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Research Article

Prevalence of Severe Obesity among Primary School Children in 21 European Countries

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Abstract
Background: The World Health Organization (WHO) European Childhood Obesity Surveillance Initiative (COSI) was established more than 10 years ago to estimate prevalence and monitor changes in overweight and obesity in children aged 6–9 years. Since then, there have been five rounds of data collection in more than 40 countries involving more than half a million children. To date, no comparative studies with data on severe childhood obesity from European countries have been published. ***Objectives:*** The aim of this work was to present the prevalence of severe obesity in school-aged children from 21 countries participating in COSI. ***Method:*** The data are from cross-sectional studies in 21 European WHO member states that took part in the first three COSI rounds of data collection (2007/2008, 2009/2010, 2012/2013). School-aged children were measured using standardized instruments and methodology. Children were classified as severely obese using the definitions provided by WHO and the International Obesity Task Force (IOTF). Analyses overtime, by child's age and mother's educational level, were performed in a select group of countries. ***Results:*** A total of 636,933 children were included in the analysis (323,648 boys and 313,285 girls). The prevalence of severe obesity varied greatly among countries, with higher values in Southern Europe. According to the WHO definition, severe obesity ranged from 1.0% in Swedish and Moldovan children (95% CI 0.7–1.3 and 0.7–1.5, respectively) to 5.5% (95% CI 4.9–6.1) in Maltese children. The prevalence was generally higher among boys compared to girls. The IOTF cut-offs lead to lower estimates, but confirm the differences among countries, and were more similar for both boys and girls. In many countries 1 in 4 obese children were severely obese. Applying the estimates of prevalence based on the WHO definition to the whole population of children aged 6–9 years in each country, around 398,000 children would be expected to be severely obese in the 21 European countries. The trend between 2007 and 2013 and the analysis by child's age did not show a clear pattern. Severe obesity was more common among children whose mother's educational level was lower. ***Conclusions:*** Severe obesity is a serious public health issue which affects a large number of children in Europe. Because of the impact on educational, health, social care, and economic systems, obesity needs to be addressed via a range of approaches from early prevention of overweight and obesity to treatment of those who need it.

Introduction

Childhood obesity is one of the major public health concerns of the 21st century. A pooled analysis of 2,416 population-based measurement studies showed that from 1975 to 2016 there was a rising trend in children's and adolescents' BMI [1]. In 2016, 124 million children and adolescents, aged 5–19 years, were estimated to suffer from obesity worldwide, and 213 million were overweight [1].

Childhood obesity is associated with immediate adverse consequences, such as psychological problems and lower educational attainment, and a higher risk for many harmful comorbidities later in life, such as type 2 diabetes mellitus, dyslipidemia, non-alcoholic fatty liver disease, hypertension, and coronary heart disease [2–5]. In most cases, obesity is the result of chronic caloric imbalance, with more calories being consumed than expended each day. Hereditary, environmental, metabolic, behavioural, mental, cultural, and socioeconomic factors (along with having a history of obesity) all play a role in the development of obesity. In children, the relation between body mass index (BMI) and adiposity varies with age and

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sex, so BMI thresholds are usually defined in terms of specific centiles on a growth reference curve [6]. Extremely high BMI values considerably increase children's physical and mental health risks [7–11]. When compared with children with overweight or obesity, who often do not experience visible morbidities during childhood, children with severe obesity frequently have immediate health consequences, including a worse cardiometabolic risk profile, earlier signs of vascular dysfunction, and subclinical atherosclerosis [12–23]. They are also more likely to suffer from depression [9, 11] due to teasing and bullying, as well as other social risks. Persistence of adiposity from childhood to adulthood is much more common for severely obese children [24, 25]. There is a lack of a standard definition of severe obesity in children, both in terminology (severe obesity can be a synonym for morbid or extreme obesity) and in the methodology that defines it, which makes interpreting data about its prevalence difficult [26]. In 2007, the Centers for Disease Control and Prevention (CDC) proposed the age and gender-specific 99th percentile and above of their growth curves as a definition of severe obesity in children [27], while the World Health Organization (WHO) growth reference curves from 2007 enable the extrapolation of a cut-off to define severe obesity [28] at +3 *Z*-scores relative to the median. In 2012, the International Obesity Task Force (IOTF) also provided extended cut-offs including the cut-offs for morbid (severe) obesity [29].

