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WHO European Childhood Obesity Surveillance Initiative 2008: weight, height and body mass index in 6–9-year-old children

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What is already known about this subject

- Overweight and obesity prevalence estimates among children based on International Obesity Task Force definitions are substantially lower than estimates based on World Health Organization definitions.
- Presence of a north–south gradient with the highest level of overweight found in southern European countries.
- Intercountry comparisons of overweight and obesity in primary-school children in Europe based on measured data lack a similar data collection protocol.

What this study adds

- Unique dataset on overweight and obesity based on measured weights and heights in 6–9-year-old children from 12 European countries using a harmonized surveillance methodology.
- Because of the use of a consistent data collection protocol, it is possible to perform valid multiple comparisons between countries.
- It demonstrates wide variations in overweight and obesity prevalence estimates among primary-school children between European countries and regions.

Summary

Background: Nutritional surveillance in school-age children, using measured weight and height, is not common in the European Region of the World Health Organization (WHO). The WHO Regional Office for Europe has therefore initiated the WHO European Childhood Obesity Surveillance Initiative.

Objective: To present the anthropometric results of data collected in 2007/2008 and to investigate whether there exist differences across countries and between the sexes.

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Methods: Weight and height were measured in 6–9-year-old children in 12 countries. Prevalence of overweight, obesity, stunting, thinness and underweight as well as mean Z-scores of anthropometric indices of height, weight and body mass index were calculated.

Results: A total of 168 832 children were included in the analyses and a school participation rate of more than 95% was obtained in 8 out of 12 countries. Stunting, underweight and thinness were rarely prevalent. However, 19.3–49.0% of boys and 18.4–42.5% of girls were overweight (including obesity and based on the 2007 WHO growth reference).The prevalence of obesity ranged from 6.0 to 26.6% among boys and from 4.6 to 17.3% among girls. Multi-country comparisons suggest the presence of a north–south gradient with the highest level of overweight found in southern European countries.

Conclusions: Overweight among 6–9-year-old children is a serious public health concern and its variation across the European Region highly depends on the country. Comparable monitoring of child growth is possible across Europe and should be emphasized in national policies and implemented as part of action plans.

Keywords: Overweight, obesity, schoolchildren, COSI.

Abbreviations: BMI, body mass index; BMI/A, body mass index-for-age; COSI, Childhood Obesity Surveillance Initiative; GSHS, Global Student Health Survey; H/A, height-for-age; HBSC, Health Behaviour in School-aged Children; IOTF, International Obesity Task Force; PSU, primary sampling unit; SD, standard deviation; SSU, secondary sampling unit; W/A, weight-for-age; WHO, World Health Organization.

Introduction

Excessive body weight in children and adolescents is a serious public health concern in the European Region of the World Health Organization (WHO) (1) and was addressed at the WHO European Ministerial Conference on Counteracting Obesity (2). Based on the cut-offs recommended by the International Obesity Task Force (IOTF) (3), it was then estimated that about 20% of the children and adolescents in the WHO European Region were overweight (including obesity) and that a third of them could be classified as obese (1). A recent review of the data on overweight among pre-school children reports prevalence estimates (based on the 2006 WHO Child Growth Standards (4)) of more than 25% in Albania, Bosnia and Herzegovina and Ukraine (5).

While it is generally recognized that nutritional surveillance data are crucial for the development of targeted action and the monitoring of progress and success in counteracting obesity, regular assessments of the magnitude of overweight and obesity, particularly in children and adolescents, are not common in the majority of the 53 WHO European Member States. A comprehensive review conducted for the 2006 Ministerial Conference revealed that by 2006, only 15 Member States had nationally representative objective data for children aged 0–6 years available from 1999 onwards. Based on weight and height measurements, 13 only had national data for the age group 6–10 years and 19 countries monitored overweight and obesity in adolescents (10–19 years) (1). Little is known about trends in overweight in pre-school children, schoolchildren and adolescents in the WHO European Region, and the scarce objective data show variable figures (6–8).

At the first consultation with Member States (9), in the process leading to the 2006 Ministerial Conference, the need was recognized for European-wide and standardized childhood surveillance systems on which policy development within the European Region could be based. As a follow-up to this recommendation, the WHO Regional Office for Europe initiated with 13 Member States (Belgium, Bulgaria, Cyprus, Czech Republic, Ireland, Italy, Latvia, Lithuania, Malta, Norway, Portugal, Slovenia and Sweden) the WHO European Childhood Obesity Surveillance Initiative (COSI). Its aim is to fill the gap in longitudinal information on anthropometry in primary-school children by routinely measuring their body weight and body height. The main reason for choosing this population group was that intercountry-comparable, nationally representative surveys carried out in the European Region mainly target pre-school children aged 0–5 years (e.g. through the Demographic Health Surveys (10) and the Multiple Indicator Cluster Surveys (11)) or adolescents aged 11–15 years (e.g. through the Health Behaviour in School-aged Children (HBSC) survey (12) and the Global School-based Student Health Survey (GSHS) (13)).

The first data collection in primary-school children according to the COSI harmonized surveillance methodology took place during the school year 2007/2008. All countries except Cyprus delivered

their 2007/2008 data to the WHO-COSI database and nine countries have already published their national data analyses (14–22). This paper compares the weight, height, body mass index (BMI) and their derived indices, including estimates of the prevalence of overweight and obesity, of 6–9-year-old schoolchildren from the 12 countries represented in the WHO-COSI database. This age range was chosen because these ages precede puberty and eliminate possible intercountry differences that could be attributed to variations in the onset of signs of puberty (23).

The paper's aim is to investigate whether differences exist in mean values of weight, height and BMI as well as their derived indices and prevalence estimates across the countries and between boys and girls.

Methods

Protocol development

An agreed common protocol was developed throughout 2007 by participating Member States and the Regional Office and finalized in 2008 (24). The main documents consulted were the protocol of the 2001/2002 HBSC survey (25), the GSHS manual (26), the manuals of the WHO STEPwise Approach to Surveillance (27), the surveillance protocol proposed by the European Childhood Obesity Group (23) and the child obesity monitoring guidance of the Department of Health in the United Kingdom (28). Although each participating country was free to develop a system that fitted its local circumstances, it was important that data were collected according to the COSI protocol. It was also stressed that the COSI system should not replace countries' existing health, anthropometric and dietary surveillance systems that had already been in place or were at the planning stage; on the contrary, the COSI approach should be integrated into the existing systems if possible.

Study population and sampling design

Age groups chosen

Given the differences among countries in school systems, the age of children entering the first class of primary school (reception year), and the number of children repeating a grade, it was difficult to implement a uniform sampling approach that was applicable in every country. Age was therefore taken as the first condition for the sampling procedures. Countries were free to select one or more of the following four COSI age groups: 6.0–6.9, 7.0–7.9, 8.0–8.9 or 9.0–9.9 years. Because children of this age in all countries are enrolled in primary schools, the school population was therefore taken to be representative of the total population in these age groups.

Stratification

Stratification was applied if it was expected that differences in anthropometric measurements and indices across strata would be observed. This was done by seven countries: the Czech Republic by region and level of urbanization; Ireland by health service executive region; Italy by region; Latvia by level of urbanization and language of instruction; Lithuania by district and level of urbanization; Norway by county and administrative health region; and Sweden by type of municipality and type of school (public/private). Countries took account of the expected refusal rates in determining the necessary oversampling.

Sampling units

The entire population of interest was included by Belgium (Flanders only) and Malta (all first grade primary-school classes) and nationally representative samples were taken by the other 10 countries except Portugal (all regions except Madeira) through cluster sampling, whereby the primary sampling unit (PSU) was the primary school or the class (except in the Czech Republic and Norway, as explained below).

