU, Lithuania; MKD, North Macedonia; NOR, Norway; and SWE, Sweden). To facilitate comparison of results, countries were grouped into three macro-regions according to United Nations "Standard Country or Area Codes for Statistical Use" (EasternEurope, Northern Europe, and Southern Europe).[22] Children aged 7.00–7.99 years old were selected from each of the three rounds as the most numerous group. The other age groups could not be included in the calculations due to a low numbers of children in the samples. The total number of children with measured WC in the 10 countries was 77,221, and the number of 7 year olds with measured WC was 39,358. Age-adjusted (by month) *Z* scores for BMI (BAZ), height (HAZ), and weight (WAZ) were calculated according to WHO growth reference charts for school-age children and adolescents.[23] Children with extreme values for weight, height, and BMI (WAZ values below −6 or above +5; HAZ values below −6 or above +6; and BAZ values below −5 or above +5), in total 105 children, were excluded from the analysis.[24] WC was measured during all three rounds in four countries (Czechia, Ireland, Latvia, and Norway).

2.4 | Statistical analysis

2.4.1 | Study population

Statistical analysis was performed in the R environment, R core.[25] The data were analyzed in the raw (unweighted) form with no survey sampling weights as these were not available.

Because there has been no significant change of WC between individual rounds (the effect of the year of the study was tested in a linear regression model together with the country effect and with correction for the children's age), we pooled the data from all rounds. Due to the not so numerous sample sizes for country-round combinations (not sufficient for high percentile estimation relevant for this study), missing rounds in some countries, and other irregularities, we decided to pool the data from different rounds and analyze them at country level. Cumulative distribution of BMI, WC, and WHtR was calculated from samples of children in individual countries.

2.4.2 | Intercountry comparison

WC was evaluated using IDEFICS (Identification and prevention of Dietary- and lifestyle-induced health EFfects In Children and infantS) values for the 50th and the 90th percentile in a sample of children from the IDEFICS study, which covers eight European countries including Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, and Sweden,[26] and uses International Obesity Task Force (IOTF) criteria to evaluate thinness, overweight (excluding obesity), and

obesity. We therefore also mention thinness, normal weight, overweight (excluding obesity), and obesity and overweight (including obesity) prevalence in the COSI sample according to these criteria (thinness BMI < 18.5 kg/m^2 at age 18, normal weight BMI from 18.5 to 25 kg/m^2 at age 18, overweight (excluding obesity) BMI from 25 to 30 kg/m^2 at age 18, and obesity BMI > 30 kg/m^2 at age 18, respectively).[27,28] For WHtR, a cutoff of 0.5 has been proposed and used as a threshold for abdominal obesity for children in several studies[11,29–31] and therefore was employed for identification of children at risk in our study as well.

3 | RESULTS

3.1 | Study population

The final sample size included 38,975 children (Table 1).

Mean values and standard deviation (SD) of height, BMI, WC, and WHtR in boys and girls in individual countries are shown in Table 2. The highest values for WC and WHtR were observed in the three Southern European countries (Greece, North Macedonia, and Spain).

3.2 | Overweight and obesity prevalence

The prevalence of BMI categories evaluated according to WHO growth reference is shown in Table 3 and according to IOTF cutoff points in Table 4. According to the WHO reference, overall, the prevalence of overweight was 29.5% in boys and 27.2% in girls. Countries where the prevalence of overweight in children exceeds 40% include Greece (49.1% in boys; 45.1% in girls) and Spain (44.4% in boys; 40.5% in girls). The lowest prevalence of overweight and obesity was found in Norway, Czechia, and Sweden for boys (22.8%, 23.5%, and 23.6%, resp.) and Latvia, Czechia, and Lithuania for girls (20.8%, 21.4%, and 21.5%, resp.).

3.3 | Intercountry comparison

Southern European countries (Greece and Spain) differed from both Eastern and Northern European countries (Bulgaria, Czechia, Ireland, Latvia, Lithuania, Norway, and Sweden) in BMI, WC, and WHtR (for both genders). Testing for differences between Southern countries and the rest confirmed that these differences were statistically significant for means (±SD) and for percentiles ($p < 0.0001$).

The BMI, WC, and WHtR values were the highest in children from Greece and Spain. The differences are noticeable across the entire range of values of these body parameters, that is, from the lowest to the highest percentiles.

Table 5 shows the percentages of children with WC exceeding the 50th and 90th percentile IDEFICS values[26] and the percentages of children with WHtR > 0.5 in each country. More than 50% of children in all countries except Bulgaria exceed the 50th percentile IDEFICS WC values. The highest percentage of children whose WC values exceed the 50th and 90th IDEFICS percentile was observed in the Southern European countries. WHtR > 0.5 was found in 12.1% of boys and 12.5% of girls. There was a significantly lower percentage of boys ($p < 0.001$, OR 0.80) and girls ($p < 0.001$, OR 0.65) with WHtR > 0.5 in Northern and Eastern European countries (Bulgaria,

TABLE 1 Number of children per country and round of COSI used in the current cross-sectional analysis; COSI/WHO Europe rounds 1–3 (2007/2008, 2009/2010 and 2012/2013)