While there are a good number of studies about the prevalence of severe obesity in American children [30–37], the evidence on severe childhood obesity prevalence in Europe is scarce [26, 38–41]. Moreover, no publication comparing data from different European countries has been found.

The aim of this paper is therefore to assess the prevalence of severe obesity in 6- to 9-year-old school children from 21 countries of the WHO European Region, which participated in the WHO European Childhood Obesity Surveillance Initiative (COSI) data collections between 2007 and 2013.

Materials and Methods

The first data collection in primary school children according to the COSI surveillance methodology took place in 2007/2008, the second in 2009/2010, and the third in 2012/2013. The number of countries that collected data has increased over time from 12 in the first round to 14 in the second round, and 19 in the third (Table 1). Overall, 21 countries have participated in at least 1 round of data collection within the period 2007–2013: 10 countries took part in all rounds,[1] 4 in 2 rounds,[2] and 7 in just 1 round,[3] most of them in the third round. Data collection followed a common protocol that was developed in 2007 by the WHO Regional Office for Europe together with the member states, and slightly amended for COSI rounds 2 and 3 [42–45].

According to the COSI protocol, countries could choose one or more of the following age groups: 6.0–6.9, 7.0–7.9, 8.0–8.9, or 9.0–9.9 years. Belgium and Slovenia included all age groups (only in 2009/10 and 2012/13). Among the other countries, most considered 7-year-old children (Bulgaria, Czech Republic, Greece, Hungary, Ireland, Lithuania, Latvia, Malta – only in 2012/2013; Moldova, Portugal, Spain, Sweden, Republic of Macedonia – only in 2009/2010, and Turkey). Spain and Sweden also targeted 8-year-old children, and Greece

[1] Belgium, Czech Republic, Ireland, Italy, Latvia, Lithuania, Malta, Norway, Portugal, and Slovenia.
[2] Bulgaria – 2007/08 and 2012/13, Greece – 2009/10 and 2012/13, Spain – 2009/10 and 2012/13, Republic of Macedonia – 2009/10 and 2012/13.
[3] Albania – 2012/13, Hungary – 2009/10, Republic of Moldova – 2012/13, Romania – 2012/13, San Marino – 2012/13, Turkey – 2012/13, and Sweden – 2007/08.

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Table 1. Targeted age groups and availability of the family forms in COSI round 1 (2007/2008), round 2 (2009/2010), and round 3 (2012/2013), by country

Country	Round 1		Round 2		Round 3	
	age group, years	family form	age group, years	family form	age group, years	family form
Albania	NP		NP		8	
Belgium	6, 7, 8, 9		6, 7, 8, 9		6, 7, 8, 9	
Bulgaria	7	✓	NP		7	✓
Czech Republic	7	✓	7	✓	7	✓
Greece	NP		7, 9		7,9	
Hungary	NP		7		NP	
Ireland	7		7	✓	7	✓
Italy	8, 9		8, 9	✓	8, 9	✓
Latvia	7		7		7	
Lithuania	7	✓	7	✓	7	✓
Malta	6		6		7	✓
Moldova	NP		NP		7	✓
Republic of Macedonia	NP		7		6	
Norway	8		8		8	
Portugal	7	✓	7	✓	7	✓
Romania	NP		NP		8	
San Marino	NP		NP		8, 9	✓
Spain	NP		7, 8		7,8	✓
Slovenia	6, 7, 8		6, 7, 8		6, 7, 8	
Sweden	7, 8	✓	NP		NP	
Turkey	NP		NP		7, 8	✓

NP, not participant.

9-year-olds. Albania, Norway, and Romania considered only 8-year-old children, and Italy and San Marino 8- and 9-year-olds.

Most countries adopted a two-stage sampling design with primary schools as the primary sampling units (PSU) and whole classes as the secondary sampling units, except in the Czech Republic, Italy, Norway, and Spain, where the PSUs were paediatric clinics, classes, counties, and provinces, respectively.[4]

Three countries included all classes of their targeted grades of primary schools (Belgium, Malta, and San Marino), while a nationally representative sample was selected in the other countries. Among the 12 countries that participated in more than 1 round of data collection, 6 had a sentinel site approach (i.e., involved the same schools that were selected in previous rounds) while 6 countries selected a new sample of schools.[5] Table 1 reports detailed information for each country.