Primary schools and classes were selected randomly from the list of all primary schools (public, private and special schools) centrally available in each country through the Ministry of Education or at the national school registry (or national list of primary care paediatricians). If less than about 1% of the target children were enrolled in private or special schools (e.g. schools for mentally handicapped children or children with visual impairment and blindness), countries had the choice of excluding these schools from the sampling frame. If the majority of the children of the targeted age group were in the same grade, then the sample was drawn from within that grade level. If the targeted age group was spread across grades, however, all grades where most children from this age group were present were sampled. In every sampled class, all children were invited to participate. The PSU in the Czech Republic was composed of paediatric clinics, because COSI was attached to the mandatory health checks that are performed by paediatricians. The PSU in Norway was composed of counties, which were selected by simple random sampling and with probability proportional to size.

Sample size

Rudolf *et al*. suggest using the standard deviation (SD) scores or Z-scores of a BMI distribution to demonstrate whether a halt in the rise in overweight or obesity is achieved (29). The calculated sample size of ≈2300 children per age group was based on an 80% power to detect a minimum difference of 0.10 Z-score in mean BMI per year at a two-sided 5% significance level. To achieve the same precision with a cluster sample design as with a simple random sample, the minimum final effective sample size should be ≈2800 children per age group, whereby a design effect of 1.2 was taken into account (25).

Data collection procedures

The COSI protocol is in accordance with the International Ethical Guidelines for Biomedical Research Involving Human Subjects (30). Depending on local circumstances, the procedures were also approved by local ethical committees. Parents were fully informed about all study procedures. Informed consent was obtained using either an active or passive approach, depending on local legal and ethical requirements. In the case of the active approach, their informed consent for the measurements and data treatment was obtained prior to the child's measurement. The child's consent was always obtained prior to the measurements. Confidentiality of all collected and archived data was ensured. The children's names and, in some cases, the entire birth date were not included in the electronic data files sent to the Regional Office.

Countries decided on the measurement period. Data collection, however, was avoided during the first 2 weeks of a school term or immediately after a major holiday. Taking the local arrangements, circumstances and budget into account, countries chose the most appropriate professionals to collect the data from the children, hereafter called examiners. The following child variables were collected through the examiner's record form: date of birth, sex, postal code or living area, school grade, date of measurement, clothes worn when measured, school code, body weight and body height. A school form was completed either by the school principal, by the teachers of the sampled classes or by someone else who would be able to report on the location of the school, the number of children registered and measured per sampled class, the number registered who had refused to be measured, and the number absent on the day of measurement.

Anthropometric measurements

Prior to data collection, all examiners were trained in measuring weight and height using the outlined WHO standardized techniques (31). The training also included a review of the background and objectives of the surveillance system, standardized use of the forms, support to children with anxieties, recording measurement values immediately after reading them, and writing legibly to reduce mistakes during data transfer. Measurements were carried out in close collaboration with teachers and other school personnel in a private room in the school (except in the Czech Republic, where measurements were made in paediatric clinics). Children were not routinely informed of their body weight and body height, as this is a surveillance and not a screening programme, which would entail a referral to treatment and follow-up of children who had been identified as being overweight or obese (32).

Children were asked to take off their shoes and socks as well as all heavy clothing (coats, sweaters, jackets, etc.). Furthermore, wallets, mobile phones, key chains, belts or any other objects were removed, as well as hair ornaments or braids. Body weight was measured to the nearest 0.1 kg with portable digital (mainly manufacturer-calibrated) scales (SECA 872, SECA 862, SECA Bella 840, Bellissima 841, Tanita UM-072 or Beurer PS07) and body height was measured standing upright to the nearest 0.1 cm with a portable stadiometer (SECA 214, TB I Hyssna 4205, SECA 206 or Leicester) according to WHO's measurement protocol (31). Body weight was then adjusted for the weight of the clothes worn. The average weights of types of clothing (underwear only, gym clothes, light clothing and heavy clothing) were provided by each country. Where possible, the same anthropometric equipment was used throughout a country.

Data elaboration and statistical analysis

All country datasets were reviewed in a standard manner at the Regional Office for inconsistencies and completeness before they were merged for the intercountry analyses. The final dataset included children with informed consent and complete information on age, sex, weight and height. Children were excluded from the final dataset if their age did not fall within the targeted age group.

The child's age was calculated using the formula: (date of measurement minus date of birth)/365.25. When only the month and year of birth were provided, the day of birth was chosen randomly (this was done for 48 Latvian children and the entire Italian

dataset). BMI was calculated using the formula: weight (kg) divided by height squared (m^2).

The 2007 WHO recommended cut-offs for school-age children and adolescents were used to compute height-for-age (H/A), weight-for-age (W/A) and BMI-for-age (BMI/A) Z-scores, and to interpret anthropometric indicators (33,34), whereby stunting and severe stunting were defined as the proportion of children with a H/A value below –2 Z-scores and below –3 Z-scores, respectively, relative to the 2007 WHO growth reference mean. Underweight and severe underweight were defined as the proportion of children with a W/A value below –2 Z-scores and below –3 Z-scores, respectively. Thinness and severe thinness were defined as the proportion of children with a BMI/A value below –2 Z-scores and below –3 Z-scores, respectively. Overweight and obesity were defined as the proportion of children with a BMI/A value above +1 Z-score and above +2 Z-scores, respectively. Overweight and obesity were also estimated using the IOTF cut-off points (3), as they are widely used in the WHO European Region (Appendix I).

According to WHO definitions, the prevalence estimates for stunted children include those who are severely stunted, the prevalence estimates for underweight children include those who are severely underweight, the prevalence estimates for thin children include those who are severely thin, and the prevalence estimates for overweight children include those who are obese (31).

Children with biologically implausible (or extreme) values were excluded from the analysis (34): W/A values below –6 or above +5 Z-scores; H/A values below –6 or above +6 Z-scores; and BMI/A values below –5 or above +5 Z-scores relative to the 2007 WHO growth reference mean.

Sampling weights to adjust for the applied sampling design, oversampling and non-response rate were available for only three countries, and thus the analyses were performed unweighted. Means ± SDs, medians and interquartile ranges were calculated for all measurements (weight, height and BMI) and anthropometric indices (W/A, H/A and BMI/A Z-scores) by age group, sex and country. For each country-specific dataset these six continuous variables were tested by age group for normality using normal quantile–quantile plots. Weight and BMI were found to be highly positively skewed in all datasets. They were therefore transformed to attain normality and their transformed values were used for the intercountry comparisons. Using the command 'ladder' in Stata 10.1 (StataCorp, College Station, TX, USA), the best option suggested was inverse transformation for weight and 1/square transformation for BMI. Although the distribution of W/A and BMI/A Z-scores was slightly skewed to the right, the command 'ladder' showed no need to apply transformations to normalize them. Prevalence estimates are presented as percentages. The homogeneity of variances was tested using Levene's test (35). Because the data showed heterogeneity of variances between countries and because of an unbalanced design (unequal group sizes), the main effects of country and sex and their interaction on all mean anthropometric values were assessed using two-way analysis of variance (ANOVA), with the Games–Howell *post hoc* test for the multiple comparisons between countries (36). This was done separately for three age groups (6-, 7- and 8-year-olds) because not every country had included all age groups. In the case of an interaction effect, a one-way ANOVA was performed to assess significant differences across countries by sex and between sexes by country for all four age groups. Within each age group, the chi-squared test was used to determine differences in the prevalence estimates across countries for the total group and for boys and girls separately. If the chi-squared test was found significant, the Marascuilo procedure was used for the multi-group comparisons of proportions between countries (37). A chi-squared test was used to assess a linear trend in the prevalence estimates with increasing age for the countries with multiple age groups selected. A *P*-value of 0.05 was used to determine significance. All statistical analyses, except the Games–Howell *post hoc* tests, were performed in Stata version 10.1. The latter was performed in SPSS version 20.0 (IBM, Armonk, NY, USA).

Results

Sampling, subject and data collection characteristics

A total of 168 832 children aged 6–9 years were included in the data analyses (85 934 boys and 82 898 girls). A school and class participation rate of more than 95% was observed in eight countries. Table 1 summarizes the sampling characteristics for each of the 12 participating countries. Table 2 shows the number of children who were invited to participate, who were measured, who had complete information on age, sex, weight and height, and who fell within the targeted age group. Table 3 gives an overview of the application of the COSI protocol characteristics in each country.