	2007/2008		2009/2010		2012/2013		Total	
Round	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Eastern Europe								
BUL	1,243	1,250	N/A	N/A	1,659	1,664	2,902	2,914
CZH	443	469	637	631	757	693	1837	1793
Southern Europe								
ESP	N/A	N/A	1,096	1,093	871	942	1967	2035
GRE	N/A	N/A	1,275	1,247	N/A	N/A	1,275	1,247
MKD	N/A	N/A	1,294	1,221	N/A	N/A	1,294	1,221
Northern Europe								
IRL	1,095	1,283	533	465	508	504	2,136	2,252
LTU	1,650	1,647	N/A	N/A	N/A	N/A	1,650	1,647
LVA	1,643	1,600	1,376	1,456	1,802	1,676	4,821	4,732
NOR	312	316	286	248	310	292	908	856
SWE	766	722	N/A	N/A	N/A	N/A	766	722
Total	7,152	7,287	6,497	6,361	5,907	5,771	19,556	19,419

Abbreviations: BUL, Bulgaria; COSI, Childhood Obesity Surveillance Initiative; CZH, Czechia; ESP, Spain; GRE, Greece; IRL, Ireland; LVA, Latvia; LTU, Lithuania; MKD, North Macedonia; N/A = not available; NOR, Norway; SWE, Sweden.

TABLE 2 Means (±SD) for height, BMI, waist circumference, and waist to height ratio, stratified by gender; COSI/WHO Europe rounds 1–3 (2007/2008, 2009/2010 and 2012/2013)

		Height (cm)		BMI (kg/m^2)		WC (cm)		WHtR	
Country	Number	means	SD	means	SD	means	SD	means	SD
Boys									
Eastern Europe									
BUL	2,902	126.01	6.33	16.53	2.68	56.27	6.95	0.45	0.05
CZH	1,837	127.67	5.45	16.35	2.38	58.03	6.09	0.45	0.04
Southern Europe									
ESP	1,967	127.27	5.39	17.43	2.61	59.71	6.96	0.47	0.05
GRE	1,275	128.4	5.77	17.75	2.66	60.8	7.36	0.47	0.05
MKD	1,294	127.36	6.17	16.86	2.89	60.44	7.91	0.47	0.05
Northern Europe									
IRL	2,136	126.35	5.32	16.55	1.99	57.86	5.5	0.46	0.04
LTU	1,650	128.32	5.43	16.38	2.15	58.87	5.83	0.46	0.04
LVA	4,821	127.74	5.44	16.38	2.15	57.24	5.67	0.45	0.04
NOR	908	128.18	5.31	16.15	2.05	56.63	5.09	0.44	0.03
SWE	766	128.36	5.36	16.25	1.85	56.79	4.78	0.44	0.03
Total	19,556	127.38	5.67	16.63	2.4	58.05	6.43	0.46	0.03
Girls									
Eastern Europe									
BUL	2,914	125.28	6.19	16.55	2.87	55.4	7.23	0.44	0.05
CZH	1,793	126.38	5.56	16.12	2.44	56.38	6.16	0.45	0.04
Southern Europe									
ESP	2,035	126.21	5.43	17.38	2.61	58.9	6.77	0.47	0.05
GRE	1,247	127.63	5.74	17.71	2.76	60.32	7.48	0.47	0.05
MKD	1,221	126.42	6.22	16.51	2.92	59.0	8.01	0.47	0.05
Northern Europe									
IRL	2,252	124.82	5.5	16.8	2.33	58.04	6.52	0.46	0.05
LTU	1,647	127.93	5.31	16.21	2.33	58.14	6.17	0.45	0.04
LVA	4,732	126.88	5.45	16.16	2.25	55.92	5.79	0.44	0.04
NOR	856	126.84	5.42	16.38	2.16	56.46	5.53	0.45	0.04
SWE	722	127.13	5.54	16.26	2.07	56.29	5.47	0.44	0.04
Total	19,419	126.39	5.7	16.56	2.53	57.16	6.69	0.45	0.04

Abbreviations: BMI, body mass index, BUL, Bulgaria; COSI, Childhood Obesity Surveillance Initiative; CZH, Czechia; GRE, Greece; IRL, Ireland; LVA, Latvia; LTU, Lithuania; MKD, North Macedonia; NOR, Norway; ESP, Spain; SD, standard deviation; SWE, Sweden; WC, waist circumference; WHtR, waist to height ratio.

Czechia, Ireland, Latvia, Lithuania, Norway, and Sweden) as compared to Southern countries (Greece, North Macedonia, and Spain).