According to the COSI protocol, the minimum final effective sample size should be 2,800 children per single age group [43]. In 6 countries, the number of children measured was considerably lower [42, 45].

[4] The sampling process including sample size considerations have been described elsewhere [43, 44].
[5] Sentinel site approach: Bulgaria, Ireland, Lithuania, Norway, Portugal, and Republic of Macedonia. New sample of schools: Latvia, Greece, Spain, and Slovenia. New sample of classes: Italy. New sample of paediatric clinics: Czech Republic.

During the data collection, children were measured by examiners who were trained in measuring weight and height using the WHO standardized techniques. Measurements were taken after having removed shoes and socks, as well as all heavy clothes (coats, sweaters, jackets, etc.) and items such as wallets, mobile phones, or key chains. Each child was weighed to the nearest 0.1 kg and height was measured to the nearest 1 mm. Each country provided the average weights of the types of clothes worn during the measurements, which were used to adjust the observed weight.

Besides the record form for registering the child's demographic characteristics and anthropometric measures, COSI also used an optional family record form which was completed by the child's parent or guardian to gather information on the child's eating habits and physical activity patterns. Through the family record form, data on family socioeconomic characteristics, such as parents' education and employment status, were also collected. Given the voluntary nature of the form, not all countries adopted it (Table 1). Twelve of the 21 countries had family data available for at least one COSI round (Bulgaria, Czech Republic, Ireland, Italy, Lithuania, Malta, Moldova, Portugal, San Marino, Spain, Sweden, and Turkey).

The COSI study follows the International Ethical Guidelines for Biomedical Research Involving Human Subjects [46]. Local ethical committees also approved the study. More details on data collection procedures are provided elsewhere [42, 45, 47, 48].

All country datasets were reviewed for inconsistencies and completeness in a standard manner at the WHO Regional Office before they were aggregated for the inter-country comparisons. The final dataset, with data from the all rounds and countries, only included children with informed consent and complete information on age, gender, weight, and height. Children whose age did not fall within the target age group were excluded. Children with biologically implausible (or extreme) values were also excluded from the analysis (i.e., BMI-for-age values below –5 *Z*-scores or above +5 *Z*-scores), as recommended by the WHO [49].

The 2007 WHO cut-offs for school-aged children and adolescents were used to compute anthropometric indicators (height-for-age, weight-for-age, BMI-for-age) and their *Z*-scores [28, 49]. Severe obesity was defined as the proportion of children with BMI-for-age above +3 *Z*-scores relative to the 2007 WHO growth reference median. Severe obesity was also estimated using IOTF cut-off points, as they are also widely used in the WHO European Region. According to the IOTF, these points are age (in months) and gender specific, and correspond to a BMI greater than 35 at the age of 18 years [29]. The definition of severe obesity proposed by CDC in 2007 was not applied because percentiles greater than the 97th are beyond the range of the data used to estimate the growth curves and should be treated with caution [50].

Estimates of the prevalence of severe obesity are presented as percentages and have been calculated by country and gender. In order to protect confidentiality and to improve statistical power, prevalence estimates by round of data collection and target age group have been calculated only for those countries with enough observations and for those who used the same target age group(s) over time. More specifically, changes over time were investigated in 9 countries (Belgium, Bulgaria, Greece, Italy, Latvia, Lithuania, Portugal, Spain, and Slovenia) and age groups were compared for 5 countries (Belgium, Greece, Italy, Slovenia, and Spain).

Sampling weights to adjust for the sampling design, oversampling, and non-response were available only for a few countries. For this reason, the analysis was performed unweighted. Where appropriate, the standard errors and 95% confidence intervals (CIs) have been estimated taking account of the cluster design using primary sampling units (schools in most countries) and by applying the finite population correction factor. For each country, the estimates of prevalence of severe obesity were adjusted for deviations from the distribution of the target population by gender, age group, and year of data collection according to the most recent data from official statistics [51].