Table 1 Sampling characteristics for each of the 12 participating countries

Characteristics	Countries											
	BEL	BUL	CZH	IRE	ITA	LVA	LTU	MAT	NOR	POR	SVN	SWE
Sampling design												
Inclusion of entire targeted age group	✓							✓*				
Cluster sampling design		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Schools (PSU)												
Total approached (*n*)	NA	184	60†	498	NA	193	161	97	131‡	189	118	220
Total included (*n*)	NA	184	46†	163	NA	190	155	95	127‡,§	181	118	94
Participation rate (%)	NA	100	76.7	32.7	NA	98.4	96.3	97.9	96.9	95.8	100	42.7
Classes (SSU)												
Total approached (*n*)	NA	190	NA	163	459¶	300	309	192	131**	362	774	306
Total included (*n*)	NA	190	NA	163	456¶	300	309	192	127**	362	774	306
Participation rate (%)	NA	100	NA	100	99.3	100	100	100	96.9	100	100	100

*All first grade classes of 95 primary schools in Malta were included.
†Paediatric clinics formed the PSU.
‡Counties formed the PSU.
§Four selected schools were excluded because they had only one pupil from the targeted age group.
¶Classes formed the PSU.
**Schools formed the SSU.
✓, applicable; BEL, Belgium (Flanders); BUL, Bulgaria; CZH, Czech Republic; IRE, Ireland; ITA, Italy; LTU, Lithuania; LVA, Latvia; MAT, Malta; NA, not applicable; NOR, Norway; POR, Portugal (all regions except Madeira); PSU, primary sampling unit; SSU, secondary sampling unit; SVN, Slovenia; SWE, Sweden.

Weight, height, body mass index, weight-for-age, height-for-age and BMI-for-age Z-scores

Median values for weight and mean values for W/A Z-score are presented in Table 4, mean values for height and H/A Z-score in Table 5, and median values for BMI and mean values for BMI/A Z-score in Table 6. All mean Z-score values except one were found to be positive. Weight (Table 4) and height (Table 5) increased with age and boys were taller and heavier than girls in all age groups.

In general, two groups of countries with relatively similar mean BMI/A Z-score values (sexes combined) could be identified: a group with mean BMI/A Z-score values below 0.35 ('low') whereby values for most countries did not statistically differ from each other (Belgium, Bulgaria, Czech Republic, Latvia, Lithuania, Norway and Sweden) and a group with mean values above 0.45 ('high') (Ireland, Italy, Malta, Portugal and Slovenia) (Table 6). High values were found in two out of three Slovenian age groups, and thus Slovenia was included in the group with high mean BMI/A Z-scores.

Two-way ANOVA showed a statistically significant interaction effect of country and sex on most mean anthropometric values (W/A Z-score and BMI/A Z-score [$P < 0.0001$] for each of the three age groups; height and H/A Z-score for the 8-year-old group [$P < 0.05$]; inverse-transformed weight and 1/square-transformed BMI for both the 7- and the 8-year-old groups [$P < 0.0001$]). Hence, one-way ANOVA analyses were performed to assess within each age group the country effect for boys and girls separately and the sex effect for each country separately. The main effect of country ($P < 0.001$) on all mean values (except for one) and the main effect of sex ($P < 0.05$) on most mean values were statistically significant. Results from the one-way ANOVA analyses are also presented in Tables 4–6. Subsequently, Games–Howell *post hoc* tests were performed for boys and girls separately within each age group to study the differences between countries in more detail (see Tables 4–6).

Prevalence of stunting, underweight and thinness

Stunting, underweight and thinness were rarely prevalent in all countries. All values for severe stunting, stunting, severe underweight, underweight and severe thinness were below 2.5%. Values for thinness greater than 2.5%, but still close to what is expected in a normally distributed population, were found in Bulgarian and Czech 7-year-old boys (both 3.2%).

Prevalence of overweight and obesity

Table 7 presents the proportions of overweight and obese boys and girls in each age group and country,

Table 2 Number of children targeted, measured and included in the final dataset for each of the 12 participating countries

	Countries											
	BEL	BUL	CZH	IRE	ITA	LVA	LTU	MAT	NOR	POR	SVN	SWE
Total number of children sampled, and												
Invited to participate (*n*)	–	4308	1708	3637	8850	5689	5877	3734	3952	4458	13 670	5326
Measured (%)	–	78.7	99.2	72.3	90.4	78.9	84.2	91.3	87.9	81.6	87.4	88.4
With complete information (%)	–	78.5	99.1	72.3	90.4	78.9	84.0	91.3	87.9	81.6	87.4	84.9
Fell within the targeted age group(s) (%)	–	57.8	53.6	66.2	90.4	57.1	56.3	57.1	71.7	40.7	87.4	68.9
Total number of targeted children included for this paper's analyses												
6-year-olds; boys/girls (*n*)	25 071/24 465	0	0	0	0	0	0	1092/1041	0	0	1620/1654	0
7-year-olds; boys/girls (*n*)	7384/6419	1258/1230	445/470	1143/1266	0	1651/1598	1660/1649	0	0	911/904	2374/2319	763/709
8-year-olds; boys/girls (*n*)	22 681/22 256	0	0	0	2629/2515	0	0	0	1435/1399	0	2028/1945	1131/1062
9-year-olds; boys/girls (*n*)	9186/8616	0	0	0	1472/1381	0	0	0	0	0	0	0

–, this information was not collected by age, thus was unknown for the age group 6–9-year-olds.
BEL, Belgium (Flanders); BUL, Bulgaria; CZH, Czech Republic; IRE, Ireland; ITA, Italy; LTU, Lithuania; LVA, Latvia; MAT, Malta; NOR, Norway; POR, Portugal (all regions except Madeira); SVN, Slovenia; SWE, Sweden.

Table 3 Implementation of the WHO European Childhood Obesity Surveillance Initiative's protocol characteristics by each of the 12 participating countries

COSI protocol characteristics	Countries											
	BEL	BUL	CZH	IRE	ITA	LVA	LTU	MAT	NOR	POR	SVN	SWE
COSI surveillance system												
Integration with routine measurements	✓		✓					✓			✓	
Newly established surveillance system		✓		✓	✓	✓	✓		✓	✓		✓
Data collection period												
Starting (month/year)	09/07	03/08	01/08	04/08	04/08	02/08	04/08	04/08	09/08	05/08	04/08	03/08
Ending (month/year)	07/08	06/08	12/08	06/08	06/08	03/08	05/08	06/08	11/08	06/08	04/08	06/08
Informed parental consent approach												
Passive	NA*	✓			✓	✓						✓
Active	NA*		✓	✓			✓	✓	✓	✓	✓	
Field examiners												
External health professionals linked to the school			✓		✓			✓	✓			
Physical education teachers											✓	
Nationally or regionally based examiners	✓	✓		✓		✓	✓			✓		✓

*In Flanders (Belgium), measurements of body weight and body height in schoolchildren are part of the preventive medical examinations, which are carried out within the school system and are mandatory by law.
✓, applicable; BEL, Belgium (Flanders); BUL, Bulgaria; COSI, Childhood Obesity Surveillance Initiative; CZH, Czech Republic; IRE, Ireland; ITA, Italy; LTU, Lithuania; LVA, Latvia; MAT, Malta; NA, not applicable; NOR, Norway; POR, Portugal (all regions except Madeira); SVN, Slovenia; SWE, Sweden; WHO, World Health Organization.

based on both the WHO and IOTF definitions. Based on WHO definitions, comparing the countries with low mean BMI/A Z-scores, the prevalence of overweight (including obesity) varied from 19.3 to 28.2% in boys and from 18.4 to 27.7% in girls, whereas the prevalence of obesity varied from 6.0 to 12.6% in boys and from 4.6 to 12.0% in girls. In those countries with high BMI/A Z-scores, the prevalence of overweight varied from 28.0 to 49.0% in boys and from 23.6 to 42.5% in girls, and the prevalence of obesity varied from 11.6 to 26.6% in boys and from 7.7 to 17.3% in girls. Based on IOTF definitions, the COSI results revealed a range in overweight (including obesity) prevalence in the countries with low mean BMI/A Z-score values from 11.2 to 20.1% in boys and from 14.7 to 24.2% in girls, while the prevalence of obesity varied from 2.1 to 6.6% in boys and from 3.1 to 9.0% in girls. In the countries with high mean BMI/A Z-score values, the prevalence of overweight varied from 19.2 to 37.2% in boys and from 19.3 to 34.7% in girls, and the prevalence of obesity varied from 6.0 to 13.6% in boys and from 5.6 to 11.8% in girls.