4 | DISCUSSION

WC, WHtR, and BMI differed significantly between Southern European (Greece, North Macedonia, and Spain) and Eastern and Northern European (Bulgaria, Czechia, Ireland, Latvia, Lithuania, Norway, and Sweden) countries. The north–south difference has been shown in many previous studies using BMI-defined overweight/obesity prevalence, including COSI studies.[14,16,18] Overweight and obesity prevalence differed according to reference method used as shown previously[14]; the WHO reference generally leads to higher prevalence values for overweight/obesity as compared to the IOTF reference. WC and WHtR were not assessed to such an extent using high-quality methods. The observed differences in WC in previous studies may be related to different years of data collection (e.g., 2008 in Bulgaria[32] and 1988 in the UK[33]) that may reflect different periods within the epidemiological transition of obesity in each country. In our study, the percentage of children with WHtR > 0.5 reached 25% in Greece and North Macedonia and over 20% in Spain. Hassapidou et al.[34]

TABLE 3 Percentages (confidence interval 95%) of boys and girls in BMI categories using the WHO classification; COSI/WHO Europe rounds 1–3 (2007/2008, 2009/2010 and 2012/2013)

BMI categories	Thinness < −2 SD	Normal weight from −2 SD to +1 SD	Overweight (excluding obesity) from +1 SD to +2 SD	Obesity > +2 SD	Overweight (including obesity) > +1 SD
Boys					
Eastern Europe					
BUL	3.1	67.6	15.4	13.9	29.3
	(2.6–3.8)	(65.9–69.3)	(14.1–16.8)	(12.6–15.2)	(27.6–30.9)
CZH	2.4	74.2	13.1	10.4	23.5
	(1.7–3.1)	(72.1–76.1)	(11.6–14.7)	(9.1–11.9)	(21.6–25.5)
Southern Europe					
ESP	0.8	54.8	24.1	20.3	44.4
	(0.5–1.3)	(52.6–57.0)	(22.3–26.0)	(18.6–22.1)	(42.2–46.6)
GRE	0.4	50.6	24.9	24.2	49.1
	(0.1–0.8)	(47.8–53.3)	(22.6–27.3)	(22.0–26.7)	(46.4–51.8)
MKD	2.8	63.4	16.1	17.6	33.7
	(2.1–3.9)	(60.8–66.0)	(14.2–18.2)	(15.6–19.8)	(31.2–36.3)
Northern Europe					
IRL	0.6	73.0	17.8	8.5	26.3
	(0.4–1.1)	(71.1–74.9)	(16.2–19.5)	(7.4–9.8)	(24.5–28.2)
LTU	1.3	73.8	15.7	9.3	25.0
	(0.8–1.9)	(71.6–75.8)	(14.0–17.5)	(8.0–10.8)	(22 9–27.1)
LVA	1.5	73.9	15.2	9.4	24.6
	(1.2–1.9)	(72.7–75.1)	(14 2–16.2)	(8.6–10.3)	(23.4–25.8)
NOR	2.1	75.1	15.3	7.5	22.8
	(1.3–3.2)	(72.2–77.8)	(13.1–17.8)	(6.0–9.4)	(20.2–25.6)
SWE	0.9	75.5	16.8	6.8	23.6
	(0.4–1.9)	(72.3–78.4)	(14.4–19.7)	(5.2–8.8)	(20.8–26.8)
Total	1.7	68.9	17.0	12.5	29.5
	(1.5–1.9)	(68.2–69.5)	(16.5–17.5)	(12.0–12.9)	(28.8–30.1)
Girls					
Eastern Europe					
BUL	2.7	69.9	15.6	11.7	27.3
	(2.2–3.4)	(68.2–71.5)	(14.4–17.0)	(10.6–13.0)	(25.8–29.0)
CZH	2.2	76.4	14.9	6.5	21.4
	(1.6–3.0)	(74.4–78.3)	(13.4–16.7)	(5.4–7.7)	(19.6–23.4)
Southern Europe					
ESP	0.7	58.8	25.4	15.1	40.5
	(0.4–1.2)	(56.6–60.9)	(23.6–27.3)	(13.6–16.7)	(38.4–42.6)
GRE	0.6	54.4	26.5	18.6	45.1
	(0.3–1.2)	(51.6–57.1)	(24.1–29.0)	(16.5–20.9)	(42.3–47.8)
MKD	2.5	70.3	15.2	12.0	27.2
	(1.8–3.6)	(67.6–72.8)	(13.3–17.4)	(10.3–13.9)	(24.8–29.8)
Northern Europe					
IRL	0.4	69.8	21.3	8.5	29.8
	(0.2–0.8)	(67.8–71.6)	(19.7–23.1)	(7.4–9.7)	(27.9–31.7)
LTU	2.0	76.4	14.3	7.2	21.5
	(1.4–2.8)	(74.3–78.4)	(12.7–16.1)	(6.1–8.6)	(19.6–23.6)
LVA	1.3	77.9	14.5	6.3	20.8
	(0.9–1.6)	(76.7–79.1)	(13.5–15.6)	(5.7–7.0)	(19.7–22.0)
NOR	0.9	74.4	18.3	6.3	24.6
	(0.5–1.8)	(71.4) – 77.2)	(15.9–21.1)	(4.9–8.1)	(21.9–27.6)
SWE	0.4	76.9	17.5	5.3	22.8
	(0.1–1.2)	(73.7–79.8)	(14.9–20.4)	(3.9–7.1)	(19.8–25.9)
Total	1.5	71.3	17.7	9.5	27.2
	(1.3–1.6)	(70.7–71.9)	(17.2–18.3)	(9.1–9.9)	(26.6–27.9)

Abbreviations: BMI, body mass index, BUL, Bulgaria; COSI, Childhood Obesity Surveillance Initiative; CZH, Czechia; ESP, Spain; GRE, Greece; IRL, Ireland; LVA, Latvia; LTU, Lithuania; MKD, North Macedonia; NOR, Norway; SD, standard deviation; SWE, Sweden; WHO, World Health Organization.