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Table 2. Prevalence of severe obesity in boys and girls aged 6–9 years in COSI round 1 (2007/2008), COSI round 2 (2009/2010), and COSI round 3 (2012/2013) by country using the WHO and IOTF definitions – rounds combined

Country	Children included in the analysis, *n*	Prevalence of severe obesity – WHO definition, % (95% CI)			Prevalence of severe obesity – IOTF definition, % (95% CI)		
		Boys	Girls	Total	Boys	Girls	Total
Albania[1]	3,312	2.1 (1.4–2.9)	0.4 (0.2–0.8)	1.2 (0.9–1.7)	0.7 (0.4–1.4)	0.4 (0.2–0.9)	0.6 (0.3–0.9)
Belgium[1]	397,209	2.3 (2.2–2.4)	1.1 (1.1–1.2)	1.7 (1.7–1.8)	1.1 (1.0–1.1)	1.4 (1.3–1.6)	1.2 (1.2–1.3)
Bulgaria[1]	5,848	5.2 (4.4–6.1)	2.8 (2.1–3.5)	4.0 (3.5–4.6)	2.6 (2.0–3.3)	3.3 (2.6–4.0)	2.9 (2.5–3.4)
Czech Republic[2]	3,634	3.0 (2.3–3.9)	1.4 (0.9–2.1)	2.2 (1.8–2.8)	1.6 (1.0–2.2)	1.6 (1.0–2.4)	1.6 (1.2–2.1)
Greece[1]	10,616	7.2 (6.2–8.5)	2.4 (1.6–3.3)	4.8 (4.1–5.7)	2.8 (2.2–3.6)	2.7 (2.0–3.7)	2.8 (2.2–3.4)
Hungary[2]	1,231	4.2 (2.8–6.3)	2.1 (1.2–3.5)	3.1 (2.2–4.4)	1.3 (0.6–2.6)	2.9 (1.9–4.5)	2.1 (1.4–3.0)
Ireland[2]	4,395	2.1 (1.6–2.9)	1.1 (0.7–1.6)	1.6 (1.2–2.1)	1.0 (0.6–1.6)	1.4 (1.0–2.0)	1.2 (0.9–1.6)
Italy[1]	95,089	6.4 (6.1–6.7)	2.0 (1.8–2.2)	4.3 (4.1–4.5)	2.7 (2.5–2.9)	2.3 (2.1–2.5)	2.5 (2.3–2.6)
Lithuania[1]	9,324	3.2 (2.7–3.7)	1.2 (0.9–1.6)	2.2 (1.9–2.5)	1.4 (1.1–1.7)	1.6 (1.3–2.0)	1.5 (1.3–1.8)
Latvia[1]	9,561	2.7 (2.2–3.2)	1.1 (0.8–1.5)	1.9 (1.6–2.2)	1.2 (0.9–1.5)	1.2 (1.0–1.6)	1.2 (1.0–1.5)
Malta[1]	6,458	6.9 (6.0–7.9)	4.1 (3.4–4.8)	5.5 (4.9–6.1)	3.8 (3.2–4.5)	4.7 (3.9–5.5)	4.2 (3.7–4.8)
Moldova[1]	2,573	1.4 (0.9–2.4)	0.6 (0.2–1.3)	1.0 (0.7–1.5)	1.0 (0.5–1.8)	0.6 (0.3–1.3)	0.8 (0.5–1.3)
Republic of Macedonia[1]	4,919	6.4 (5.4–7.5)	2.3 (1.8–3.0)	4.4 (3.8–5.1)	3.6 (2.9–4.5)	2.9 (2.3–3.7)	3.2 (2.7–3.8)
Norway[1]	8,328	2.1 (1.7–2.6)	0.6 (0.4–0.9)	1.4 (1.1–1.7)	0.9 (0.6–1.2)	0.6 (0.4–0.9)	0.8 (0.6–1.0)
Portugal[1]	6,262	4.6 (3.9–5.4)	2.2 (1.7–2.8)	3.4 (3.0–3.9)	2.1 (1.6–2.6)	2.9 (2.3–3.5)	2.5 (2.1–2.9)
Romania[1]	4,274	3.8 (3.0–4.9)	0.5 (0.3–1.0)	2.2 (1.8–2.8)	1.7 (1.1–2.6)	0.6 (0.4–1.1)	1.2 (0.9–1.7)
San Marino	278	5.9 (3.0–11.3)	3.1 (1.2.–7.8)	4.6 (2.7–7.8)	3.1 (1.1–8.0)	3.1 (1.2–7.8)	3.1 (1.6–6.0)
Spain[1]	7,747	5.9 (4.6–7.6)	1.9 (1.5–2.6)	4.0 (3.2–4.8)	2.5 (1.8–3.6)	2.3 (1.8–3.0)	2.4 (2.0–3.1)
Slovenia[1]	47,205	4.3 (4.0–4.6)	1.7 (1.5–1.9)	3.0 (2.8–3.2)	1.9 (1.7–2.1)	2.1 (1.9–2.3)	2.0 (1.8–2.1)
Sweden	3,716	1.2 (0.8–1.9)	0.7 (0.4–1.2)	1.0 (0.7–1.4)	0.5 (0.3–1.0)	0.9 (0.5–1.5)	0.7 (0.4–1.0)
Turkey[1]	4,951	3.2 (2.7–4.0)	1.2 (0.8–1.7)	2.2 (1.8–2.7)	1.7 (1.2–2.3)	1.3 (0.9–1.8)	1.5 (1.1–1.9)