The chi-squared test comparing the prevalence estimates across countries was significant for all age groups ($P < 0.0001$ for boys and girls separately). The Marascuilo procedure was then used to study country differences for each age group (see Table 7; countries within each sex-age group that share the same superscript do not statistically differ from each other).

Based on WHO definitions, the observed linear trend in the prevalence of both overweight and obesity with increasing age was significant for boys and girls separately for Belgium ($P < 0.001$) and for Slovenia ($P < 0.05$). For Sweden, the increasing obesity trend with increasing age was significant only in boys ($P = 0.026$). The observed decreasing trend in Italy with increasing age was not significant for both boys and girls. Similar results were found when comparing the prevalence estimates based on IOTF definitions, except no significant increasing obesity trend was found in Slovenia and no significant increasing overweight and obesity trends with increasing age in Sweden.

Figure 1 illustrates the geographical distribution of the prevalence of overweight and obesity in 12

Table 4 Median and interquartile range (Q1–Q3) values of weight and mean (SD) values of weight-for-age Z-scores* of boys and girls aged 6–9 years, by age and country¶

Age group and country	Weight‡ (kg)		W/A Z-score	
	Boys Median (Q1–Q3)	Girls	Boys Mean (SD)	Girls
6-year-olds	†	†	†	†
BEL	22.7 (20.7–24.9)[§a]	22.2 (20.2–24.7)[a]	0.37 (1.06)[§a]	0.34 (1.00)[a]
MAT	23.4 (21.1–26.3)[§b]	22.5 (20.2–25.9)[b]	0.52 (1.32)[§b]	0.38 (1.21)[a]
SVN	24.0 (21.9–27.1)[§c]	23.8 (21.3–26.6)[c]	0.76 (1.18)[§c]	0.66 (1.10)[b]
7-year-olds	†	†	†	†
BEL	25.1 (22.7–28.3)[a]	25.0 (22.3–28.6)[a]	0.38 (1.18)[a]	0.42 (1.11)[a]
BUL	25.2 (22.5–29.3)[ab]	25.1 (22.1–29.4)[ab]	0.39 (1.36)[a]	0.40 (1.32)[ab]
CZH	24.9 (22.5–28.0)[§a]	24.0 (21.9–27.2)[c]	0.57 (1.22)[§ab]	0.42 (1.00)[ac]
IRE	25.9 (23.6–29.2)[§bc]	25.6 (23.0–28.6)[bd]	0.57 (1.18)[b]	0.54 (1.02)[bcde]
LVA	26.4 (23.8–29.4)[§cd]	25.5 (23.0–28.7)[be]	0.61 (1.12)[§b]	0.45 (1.03)[adf]
LTU	26.6 (24.3–29.7)[§de]	25.9 (23.5–29.4)[df]	0.66 (1.14)[§b]	0.56 (1.06)[cfg]
POR	26.4 (23.5–30.1)[cd]	25.8 (22.8–29.6)[deg]	0.70 (1.28)[b]	0.64 (1.17)[egh]
SVN	26.9 (24.1–31.0)[§e]	26.1 (23.5–30.0)[fgh]	0.87 (1.25)[§c]	0.70 (1.11)[h]
SWE	26.5 (24.4–29.6)[§de]	26.1 (23.5–29.3)[deh]	0.63 (1.04)[b]	0.53 (0.98)[adg]
8-year-olds	†	†	†	†
BEL	28.4 (25.7–31.9)[§a]	28.1 (25.2–32.1)[a]	0.46 (1.10)[§a]	0.40 (1.05)[a]
ITA	31.3 (27.3–37.2)[§b]	30.4 (26.2–35.5)[b]	1.00 (1.33)[§b]	0.71 (1.22)[b]
NOR	28.7 (26.1–32.0)[§a]	28.3 (25.3–32.0)[ac]	0.59 (1.07)[§c]	0.48 (1.01)[c]
SVN	30.0 (26.8–34.9)[§c]	29.8 (26.1–34.1)[d]	0.89 (1.26)[§d]	0.73 (1.12)[b]
SWE	29.5 (26.4–33.4)[§d]	28.7 (25.8–32.7)[c]	0.67 (1.12)[§c]	0.52 (1.04)[c]
9-year-olds	†		†	†
BEL	31.6 (28.2–36.3)	31.7 (27.9–37.1)	0.47 (1.16)[§]	0.37 (1.16)
ITA	32.6 (28.5–39.0)[§]	31.7 (27.5–37.7)	0.88 (1.29)[§]	0.58 (1.26)

[a,b,c,d,e,f,g,h]Within each sex-age group (e.g. 6-year-old boys), mean values that share the same superscript letter do not statistically significantly differ from each other (Games–Howell *post hoc* test). For example, for the 6-year-old boys, each mean W/A Z-score value is significantly different from the other two whereas the value of Slovenian 6-year-old girls differed significantly from the other two and no significant difference was found between Belgian and Maltese 6-year-old girls.
*Based on the 2007 WHO growth reference for school-age children and adolescents (33).
†Statistically significant difference of mean value across countries for the indicated age group (one-way ANOVA).
‡Non-normally distributed and underwent inverse transformation prior to ANOVA and Games–Howell *post hoc* tests.
§Statistically significant difference of mean value between boys and girls for the indicated country (one-way ANOVA).
¶Body weight was adjusted for clothes worn when measured and children with a W/A Z-score <–6 or >+5 were excluded.
ANOVA, analysis of variance; BEL, Belgium (Flanders); BUL, Bulgaria; CZH, Czech Republic; IRE, Ireland; ITA, Italy; LTU, Lithuania; LVA, Latvia; MAT, Malta; NOR, Norway; POR, Portugal (all regions except Madeira); Q1, first quartile; Q3, third quartile; SD, standard deviation; SVN, Slovenia; SWE, Sweden; W/A, weight-for-age; WHO, World Health Organization.

countries, grouped by subregions, of the WHO European Region (sexes combined and based on WHO definitions).

Discussion

Stunting, underweight and thinness were rarely prevalent in all countries under study. With just a single exception all mean Z-score values were positive, meaning that the entire distribution has shifted to the right compared to the reference distribution. The prevalence of overweight (including obesity and based on WHO definitions (33)) varied from 19.3 to 49.0% in boys and from 18.4 to 42.5% in girls, and the prevalence of overweight (including obesity and based on IOTF definitions (3)) varied from 11.2 to 37.2% in boys and from 14.7 to 34.7% in girls.

The overweight and obesity prevalence estimates based on WHO definitions were in all cases higher than those based on IOTF definitions. Based on WHO definitions, boys were more overweight than girls in all age groups except Belgian 7- and 8-year-olds and Norwegian 8-year-olds; boys were more obese than girls in all age groups. Based on IOTF definitions, an opposite pattern was observed whereby girls were more overweight or obese than boys in most cases.