TABLE 4 Percentages (confidence interval 95%) of boys and girls in BMI categories using the IOTF classification; COSI/WHO Europe rounds 1–3 (2007/2008, 2009/2010 and 2012/2013)

BMI categories	Thinness BMI < 18.5 kg/m^2 at age 18	Normal weight BMI from 18.5 to 25 kg/m^2 at age 18	Overweight (excluding obesity) BMI from25to 30 kg/m^2 at age 18	Obesity BMI > 30 kg/m^2 at age 18	Overweight (including obesity) BMI > 25 kg/m^2 at age 18
Boys					
Eastern Europe					
BUL	12.8	66.9	13.1	7.2	20.3
	(11.6–14.0)	(65.1–68.5)	(11.9–14.4)	(6.3–8.2)	(18.9–21.9)
CZH	12.1	73.1	10.7	4.1	14.8
	(10.7–13.7)	(71.0–75.0)	(9.4–12.2)	(3.3–5.1)	(13.3–16.6)
Southern Europe					
ESP	4.2	65.0	21.1	9.6	30.7
	(3.4–5.2)	(62.9–67.1)	(19.4–23.0)	(8.4–11.0)	(28.8–32.8)
GRE	2.7	61.6	23.8	11.8	35.6
	(2.0–3.8)	(58.9–64.2)	(21.6–26.3)	(10.2–13.7)	(33.1–38.4)
MKD	12.8	63.3	14.9	9.0	23.9
	(11.0–14.7)	(60.6–65.9)	(13.1–17.0)	(7.6–10.7)	(21.7–26.4)
Northern Europe					
IRL	4.9	80.6	11.2	3.3	14.5
	(4.0–5.9)	(78.9–82.2)	(10.0–12.6)	(2.6–4.1)	(13.1–16.1)
LTU	7.6	77.3	10.8	4.2	15.0
	(6.4–9.0)	(75.3–79.3)	(9.4–12.4)	(3.4–5.3)	(13.4–16.9)
LVA	7.9	77.5	10.6	4.0	14.6
	(7.2–8.7)	(76.3–78.7)	(9.8–11.5)	(3.5–4.6)	(13.6–15.6)
NOR	8.4	77.2	11.0	3.4	14.4
	(6.7–10.4)	(74.4–79.8)	(9.1–13.2)	(2.4–4.8)	(12.3–16.9)
SWE	6.9	79.2	12.0	1.8	13.8
	(5.3–8.9)	(76.2–82.0)	(9.9–14.5)	(1.1–3.0)	(11.6–16.5)
Total	8.3	72.6	13.4	5.7	19.1
	(7.9–8.7)	(72.0–73.3)	(12.9–13.8)	(5.4–6.1)	(18.5–19.7)
Girls					
Eastern Europe					
BUL	14.8	62.4	15.4	7.4	22.8
	(13.5–16.1)	(60.6–64.2)	(14.1–16.8)	(6.5–8.4)	(21.3–24.4)
CZH	15.1	68.9	11.9	4.1	16.0
	(13.5–16.8)	(66.8–71.0)	(10.5–13.5)	(3.3–5.1)	(14.3–17.7)
Southern Europe					
ESP	5.3	61.0	25.1	8.6	33.7
	(4.4–6.3)	(58 9–63.1)	(23.2–27.0)	(7.5–9.9)	(31.7–35.8)
GRE	4.3	57.9	26.2	11.6	37.8
	(3.3–5.5)	(55.1–60.6)	(23.9–28.7)	(10.0–13.5)	(35.2–40.6)
MKD	15.6	63.3	13.2	7.9	21.1
	(13.6–17.7)	60 6–66.0)	(11.4–15.2)	(6.6–9.6)	(18.9–23.5)

(Continues)

TABLE 4 (Continued)

BMI categories	Thinness BMI < 18.5 kg/m^2 at age 18	Normal weight BMI from 18.5 to 25 kg/m^2 at age 18	Overweight (excluding obesity) BMI from25to 30 kg/m^2 at age 18	Obesity BMI > 30 kg/m^2 at age 18	Overweight (including obesity) BMI > 25 kg/m^2 at age 18
Northern Europe					
IRL	5.8	72.0	16.7	5.6	22.3
	(4.9–6.8)	(70.1–73.8)	(15.2–18.2)	(4.7–6.6)	(20.6–24.0)
LTU	11.6	72.5	11.4	4.5	15.9
	(10.1–13.2)	(70.3–74.6)	(10.0–13.0)	(3.6–5.6)	(14.2–17.8)
LVA	12.0	72.3	12.1	3.7	15.8
	(11.1–13.0)	(71.0–73.5)	(11.2–13.0)	(3.2–4.2)	(14.7–16.8)
NOR	8.3	73.6	13.7	4.4	18.1
	(6.6–10.3)	(70.5–76.4)	(11.5–16.1)	(3.3–6.0)	(15.7–20.8)
SWE	7.9	75.6	13.6	2.9	16.5
	(6.1–10.1)	(72.4–78.6)	(11.3–16.3)	(1.9–4.4)	(14.0–19.4)
Total	10.6	68.0	15.5	5.9	21.4
	(10.2–11.1)	(67.3–68.6)	(15.0–16.0)	(5.5–5.2.)	(20.8–21.9)