[1] Statistically significant difference between boys and girls in the prevalence of severe obesity (based on WHO definition) – Pearson's χ^2 corrected using the Rao-Scott method <0.001.
[2] Statistically significant difference between boys and girls in the prevalence of severe obesity (based on WHO definition) – Pearson's χ^2 corrected using the Rao-Scott method <0.05.

Estimates for each country with their 95% CIs were calculated. The χ^2 test was applied for comparison between boys and girls within each country. Binary logistic regression was used to appraise the relation between the probability of being severely obese and the year of measurement and the age group. For each country included in the analysis, a country-specific model with child's gender, age group, and year of data collection as covariates was estimated. Finally, differences by mother's level of education (low-medium level – primary or secondary school; high level – undergraduate/bachelor's degree or master's degree or higher) within the same country were assessed and assumed significant based on a χ^2 test. Because of the above-mentioned limit of small numbers, the analysis was run only for 8 out of 12 countries that collected data through the family record form. A p value <0.05 was used to define statistical significance. The data were analysed using STATA version 15.1 (Stata Corporation LP, College Station, TX, USA).

Results

The total number of children aged 6–9 years included in the analysis was 636,933 (323,648 boys and 313,285 girls). The number of children varies among countries as a consequence of the number of data collection rounds each country participated in and the adopted study design and sampling strategy. Belgium had the largest number of children included in

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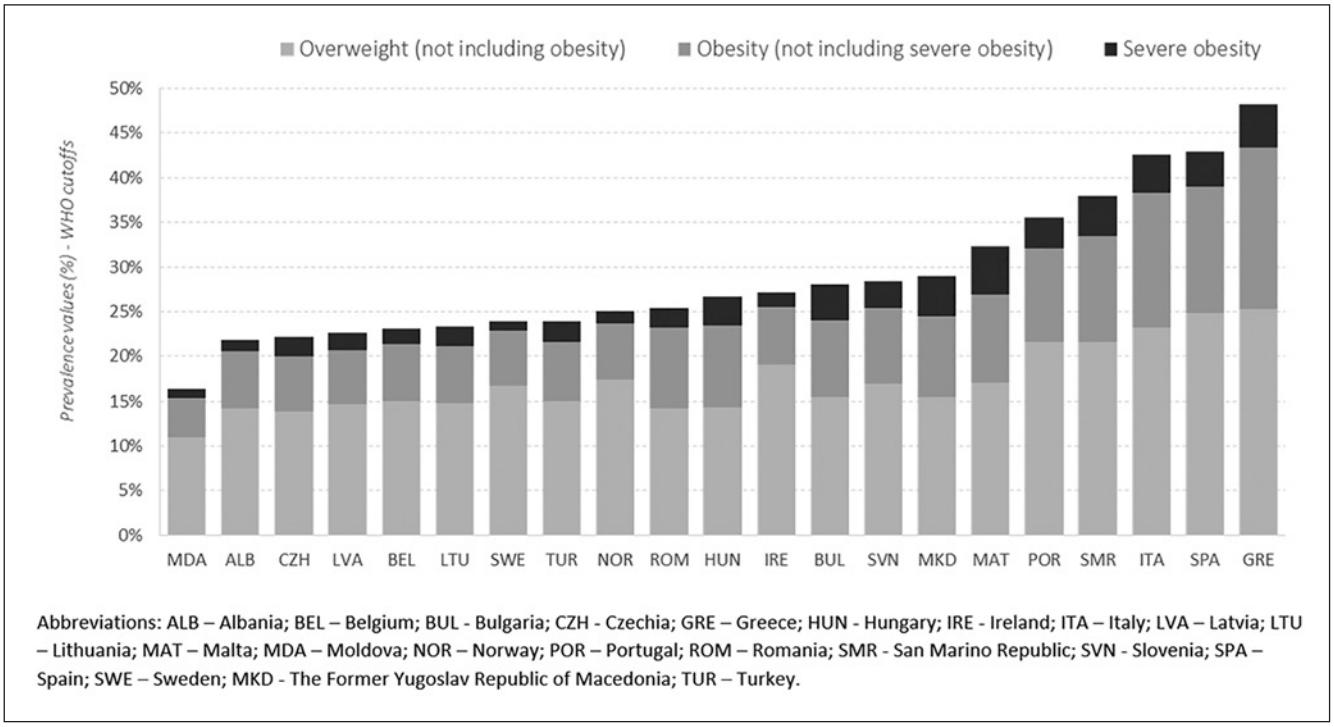