Table 5 Mean (SD) values of height and height-for-age Z-scores* of boys and girls aged 6–9 years, by age and country§

Age group and country	Height (cm)		H/A Z-score	
	Boys Mean (SD)	Girls	Boys	Girls
6-year-olds	†	†	†	†
BEL	120.7 (5.2)‡[a]	119.8 (5.3)[a]	0.35 (0.98)[a]	0.34 (0.96)[a]
MAT	120.3 (5.3)‡[a]	118.9 (5.7)[b]	0.07 (1.01)‡[b]	–0.03 (1.06)[b]
SVN	124.0 (5.4)‡[b]	123.0 (5.4)[c]	0.83 (1.02)[c]	0.78 (1.00)[c]
7-year-olds	†	†	†	†
BEL	125.9 (6.0)‡[a]	125.3 (6.2)[a]	0.29 (1.03)[a]	0.29 (1.02)[a]
BUL	126.5 (6.8)‡[a]	125.7 (6.5)[a]	0.24 (1.20)[a]	0.24 (1.12)[a]
CZH	126.2 (5.8)‡[a]	125.0 (5.2)[a]	0.67 (1.05)[bc]	0.57 (0.91)[b]
IRE	125.9 (5.7)‡[a]	125.4 (5.5)[a]	0.23 (1.05)[a]	0.30 (0.98)[a]
LVA	128.5 (5.8)‡[b]	127.4 (5.7)[b]	0.59 (1.03)[b]	0.57 (0.99)[b]
LTU	129.2 (5.6)‡[c]	128.6 (5.5)[c]	0.69 (1.01)[b]	0.72 (0.95)[c]
POR	125.8 (6.0)‡[a]	125.1 (6.2)[a]	0.24 (1.06)[a]	0.27 (1.09)[a]
SVN	129.0 (5.8)‡[bc]	128.1 (5.7)[c]	0.81 (1.00)[c]	0.77 (0.95)[c]
SWE	129.2 (5.5)‡[c]	128.0 (5.7)[bc]	0.67 (0.97)[b]	0.58 (0.98)[b]
8-year-olds	†	†	†	†
BEL	132.8 (5.9)‡[a]	131.9 (6.0)[a]	0.48 (0.99)‡[a]	0.40 (0.97)[a]
ITA	133.0 (6.0)‡[a]	131.7 (6.0)[a]	0.39 (1.01)‡[b]	0.25 (0.99)[b]
NOR	133.2 (5.9)‡[a]	131.7 (5.7)[a]	0.65 (0.99)‡[c]	0.47 (0.94)[c]
SVN	134.1 (6.0)‡[b]	133.4 (5.8)[b]	0.77 (1.00)[d]	0.71 (0.96)[d]
SWE	134.1 (6.0)‡[b]	132.8 (6.2)[b]	0.70 (1.01)‡[cd]	0.55 (1.00)[c]
9-year-olds	†	†	†	†
BEL	137.7 (6.6)‡	137.3 (6.8)	0.40 (1.01)‡	0.24 (1.03)
ITA	135.5 (6.2)‡	134.5 (6.2)	0.30 (1.02)‡	0.12 (1.02)

[a,b,c,d]Within each sex-age group (e.g. 7-year-old girls), mean values that share the same superscript letter do not statistically significantly differ from each other (Games–Howell *post hoc* test). For example, for the 7-year-old girls, the mean height of Belgian, Bulgarian, Czech, Irish and Portuguese girls does not differ from each other. Also, no significant difference was found between Latvian and Swedish girls or among Lithuanian, Slovenian and Swedish girls; however, they differ significantly from each other with the use of another superscript.
*Based on the 2007 WHO growth reference for school-age children and adolescents (33).
†Statistically significant difference of mean value across countries for the indicated age group (one-way ANOVA).
‡Statistically significant difference of mean value between boys and girls for the indicated country (one-way ANOVA).
§Children with a H/A Z-score <–6 or >+6 were excluded.
ANOVA, analysis of variance; BEL, Belgium (Flanders); BUL, Bulgaria; CZH, Czech Republic; H/A, height-for-age; IRE, Ireland; ITA, Italy; LTU, Lithuania; LVA, Latvia; MAT, Malta; NOR, Norway; POR, Portugal (all regions except Madeira); SD, standard deviation; SVN, Slovenia; SWE, Sweden; WHO, World Health Organization.

A possible explanation for this difference is that the WHO cut-off values (for both overweight and obesity) for boys are lower than the values for girls at all age points from 6 to 9 years. On the contrary, the IOTF overweight cut-off values for boys are higher than the values for girls up to '9 years:6 months' and the IOTF obesity cut-off values for boys are higher than the values for girls from the age '6 years:0 months' up to '8 years:3 months', at which stage they become similar or lower with increasing age (Appendix I). Furthermore, the WHO BMI/A growth reference was constructed up to the age of 19 years, which is the WHO upper age limit of adolescence (38). The IOTF growth reference extends to the age of 18 years, and hence the cut-offs for overweight and obesity are higher than those of WHO at similar ages, resulting in lower prevalence estimates (3).

The European Childhood Obesity Group has recently recommended the use of both IOTF and WHO definitions in prevalence studies so that comparisons between epidemiological studies can be made (39). The observed differences between WHO and IOTF prevalence estimates may, however, have consequences for national policy making. Depending on the definitions used, resulting in different estimates and magnitudes, policy makers may opt for targeted policy actions or for no further action because overweight is considered or not considered a public health problem, respectively. Moreover, recent research has demonstrated that the WHO-

Table 6 Median and interquartile range (Q1–Q3) values of BMI and mean (SD) values of BMI-for-age Z-scores* of boys and girls aged 6–9 years, by age and country¶

Age group and country	BMI‡ (kg m^{-2})		BMI/A Z-score	
	Boys Median (Q1–Q3)	Girls	Boys Mean (SD)	Girls
6-year-olds	†	†	†	†
BEL	15.5 (14.7–16.5)[§a]	15.5 (14.6–16.6)[a]	0.20 (1.09)[a]	0.18 (1.01)[a]
MAT	16.2 (15.1–17.6)[b]	16.0 (15.0–17.5)[b]	0.66 (1.34)[§b]	0.54 (1.19)[b]
SVN	15.7 (14.7–17.2)[c]	15.7 (14.6–17.1)[c]	0.35 (1.33)[c]	0.29 (1.21)[c]
7-year-olds	†	†	†	†
BEL	15.8 (14.9–17.1)[§a]	15.9 (14.8–17.4)[a]	0.28 (1.21)[§a]	0.32 (1.11)[a]
BUL	15.8 (14.8–17.6)[ab]	16.0 (14.6–18.0)[ab]	0.31 (1.41)[a]	0.34 (1.33)[ab]
CZH	15.7 (14.8–16.9)[a]	15.4 (14.4–16.9)[c]	0.22 (1.31)[a]	0.09 (1.09)[c]
IRE	16.3 (15.4–17.8)[cd]	16.2 (15.3–17.7)[d]	0.61 (1.18)[§bc]	0.50 (1.00)[d]
LVA	16.0 (15.1–17.2)[§b]	15.7 (14.7–17.0)[ce]	0.35 (1.16)[§a]	0.16 (1.02)[c]
LTU	16.0 (15.0–17.3)[§b]	15.8 (14.7–17.2)[bce]	0.36 (1.20)[§a]	0.20 (1.12)[bc]
POR	16.6 (15.4–18.4)[c]	16.5 (15.3–18.4)[f]	0.77 (1.28)[§b]	0.66 (1.14)[e]
SVN	16.2 (15.1–18.1)[§d]	16.0 (14.8–17.7)[a]	0.54 (1.38)[§c]	0.35 (1.19)[a]
SWE	16.0 (15.1–17.2)[ab]	16.0 (14.9–17.4)[ae]	0.31 (1.08)[a]	0.26 (0.99)[ac]
8-year-olds	†	†	†	†
BEL	16.0 (15.1–17.4)[§a]	16.1 (15.0–17.8)[a]	0.22 (1.16)[a]	0.23 (1.07)[a]
ITA	17.6 (16.0–20.4)[§b]	17.5 (15.7–19.9)[b]	1.05 (1.39)[§b]	0.75 (1.24)[b]
NOR	16.2 (15.2–17.5)[ac]	16.3 (15.1–17.8)[a]	0.29 (1.14)[ac]	0.28 (1.05)[a]
SVN	16.8 (15.5–18.7)[§d]	16.6 (15.2–18.7)[c]	0.63 (1.35)[§d]	0.46 (1.18)[c]
SWE	16.3 (15.3–17.8)[c]	16.3 (15.1–17.9)[a]	0.35 (1.18)[c]	0.29 (1.04)[a]
9-year-olds	†	†	†	†
BEL	16.6 (15.4–18.5)[§]	16.8 (15.4–19.0)	0.32 (1.26)	0.29 (1.17)
ITA	17.8 (16.0–20.8)[§]	17.5 (15.7–20.3)	0.96 (1.35)[§]	0.65 (1.28)