Abbreviations: BMI, body mass index; BUL, Bulgaria; COSI, Childhood Obesity Surveillance Initiative; CZH, Czechia; ESP, Spain; GRE, Greece; IOTF, International Obesity Task Force; IRL, Ireland; LVA, Latvia; LTU, Lithuania; MKD, North Macedonia; NOR, Norway; SWE, Sweden.

has previously published COSI data on WHtR among 7-year-old Greek children, which are consistent with our data. We found less than 10% of children with WHtR > 0.5 in Northern European countries (Norway, Sweden, and Latvia). The prevalence of abdominal obesity as defined by WHtR in Northern European countries was lower in our study than that reported in a recent German study, where 17.5% children aged 7.5 (±0.42) years had WHtR > 0.50.[35]

In addition to behavioral and environmental factors, genetic factors and ethnicity may also have contributed to the observed differences in WC and WHtR among the countries. A recently conducted genome-wide association meta-analysis of traits related to waist and hip circumference confirmed that body fat distribution is a heritable trait associated with loci that are linked to cardiometabolic risks.[36] Loci linked to body fat distribution—in contrast to those linked to overall obesity—exhibit strong sexual dimorphism.[37] In this cohort of 7-year-old children, sexual dimorphism in anthropometric indexes has not been demonstrated, although slightly higher values for both WC and WHtR were observed in boys compared to girls. Our results are similar to the results found in cohorts of Spanish and Dutch children, where WC tended to be higher in males than in females, and this difference was significant from 11 years of age due to sexual development.[38,39]

In recent years, many European countries have been making efforts to develop national WC references.[32,33,40–45] Similarly, de Assis et al. established WC percentiles in 7- to 10-year-old Brazilian children and compared obesity and overweight occurrence and WC values with corresponding data for British children.[11,46] However, there are no internationally agreed thresholds for normal WC in children of different age categories. Percentile values of WC and WHtR were published by the IDEFICS study in age categories 2–10.9 years consisting of normal weight children.[26] Furthermore, international WC cutoffs for the 6–18 years age group from eight countries were recently proposed.[9]

According to Brannsether,[40] the cutoff value of 0.5 for WHtR has a high sensitivity (97%) and specificity (87%) for detecting obesity in 6- to 12-year-old children, but not in children younger than 6 years. Swandt and Haas[41] suggested using age, gender-specific, and population-specific WHtR cutoff values, as these factors could be responsible for the differences found between individual participating countries. In some studies, different cutoff points for WHtR have been used. The National Health and Nutrition Examination Survey III carried out in children aged 4–17 years in the USA used cutoff points of 0.490 and 0.539 for the stratification of children with normal weight, overweight, and obesity.[47] WHtR identified children with adverse cardiovascular risk factors better when these cutoff points were used.[47] In order to obtain robust thresholds for the use of WHtR, more studies should be carried out to reveal the relation of WHtR to metabolic disturbances among children in individual populations or countries. Some studies, however, do not support the use of WHtR in comparison with WC or BMI for assessing risk in younger children.[48,49] In a Japanese population, age- and sex-dependent reference values were provided based on national survey data. A universal WHtR cutoff of 0.5 cannot be used in this population.[50] Several studies have investigated the specific national reference values for WC and WHtR in children and adolescents.[32,33,40–45] Comparison of Polish and German children aged 7–18 years found higher mean levels and percentile values of waist and WHtR in German children than in their Polish peers.[31]

TABLE 5 Percentages (confidence interval 95%) of children with values of waist circumference >50th and >90th percentile using IDEFICS classification; COSI study (2007–2013); percentages (confidence interval 95%) of boys and girls with WHtR values >0.5; COSI/WHO Europe rounds 1–3 (2007/2008, 2009/2010 and 2012/2013)

WC categories	WC > 50th perc. IDEFICS	WC > 90th perc. IDEFICS	WHtR > 0.5
Boys			
Eastern Europe			
BUL	49.0	22.5	11.3
	(47.2–50.8)	(21.0–24.1)	(10.2–12.5)
CZH	62.9	26.6	9.9
	(60.7–65.1)	(24.6–28.7)	(8.6–11.3)
Southern Europe			
ESP	71.6	42.2	19.7
	(69.5–73.5)	(40.1–44.4)	(18.0–21.5)
GRE	76.8	44.2	22.4
	(74.4–79.0)	(41.5–47.0)	(20.2–24.7)
MKD	72.9	45.7	25.6
	(70.4–75.2)	(43.0–48.4)	(23.3–28.0)
Northern Europe			
IRL	66.0	25.6	9.9
	(64.0–68.0)	(23.8–27.5)	(8.7–11.3)
LTU	74.9	33.9	11.7
	(72.8–76.9)	(31.7–36.3)	(10.2–13.3)
LVA	60.3	24.2	7.9
	(59.0–61.7)	(23.1–25.5)	(7.1–8.7)
NOR	60.6	21.5	5.5
	(57.4–63.7)	(18.9–24.3)	(4.2–7.2)
SWE	56.5	22.1	3.8
	(53.0–60.0)	(19.3–25.1)	(2.6–5.4)
Total	63.6	29.5	12.1
	(63.0–64.3)	(28.9–30.1)	(11.7–12.6)
Girls			
Eastern Europe			
BUL	48.6	24.6	10.6
	(46.8–50.4)	(23.1–26.2)	(9.5–11.7)
CZH	58.3	23.6	8.6
	(56.0–60.)	(21.7–25.6)	(7.4–10.0)
Southern Europe			
ESP	73.9	41.7	20.5
	(71.9–5.7)	(39.5–43.8)	(18.8–22.4)
GRE	78.5	49.1	23.4
	(76.1–80.7)	(46.3–51.9)	(21.1–25.8)
MKD	70.2	42.7	20.5
	(67.6–72.7)	(39.9–45.5)	(18.3–22.8)
Northern Europe			
IRL	70.2	33.7	16.1
	(68.3–72.1)	(31.8–35.7)	(14.7–17.7)
LTU	73.5	37.3	11.8
	(71.3–75.5)	(35.0–39.7)	(10.4–13.5)