Fig. 1. Prevalence by country of overweight (not including obesity), obesity (not including severe obesity), and severe obesity in children aged 6–9 years (gender and age groups combined) of COSI rounds 1, 2, and 3 (rounds combined) based on WHO definitions.

the analysis (almost 400,000), followed by Italy (almost 100,000) and Slovenia (more than 50,000). For other countries, the sample sizes and number of children included were much lower – about 10,000 or fewer (Table 2). More details of study design and sampling strategy are provided elsewhere [42, 45]. There were great differences in the prevalence of severe obesity between the participating countries. According to the WHO definition, the prevalence of severe obesity ranged from 1.0% in Swedish and Moldovan children (95% CI 0.7–1.4 and 0.7–1.5, respectively) to 5.5% (95% CI 4.9–6.1) in Maltese children (Table 2). Countries from Southern Europe (Greece, Malta, Italy, Spain, and San Marino) had the highest levels of severe obesity, above 4%. In countries from Western and Northern Europe, such as Belgium, Ireland, Norway, and Sweden, the prevalence was below 2%. A similarly low level was also found in Latvia and Lithuania. In other countries from Central and Eastern Europe (such as Albania, Bulgaria, Czech Republic, Hungary, Moldova, Romania, Slovenia, and Republic of Macedonia), a more heterogeneous picture emerged with prevalence values ranging between 1 and 4%. While in Bulgaria and the Republic of Macedonia the prevalence of severe obesity was similar to Southern European countries (4.0 and 4.4%, respectively), Moldova and Albania had values among the lowest (1.0 and 1.2%, respectively).

For all countries the IOTF definition yielded lower levels of severe obesity (Table 2) than when using the WHO definition, with IOTF values ranging in prevalence from 0.6% (95% CI 0.3–0.9) in Albanian children to 4.2% (95% CI 3.7–4.8) in Maltese children. Nevertheless, the analysis based on IOTF cut-offs confirms the existence of a great variability among countries, even though the differences were less prominent.

The prevalence based on the WHO definition was much higher in boys than in girls (Table 2). In most countries that showed a statistically significant difference by gender, prevalence

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Table 3. Multivariate associations between severe obesity based on the WHO definition and COSI rounds of data collection (2007/2008, 2009/2010, 2012/13) in Belgium, Greece, Italy, Lithuania, Latvia, Portugal, Slovenia, and Spain

Country	Prevalence, % (95% CI)			OR_{adj} (95% CI)[1]		
	2007/08	2009/10	2012/13	2007/08	2009/10	2012/13
Belgium	1.6 (1.5–1.7)	1.7 (1.6–1.8)	1.8 (1.7–1.9)	1	1.06 (0.97–1.14)	1.11 (1.02–1.20)
Bulgaria	3.9 (3.2–4.8)	NP	4.1 (3.5–4.8)	1	NP	1.05 (0.80–1.37)
Greece	NP	4.9 (4.3–5.6)	4.7 (3.2–6.9)	NP	1	0.97 (0.64–1.48)
Italy	5.0 (4.5–5.6)	4.0 (3.7–4.2)	3.9 (3.7–4.1)	1	0.77 (0.68–0.87)	0.75 (0.67–0.85)
Lithuania	2.1 (1.7–2.6)	2.2 (1.7–2.7)	2.4 (1.9–3.0)	1	1.03 (0.74–1.43)	1.14 (0.82–1.60)
Latvia	1.9 (1.4–2.4)	2.0 (1.6–2.7)	1.8 (1.4–2.4)	1	1.11 (0.76–1.62)	0.98 (0.65–1.48)
Portugal	4.2 (3.3–5.2)	3.1 (2.4–4.0)	2.9 (2.3–3.6)	1	0.74 (0.52–1.05)	0.67 (0.48–0.94)
Slovenia	3.3 (3.0–3.7)	3.0 (2.8–3.4)	2.7 (2.5–2.9)	1	0.92 (0.79–1.07)	0.80 (0.70–0.93)
Spain	NP	3.9 (2.6–5.6)	4.0 (3.4–4.8)	NP	1	1.06 (0.66–1.68)