[a,b,c,d,e,f]Within each sex-age group (e.g. 8-year-old boys), mean values that share the same superscript letter do not statistically significantly differ from each other (Games–Howell *post hoc* test). For example, for the 8-year-old boys, the mean BMI/A Z-scores of both Italian and Slovenian boys significantly differ from the other four, whereas the values of Belgian and Norwegian boys do not differ from each other as well as the values of Norwegian and Swedish boys.
*Based on the 2007 WHO growth reference for school-age children and adolescents (33).
†Statistically significant difference of mean value across countries for the indicated age group (one-way ANOVA).
‡Non-normally distributed and underwent 1/square transformation prior to ANOVA and Games–Howell *post hoc* tests.
§Statistically significant difference of mean value between boys and girls for the indicated country (one-way ANOVA).
¶Body weight was adjusted for clothes worn when measured and children with a BMI/A Z-score <–5 or >+5 were excluded.
ANOVA, analysis of variance; BEL, Belgium (Flanders); BMI/A, BMI-for-age; BMI, body mass index; BUL, Bulgaria; CZH, Czech Republic; IRE, Ireland; ITA, Italy; LTU, Lithuania; LVA, Latvia; MAT, Malta; NOR, Norway; POR, Portugal (all regions except Madeira); Q1, first quartile; Q3, third quartile; SD, standard deviation; SVN, Slovenia; SWE, Sweden; WHO, World Health Organization.

defined cut-offs for overweight are associated with a range of cardiometabolic risk factors in children and adolescents, including carotid artery stiffness as an early marker of vascular lesions (40,41). The study by Kakinami *et al*. showed that the ability of BMI to predict cardiometabolic risk varied according to the specific cardiometabolic risk factor of interest, as well as to age and sex (40). In their study, the suggested optimal BMI percentile cut-offs for detecting cardiometabolic risk were lower than the WHO-defined cut-offs for overweight and obesity, thus much lower than the IOTF-defined cut-offs.

Two European studies could be identified which reported on the physical status of schoolchildren, based on the 2007 WHO growth reference (33). A nationally representative school-based study (42) conducted in Poland between November 2007 and March 2009 among children aged 6–18 years also found a lack of prevalence of stunting (<2.5%) similar to COSI results. The second study identified was carried out in 2006 in one district of the Russian Federation (43) among adolescents aged 14–17 years. The overall prevalence of stunting and thinness was 3.3 and 3.6%, respectively, and the prevalence of overweight (including obesity) (boys 12.4%; girls 8.9%) and obesity (boys 6.1%; girls 3.7%) was lower than the COSI prevalence estimates, whereby boys were more overweight or obese than girls.

In comparing the COSI results with other nationally representative studies that had been carried out

Table 7 Prevalence of overweight (including obesity) and obesity in boys and girls aged 6–9 years, by age and country

Age group and country	Prevalence of overweight (including obesity)*				Prevalence of obesity*			
	WHO definition‡		IOTF definition†		WHO definition‡		IOTF definition†	
	Boys %	Girls	Boys	Girls	Boys	Girls	Boys	Girls
6-year-olds								
BEL	19.3[a]	18.4[a]	11.2[a]	14.9[a]	6.0[a]	5.1[a]	2.9[a]	3.8[a]
MAT	34.3[b]	29.3[b]	22.7[b]	24.8[b]	14.7[b]	11.7[b]	9.0[b]	10.6[b]
SVN	28.0[c]	23.6[c]	19.2[b]	19.3[c]	11.7[b]	8.4[c]	6.0[c]	6.7[c]
7-year-olds								
BEL	23.4[a]	24.3[ab]	15.2[a]	19.4[ab]	9.1[ab]	8.0[ab]	4.4[a]	5.9[abce]
BUL	28.2[ab]	27.7[ac]	20.1[bc]	24.2[ac]	12.6[ac]	12.0[c]	6.6[ab]	9.0[b]
CZH	21.4[a]	20.2[abd]	15.8[ab]	14.7[bd]	9.7[abc]	5.7[abd]	3.8[abc]	4.0[acd]
IRE	31.8[b]	27.3[ab]	21.1[bc]	22.8[abc]	11.6[abc]	7.7[abcd]	6.3[ab]	5.6[abcde]
LVA	24.0[a]	18.9[d]	15.3[ab]	15.1[d]	8.6[ab]	4.6[d]	4.5[ac]	3.1[d]
LTU	24.8[a]	21.0[bd]	16.1[ab]	16.2[bd]	9.4[ab]	7.2[abd]	5.1[ab]	5.1[acde]
POR	40.5[c]	35.5[c]	26.8[c]	28.5[c]	16.7[c]	12.6[c]	7.9[ab]	9.3[be]
SVN	32.5[b]	28.0[a]	24.2[c]	22.0[ac]	15.6[c]	9.8[ac]	7.6[b]	6.7[ab]
SWE	23.5[a]	22.0[ad]	14.6[ab]	17.8[abd]	6.8[b]	5.1[bd]	2.1[c]	3.2[cd]
8-year-olds								
BEL	22.1[a]	22.7[a]	13.9[a]	17.4[a]	8.1[a]	6.3[a]	3.4[a]	3.9[a]
ITA	49.0[b]	42.5[b]	37.2[b]	34.7[b]	26.6[b]	17.3[b]	13.6[b]	11.8[b]
NOR	23.0[ac]	23.1[a]	13.5[ac]	17.4[a]	7.5[a]	6.0[a]	3.0[a]	4.0[a]
SVN	35.9[d]	31.7[c]	25.2[d]	25.6[c]	16.4[c]	10.9[c]	8.0[c]	6.8[c]
SWE	26.3[c]	23.5[a]	17.4[c]	17.9[a]	9.7[a]	6.8[a]	2.9[a]	3.8[a]
9-year-olds								
BEL	27.4	27.1	18.0	21.9	10.9	8.9	4.8	5.4
ITA	47.1	40.1	35.5	33.6	25.7	15.8	12.6	10.3

[a,b,c,d,e]Within each sex-age group (e.g. 6-year-old girls), proportions that share the same superscript letter do not statistically significantly differ from each other (Marascuilo procedure). For example, for the 6-year-old girls, each prevalence estimate is significantly different from the other two. The prevalence of overweight based on IOTF definition and the prevalence of obesity based on WHO definition of Maltese and Slovenian 6-year-old boys do not differ significantly from each other but they differ significantly from the estimate found in Belgium.

*Body weight was adjusted for clothes worn when measured.

†Prevalence estimates were based on the IOTF recommended growth reference for school-age children and adolescents (3). Children with a BMI/A Z-score <–5 or >+5 were excluded (based on the 2007 WHO growth reference (33)).

‡Prevalence estimates were based on the 2007 WHO recommended growth reference for school-age children and adolescents (33). Children with a BMI/A Z-score <–5 or >+5 were excluded.

BEL, Belgium (Flanders); BMI/A, BMI-for-age; BMI, body mass index; BUL, Bulgaria; CZH, Czech Republic; IOTF, International Obesity Task Force; IRE, Ireland; ITA, Italy; LTU, Lithuania; LVA, Latvia; MAT, Malta; NOR, Norway; POR, Portugal (all regions except Madeira); SVN, Slovenia; SWE, Sweden; WHO, World Health Organization.

around the same period, had measured the children's weight and height, and had used the IOTF definitions, surprisingly only three studies (all conducted in France) could be identified (44–46). The first, conducted in 2007 in 7–9-year-old children, found a prevalence of overweight (including obesity) of 14.1% in boys and 17.7% in girls (44). The national study on individual food consumption (2006/2007) reported a prevalence of overweight (including obesity) of 11.9 and 16.7% in 3–10-year-old boys and girls, respectively (45), and the national nutrition and health survey (2006/2007) reported a prevalence of overweight (including obesity) of 11.4 and 21.9% in 3–10-year-old boys and girls, respectively (46). These prevalence estimates are within the range of COSI countries with low mean BMI/A Z-score values.