(Continues)

TABLE 5 (Continued)

WC categories	WC > 50th perc. IDEFICS	WC > 90th perc. IDEFICS	WHtR > 0.5
LVA	57.0	22.5	7.1
	(55.6–58.4)	(21.4–23.7)	(6.4–7.8)
NOR	63.3	24.1	8.3
	(60.0–66.5)	(21.3–27.0)	(6.6–10.3)
SWE	59.0	23.5	6.5
	(55.4–62.5)	(20.6–26.8)	(4.9–8.5)
Total	63.1	30.6	12.5
	(62.4–63.8)	(29.9–31.2)	(12.1–13.0)

Note. According to Vorwieger et al.[35]

Abbreviations: BUL, Bulgaria; COSI, Childhood Obesity Surveillance Initiative; CZH, Czechia; ESP, Spain; GRE, Greece; IDEFICS, Identification and prevention of Dietary- and lifestyle-induced health EFfects In Children and infantS; IRL, Ireland; LVA, Latvia; LTU, Lithuania; MKD, North Macedonia; NOR, Norway; SWE, Sweden; WHtR, waist to height ratio.

Reliable identification of children with an increased risk of cardiovascular disease and metabolic disorders is critical for surveillance, research, prevention, and intervention efforts. In addition, further research is needed for the development of international evidence-based cutoff points to identify children with increased risk. However, a common consensus on WC and WHtR cutoff points for children from different populations is yet to be reached. International WC references for children—as there currently are for BMI—would be desirable for comparison of waist and WHtR between countries and regions.

A major strength of our study is the large, international cohort covering a single age category, with a representative sample of both genders from each participating country and standardized methodology used for the surveys. Data collection adhered to a strict set of protocols to ensure robustness. A potential weakness of the study is that the data were analyzed in the raw (unweighted) form with no survey sampling weights as these were not available. Although the overall COSI study covers most of Europe, we only had data for all three rounds of data collection from four countries, and the inherent heterogeneity of these populations may have influenced our findings. However, no significant change of WC between individual rounds was observed for these countries.

5 | CONCLUSIONS

This study demonstrated heterogeneity in BMI, WC, and WHtR among 38,975 children aged 7 from 10 WHO European Region countries. A pattern emerged in which countries in Southern Europe tended to see higher prevalence of children with overweight, increased WC, and WHtR > 0.5. Including measurement of WC in surveillance of childhood weight status may provide valuable additional information and should be urgently considered. Further work is needed to reach international consensus regarding cutoffs for WC to identify children at increased risk of cardiometabolic complications.

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AUTHOR CONTRIBUTIONS

R. T. B. and M. K. conceptualized the study; J. V., M. He., H. R., A. Y., V. H., J. W., M. Br., M. Bu., and P. S. drafted the manuscript; and M. Ha., V. D., I. P., A. P., A. S., L. L., I. S., E. G.-G., C. K., T. M., and

H. Z. contributed to data collection and data cleaning. All authors contributed to and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest. The funders played no role in the design of the COSI protocol, the decision to write this paper, or its content.

ETHICS STATEMENT

The COSI study follows the International Ethical Guidelines for Biomedical Research Involving Human Subjects. Local ethics approval was also granted.

DISCLAIMER

J. B., I. R., and J. W. are staff members of WHO, and M. B. and P. S. are consultants with WHO. The authors alone are responsible for the views expressed in this article, and they do not necessarily represent the views, decisions, or policies of the institutions with which they are affiliated.