Regardless of WHO or IOTF definitions, the multiple comparisons of proportions suggested that southern European countries – Italy, Malta, Portugal and Slovenia – differed significantly from almost all other participating countries. These results suggest the presence of a north–south gradient with the highest overweight prevalence values found in southern European countries. This has also been presented in other European-wide reviews on children (6), adolescents (7) and adults (47). Regardless of magnitude, variation was also found within COSI countries based on geographical areas

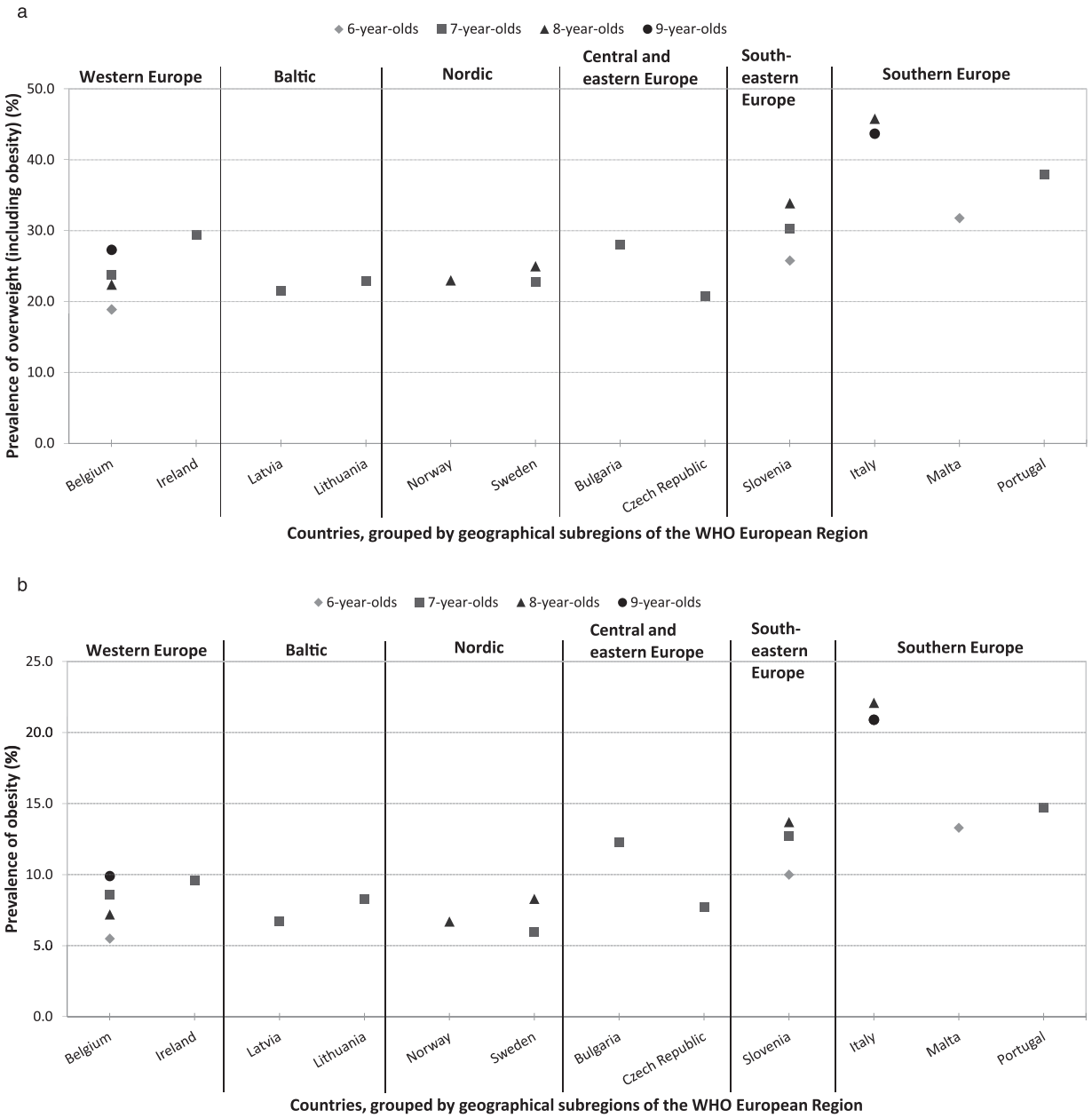

Figure 1 Geographical distribution of the prevalence of overweight (including obesity) (a) and obesity (b) in children aged 6–9 years (sexes combined), based on World Health Organization (WHO) definitions[a].

[a]Prevalence estimates were based on the 2007 WHO recommended growth reference for school-age children and adolescents (33). Children with a body mass index-for-age Z-score <–5 or >+5 were excluded. Belgium represents Flanders only and Portugal represents all regions except Madeira. WHO European Member States are grouped into eight geographic subregions to facilitate comparative analysis and interpretation. None of the central Asian republics or the Commonwealth of Independent States participated in the first round, and thus these two subregions are excluded from both figures.

(17,19,21,22). For instance, in Italy, some types of behaviour known to be associated with obesity (17) and maternal perception (48) also showed geographical differences.

Body weight and BMI were found to be highly positively skewed in all country datasets. A positively skewed BMI distribution has also been reported elsewhere (49–51), whereas to our knowledge a skewed weight distribution in European schoolchildren below 10 years of age has not been addressed except in a recent Polish study (42). Similar results have been noted outside Europe, e.g. in children aged 6–10 years in the United States (52) and children aged 7–12 years in Australia (53).

The combination of nationally representative samples and standardized weight and height measurements in about 168 000 children in a large number of countries has not previously been done. Other identified European-wide studies included local or regional samples or used self-reported data, e.g. the European-wide study 'Healthy lifestyle in Europe by nutrition in adolescence (HELENA)' (54), the 'Identification and prevention of dietary- and lifestyle-induced health effects in children and infants (IDEFICS)' (18 626 children 4–11 years old; (55)), the HBSC survey (11, 13 and 15-year-olds; (12)) or the Pro Children Study (8317 11-year-olds; (56)). The only European study that could be identified as a study using both national samples and measured data was the 'European energy balance research to prevent excessive weight gain among youth (ENERGY)' project, which targets adolescents aged 10–12 years in seven countries (57). This shows that COSI provides a unique standardized large dataset compared with the currently available European-wide studies.

COSI aimed to set up a surveillance system to be used for policy actions (rather than for research purposes) and each country was responsible for its national data collection to be funded from local resources. Although it was recognized that data comparability would have been improved if identical equipment were used, this was not mandatory, largely because of cost implications. The monitoring of data quality procedures was stressed throughout the measurement period.

For the 10 countries that took a representative sample of children, the PSU was the primary school or the class (except in the Czech Republic and Norway). Some differences in sample selection as well as in period and duration of data collection might have influenced the results. Six countries did not obtain a final sample of children that contained more than 60% of the approached children and fell within the targeted age group, while six countries did not achieve the minimum final effective sample size of ≈2800 children per age group. The sample size calculation was based on a minimum difference of 0.10 BMI/A Z-score per year and will become essential for the comparison with the results of the next data collection rounds. Another limitation was the observed low school participation rates in Ireland (32.7%) and Sweden (42.7%), although the participating schools were found to be representative of all primary schools in Ireland (15) and Sweden (22).

While 10 countries started data collection during the first semester of 2008, Norway started in September 2008 due to their joining the COSI at a later stage than the other countries, and measurements in Belgium (Flanders) already started in September 2007 because they were carried out as part of the mandatory preventive medical examinations that are done throughout the entire school year. Although 10 countries managed to collect the data over the short time span of 1–3 months, measurements were not done during the same period. Seasonal variation may have influenced weight and prevalence of obesity, as has been observed in other studies (58,59).