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REFERENCES

1. Murray CJ, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012;380(9859):2197-2223.
2. Whitaker RC, Pepe MS, Wright JA, Seidel KD, Dietz WH. Early adiposity rebound and the risk of adult obesity. *Pediatrics*. 1998;101 (3):E5.
3. Cho SJ, Kim EY, Rho YI, et al. The long-term follow-up studies of childhood obesity after puberty. *Korean J Pediatr Gastroenterol Nutr*. 2003;6(1):47-53.
4. Spinelli A, Buoncristiano M, Nardone P, et al. Thinness, overweight, and obesity in 6- to 9-year-old children from 36 countries: The World Health Organization European Childhood Obesity Surveillance Initiative—COSI 2015–2017. *Obes Rev*. 2021;e13214. https://doi.org/10.1111/obr.13214
5. Vanderwall C, Clark RR, Eickhoff J, Carrel AL. BMI is a poor predictor of adiposity in young overweight and obese children. *BMC Pediatr*. 2017;17(1):135. https://doi.org/10.1186/s12887-017-0891-z
6. Pouliot MC, Després JP, Lemieux S, et al. Waist circumference and abdominal sagittal diameter: best simple anthropometric indexes of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women. *Am J Cardiol*. 1994;73(7):460-468.
7. Brambilla P, Bedogni G, Moreno LA, 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(1):23-30.
8. O'Connor M, Ryan J, Foley S. Best single-slice location to measure visceral adipose tissue on paediatric CT scans and the relationship between anthropometric measurements, gender and VAT volume in children. *Br J Radiol*. 2015;88(1054):20140711.
9. Xi B, Zong X, Kelishadi R, Litwin M, et al. International waist circumference percentile cutoffs for central obesity in children and adolescents aged 6 to 18 years. *J Clin Endocrinol Metab*. 2020;105(4): e1569-e1583.
10. Kelly AS, Dengel DR, Hodges J, Zhang L, Moran A, Chow L. The relative contributions of the abdominal visceral and subcutaneous fat depots to cardiometabolic risk in youth. *Clin Obes*. 2014;4(2): 101-107.
11. McCarthy HD, Ashwell M. A study of central fatness using waist-to-height ratios in UK children and adolescents over two decades supports the simple message –"keep your waist circumference to less than half your height". *Int J Obes (Lond)*. 2006;30(6):988-992.
12. Wijnhoven TM, Branca F. *WHO European Childhood Obesity Surveillance Initiative*. Protocol, version January 2008. Copenhagen: WHO Regional Office for Europe; 2008.
13. Louer AL, Simon DN, Switkowski KM, Rifas-Shiman SL, Gillman MW, Oken E. Assessment of Child Anthropometry in a Large Epidemiologic Study. *J Vis Exp*. 2017;120:e54895.
14. Wijnhoven TM, van Raaij JM, Spinelli A, et al. WHO European Childhood Obesity Surveillance Initiative 2008: weight, height and body mass index in 6–9-year-old children. *Pediatr Obes*. 2013;8(2):79-97.
15. *WHO European Childhood Obesity Surveillance Initiative*. Protocol, version October 2012. Copenhagen: World Health Organization Regional Office for Europe; 2012.
16. *WHO European Childhood Obesity Surveillance Initiative: overweight and obesity among 6–9-year-old children*. Report of the third round of data collection 2012–2013. Copenhagen, Denmark: WHO Regional Office for Europe; 2018 https://www.euro.who.int/__data/assets/pdf_file/0010/378865/COSI-3.pdf. Accessed March 19, 2020.
17. Wijnhoven TM, van Raaij JM, Yngve A, et al. WHO European childhood obesity surveillance initiative: Health-risk behaviours on nutrition and physical activity in 6-9-year-old school children. *Public Health Nutr*. 2015;18(17):3108-3124.
18. Wijnhoven TM, van Raaij JM, Breda J. *WHO European Childhood Obesity Surveillance Initiative: implementation of round 1 (2007/2008) and round 2 (2009/2010)*. Copenhagen, Denmark: WHO Regional Office for Europe; 2014 http://wwweurowhoint/__data/assets/pdf_file/0004/258781/COSI-report-round-1-and-2_final-for-webpdf Accesed March 19, 2020.
19. World Health Organization. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. *WHO Technical Report Series*. No. 854. Geneva: 1995. http://apps.who.int/iris/bitstream/10665/37003/1/WHO_TRS_854.pdf
20. Breda J, McColl K, Buoncristiano M, et al. Methodology and implementation of the WHO European Childhood Obesity Surveillance Initiative (COSI). *Obes Rev*. 2021;e13215. https://doi.org/10.1111/obr.13215
21. WHO criteria BMI-for-age2007. http://www.who.int/growthref/who2007_bmi_for_age/en/
22. Nations U. United Nations Standard Country Code, Series M. *MiscellaneousStatisticalPapers*. No. 49. New York: United Nations. ST/ESA/STAT/SER.M/49. Availablefrom: https://unstats.un.org/unsd/methodology/m49/2020
23. WHO anthropo software. http://www.who.int/growthref/tools/en/
24. Blössner M, Siyam A, Borghi E, Onyango A, de Onis M. *WHO AnthroPlus for personal computers manual: software for assessing growth of the world's children and adolescents*. Geneva: World Health Organization; 2009.
25. R core. 2017, R software. http://cran.at.r-project.org/
26. Nagy P, Kovacs E, Moreno LA, et al. Percentile reference values for anthropometric body composition indices in European children from the IDEFICS study. *Int J Obes (Lond)*. 2014;38(Suppl 2):S15-S25.
27. Cole TJ, Flegal KM, Nicholls D, Jackson AA. Body mass index cut offs to define thinness in children and adolescents: international survey. *BMJ*. 2007;335(7612):194.

28. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320(7244):1240-1243.
29. Mokha JS, Srinivasan SR, Dasmahapatra P, et al. Utility of waist-to-height ratio in assessing the status of central obesity and related cardiometabolict risk profile among normal weight and overweight/obese children: the Bogalusa Heart Study. *BMC Pediatr*. 2010;10(1):73.
30. Bacopoulou F, Efthymiou V, Landis G, Rentoumis A, Chrousos GP. Waist circumference, waist-to-hip ratio and waist-to-height ratio reference percentiles for abdominal obesity among Greek adolescents. *BMC Pediatr*. 2015;15(1):50.
31. Nawarycz T, Haas GM, Krzyżaniak A, Schwandt P, Ostrowska-Nawarycz L. Waist circumference and waist-to-height ratio distributions in Polish and German schoolchildren: comparative analysis. *Int J Prev Med*. 2013;4(7):786-796.
32. Galcheva SV, Iotova VM, Yotov YT, Grozdeva KP, Stratev VK, Tzaneva VI. Waist circumference percentile curves for Bulgarian children and adolescents aged 6–18 years. *Int J PediatrObes*. 2009;4(4):381-388.
33. McCarthy H, Jarrett K, Crawley H. The development of waist circumference percentiles in British children aged 5.0–16.9 y. *Eur J Clin Nutr*. 2001;55:902-907.
34. Hassapidou M, Tzotzas T, Makri E, et al. Prevalence and geographic variation of abdominal obesity in 7- and 9-year-old children in Greece; World Health Organization Childhood Obesity Surveillance Initiative 2010. *BMC Public Health*. 2017;17(1):126.
35. Vorwieger E, Kelso A, Steinacker JM, Kesztyüs D, URMEL-ICE study group. Cardio-metabolic and socio-environmental correlates of waist-to-height ratio in German primary schoolchildren: a cross-sectional exploration. *BMC Public Health*. 2018;18(1):280.
36. Shungin D, Winkler TW, Croteau-Chonka DC, et al. New genetic loci link adipose and insulin biology to body fat distribution. *Nature*. 2015;518(7538):187-196.
37. Pulit SL, Karaderi T, Lindgren CM. Sexual dimorphism in genetic loci linked to body fat distribution. *Biosci Rep*. 2017;37(1). https://doi.org/10.1042/bsr20160184
38. Moreno LA, Fleta J, Mur L, Rodriquez G, Sarría A, Bueno M. Waist circumference values in Spanish children—gender related differences. *Eur J Clin Nutr*. 1999;53(6):429-433.
39. Fredriks AM, van Buuren S, Fekkes M, Verloove-Vanhorick SP, Wit J. Are age references for waist circumference, hip circumference and waist-to-hip ratio in Dutch children useful in clinical practice? *Eur J Pediatr*. 2005;164(4):216-222.
40. Brannsether B, Roelants M, Bjerknes R, Júlíusson PB. Waist circumference and waist-to-height ratio in Norwegian children 4-18 years of age: reference values and cut-offs. *Acta Paediatr*. 2011;100(12):1576-1582.
41. Schwandt P, Haas GM. Is the ratio waist circumference to height (WHtR) of 0.5 a universal measure for abdominal adiposity in children and adolescents? *Int J Obes (Lond)*. 2016;40(7):1141-1142.
42. 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(4):383-389.
43. Poh BK, Jannah AN, Chong LK, Ruzita AT, Ismail MN, McCarthy D. Waist circumference percentile curves for Malaysian children and adolescents aged 6.0-16.9 years. *Int J PediatrObes*. 2011;6(3–4):229-235.
44. Song P, Li X, Gasevic D, Flores AB, Yu Z. BMI, waist circumference reference values for Chinese school-aged children and adolescents. *Int J Environ Res Public Health*. 2016;13(6):589.
45. Mukherjee S, Leong HF, Wong XX. Waist circumference percentiles for Singaporean children and adolescents aged 6–17 years. *Obes Res Clin Pract*. 2016;10(Suppl 1):S17-S25.
46. de Assis MAA, Rolland-Cachera MF, de Vasconcelos FAG, et al. Central adiposity in Brazilian schoolchildren aged 7–10 years. *Br J Nutr*. 2007;97(4):799-805.
47. Kahn HS, Imperatore G, Cheng YJ. A population-based comparison of BMI percentiles and waist-to-height ratio for identifying cardiovascular risk in youth. *J Pediatr*. 2005;146(4):482-488.
48. Blüher S, Molz E, Wiegand S, et al. Adiposity patients registry initiative and German competence net obesity. Body mass index, waist circumference, and waist-to-height ratio as predictors of cardiometabolic risk in childhood obesity depending on pubertal development. *J Clin Endocrinol Metab*. 2013;98(8):3384-3393.
49. Sijtsma A, Bocca G, L'abée C, Liem ET, Sauer PJ, Corpeleijn E. Waist-to-height ratio, waist circumference and BMI as indicators of percentage fat mass and cardiometabolic risk factors in children aged 3-7 years. *Clin Nutr*. 2014;33(2):311-315.
50. Inokuchi M, Matsuo N, Takayama JI, Hasegawa T. Waist-to-height ratio centiles by age and sex for Japanese children based on the 1978-1981 cross-sectional national survey data. *Int J Obes (Lond)*. 2016;40(1):65-70.

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