The representativeness of a sample of the population of interest is an important source of uncertainty in prevalence studies. The children were selected from the school population in most countries, as this was presumed to be representative of the total population for the 6-, 7-, 8- and 9-year-olds. The analyses performed, however, were unweighted (which is another limitation), because sampling weights to adjust for the applied sampling design, oversampling and non-response rate were available for only three countries. Confidence intervals were therefore not presented for each of the prevalence estimates because they would reflect more the consequence of the sample size obtained. Presenting them would thus have misled the interpretation of the results.

Conclusion and way forward

COSI covers the primary school age to fill the current gap in information on the physical status of this population group. High overweight prevalence values were found during the first data collection round and its variation across the European Region significantly depends on the country. As only 13 countries participated in this round (of which 12 are presented in this paper), it is not possible to provide an estimate for the entire WHO European Region (53 Member States) or the European Union. An additional four countries (Greece, Hungary, Spain and the former Yugoslav Republic of Macedonia) joined the second COSI data collection round (2009/2010), and it is assumed that more Member States of the WHO European Region will join by the time of the planned third round (school year 2012/2013). In this way, it is expected that routinely measuring body weight and body height in primary-school children, based on a standardized methodology for sampling and data collection, as well as transferring the collected data to a national or international database, will become common activities in the WHO European Region for the monitoring of the progress and successes of counteracting overweight and obesity in

this population group. Moreover, one of the commitments (article 3.2) made by European Member States through the 2006 European Charter on Counteracting Obesity (60) could then be considered fulfilled.

Conflict of Interest Statement

The authors declare no conflicts of interest.

Author contributions

TW conceptualized and drafted the manuscript, drafted the COSI study protocol and conducted all analyses; JvR made substantial contributions to the conception and drafts of both the manuscript and the COSI study protocol as well as interpretation of the results; ASp was involved in critically reviewing the drafts of the manuscript, commented on the COSI study protocol, and contributed with data collection and data cleaning; AR, RH and MK commented on a draft of the manuscript and contributed with data collection and data cleaning; HR made substantial contributions to the development of the study protocol; GS, ASj, AP, UoD, SP, VFS, MW, AY, IMR and JB contributed with data collection and data cleaning. All authors contributed to and approved the final manuscript.

Disclaimer

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Appendix I

BMI cut-off values for overweight and obesity for children aged 6–9 years, by sex and age, according to WHO and IOTF definitions.

	Overweight				Obesity			
Age	Boys		Girls		Boys		Girls	
Years : months	WHO*	IOTF†	WHO*	IOTF†	WHO‡	IOTF§	WHO‡	IOTF§
6:0	16.76	17.55	17.01	17.34	18.52	19.78	19.22	19.65
6:1	16.78	17.57	17.03	17.37	18.55	19.85	19.26	19.72
6:2	16.80	17.60	17.05	17.40	18.59	19.92	19.31	19.79
6:3	16.82	17.62	17.07	17.43	18.63	20.00	19.35	19.86
6:4	16.84	17.65	17.09	17.46	18.67	20.08	19.39	19.93
6:5	16.86	17.68	17.11	17.50	18.70	20.16	19.44	20.01
6:6	16.89	17.71	17.13	17.53	18.75	20.23	19.48	20.08
6:7	16.91	17.74	17.15	17.56	18.79	20.30	19.53	20.15
6:8	16.94	17.78	17.18	17.60	18.83	20.37	19.58	20.22
6:9	16.96	17.81	17.20	17.63	18.88	20.43	19.63	20.29
6:10	16.99	17.85	17.23	17.67	18.92	20.50	19.68	20.36
6:11	17.02	17.88	17.26	17.71	18.97	20.56	19.73	20.44
7:0	17.05	17.92	17.29	17.75	19.02	20.63	19.79	20.51
7:1	17.08	17.96	17.32	17.79	19.07	20.70	19.85	20.59
7:2	17.11	18.00	17.35	17.84	19.12	20.77	19.90	20.67
7:3	17.14	18.04	17.38	17.88	19.17	20.85	19.96	20.75
7:4	17.17	18.08	17.42	17.93	19.22	20.93	20.02	20.83
7:5	17.20	18.12	17.45	17.98	19.27	21.01	20.09	20.92
7:6	17.23	18.16	17.49	18.03	19.33	21.09	20.15	21.01
7:7	17.26	18.20	17.53	18.08	19.38	21.17	20.21	21.10
7:8	17.30	18.25	17.56	18.13	19.44	21.25	20.28	21.19
7:9	17.33	18.29	17.60	18.19	19.50	21.34	20.35	21.28
7:10	17.37	18.34	17.65	18.24	19.56	21.42	20.42	21.38
7:11	17.40	18.39	17.69	18.30	19.62	21.51	20.49	21.47
8:0	17.44	18.44	17.73	18.35	19.68	21.60	20.56	21.57
8:1	17.47	18.49	17.77	18.40	19.74	21.69	20.63	21.67
8:2	17.51	18.54	17.82	18.46	19.80	21.78	20.71	21.77
8:3	17.55	18.60	17.87	18.52	19.86	21.88	20.78	21.87
8:4	17.59	18.65	17.91	18.57	19.93	21.97	20.86	21.97
8:5	17.62	18.70	17.96	18.63	19.99	22.07	20.94	22.08
8:6	17.66	18.76	18.01	18.69	20.06	22.17	21.02	22.18
8:7	17.70	18.82	18.06	18.75	20.12	22.27	21.10	22.28
8:8	17.74	18.87	18.11	18.81	20.19	22.37	21.18	22.39
8:9	17.78	18.93	18.17	18.88	20.26	22.47	21.26	22.49
8:10	17.82	18.98	18.22	18.94	20.33	22.57	21.35	22.60
8:11	17.87	19.04	18.27	19.01	20.40	22.67	21.43	22.70
9:0	17.91	19.10	18.33	19.07	20.47	22.77	21.51	22.81
9:1	17.95	19.16	18.38	19.13	20.54	22.87	21.60	22.92
9:2	18.00	19.22	18.44	19.20	20.61	22.98	21.68	23.03
9:3	18.04	19.28	18.49	19.26	20.69	23.08	21.77	23.13
9:4	18.09	19.34	18.55	19.32	20.76	23.18	21.86	23.24
9:5	18.13	19.40	18.61	19.39	20.84	23.29	21.94	23.35
9:6	18.18	19.46	18.67	19.45	20.92	23.39	22.03	23.46

Appendix I Continued

	Overweight				Obesity			
Age	Boys		Girls		Boys		Girls	
Years : months	WHO*	IOTF†	WHO*	IOTF†	WHO‡	IOTF§	WHO‡	IOTF§
9:7	18.23	19.52	18.73	19.52	20.99	23.49	22.12	23.57
9:8	18.28	19.59	18.79	19.58	21.07	23.60	22.21	23.68
9:9	18.33	19.65	18.85	19.65	21.15	23.70	22.30	23.78
9:10	18.38	19.71	18.91	19.72	21.23	23.80	22.39	23.89
9:11	18.43	19.78	18.97	19.79	21.32	23.90	22.48	24.00

*WHO cut-off values for overweight are defined to pass through a BMI of 25 kg m^{-2} at the age of 19 years (33). Overweight is defined as a BMI greater than the given value.

†IOTF cut-off values for overweight are defined to pass through a BMI of 25 kg m^{-2} at the age of 18 years ((3); T. Lobstein, personal communication, October 2011). Overweight is defined as a BMI equal to or greater than the given value.

‡WHO cut-off values for obesity are defined to pass through a BMI of 30 kg m^{-2} at the age of 19 years (33). Obesity is defined as a BMI greater than the given value.

§IOTF cut-off values for obesity are defined to pass through a BMI of 30 kg m^{-2} at the age of 18 years ((3); T. Lobstein, personal communication, October 2011). Obesity is defined as a BMI equal to or greater than the given value.

BMI, body mass index; IOTF, International Obesity Task Force; WHO, World Health Organization.