NP, not participant.
[1] Adjusted ORs were estimated through country-specific logistic models that included child's sex and age in years as covariates.

values in boys were more than twice those among girls. This was not found using the IOTF cut-offs. Differences in the estimated prevalence using WHO and IOTF cut-offs were mainly due to differences observed among boys.

Applying the estimates of prevalence based on the WHO definition to the whole population of children aged 6–9 years in each country, around 398,000 children would be expected to be severely obese in the 21 European countries. The pattern of severe obesity among countries was in line with those of obesity and overweight[6] – in countries with a higher prevalence of overweight and obesity, severe obesity also tended to be higher (Fig. 1). In many countries 1 in 4 children with obesity were severely obese. The picture was even worse in Bulgaria, Malta, and the Republic of Macedonia, where it was 1 out of 3. On the contrary, in countries affected by lower levels of severe obesity, less than 20% of the obese children were severely obese.

In Table 3, the prevalence values of severe obesity by COSI round, the odds ratios and 95% confidence intervals estimated using multivariate logistic regression analysis are reported for the 9 countries where the number of measured children were sufficient for comparisons over time. As already noted, childhood severe obesity varied among these 9 countries. While severe obesity was rare among Belgian, Latvian, and Lithuanian children (below 2%), Bulgarian, Greek, Italian, and Spanish children were at higher risk of being severely obese (4.0% and above). For Slovenian and Portuguese boys and girls, the risk of severe obesity was between these two (3.0%).

The models showed that Italian, Portuguese, and Slovenian children were more likely to be severely obese in 2007/2008 than in the following years of COSI data collection: the adjusted odds ratios were, respectively, 0.77 (95% CI 0.68–0.87), 0.74 (95% CI 0.52–1.05), and 0.92 (95% CI 0.79–1.07) in 2009/2010, and 0.75 (95% CI 0.67–0.85), 0.67 (95% CI 0.48–0.94), and 0.80 (95% CI 0.70–0.93) in 2012/2013. On the contrary, slightly higher odds of severe obesity have been estimated in the COSI rounds 2 and 3 for Belgium (OR_{adj} = 1.06; 95%

[6] Overweight and obesity comparisons among countries that participated in COSI are presented elsewhere [42, 45], such as comparisons by gender and age groups [47, 48].

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Table 4. Multivariate associations between severe obesity based on the WHO definition and child's age in Belgium, Greece, Italy, Slovenia, and Spain in COSI round 1 (2007/2008), round 2 (2009/2010) and round 3 (2012/2013) – rounds combined

Country	Prevalence, % (95% CI)				OR_{adj} (95% CI)[1]			
	6-year-olds	7-year-olds	8-year-olds	9-year-olds	6-year-olds	7-year-olds	8-year-olds	9-year-olds
Belgium	1.3 (1.3–1.4)	2.4 (2.3–2.6)	1.3 (1.3–1.4)	1.7 (1.6–1.9)	1	1.82 (1.68–1.97)	0.98 (0.92–1.95)	1.31 (1.21–1.42)
Greece	NA	5.3 (4.6–6.1)	NA	4.4 (3.3–6.0)	NA	1	NA	0.85 (0.60–1.19)
Italy	NA	NA	4.8 (4.6–5.1)	3.7 (3.4–4.1)	NA	NA	1	0.77 (0.70–0.85)
Slovenia	2.8 (2.5–3.2)	3.0 (2.7–3.3)	3.2 (2.9–3.5)	NA	1	1.07 (0.92–1.23)	1.13 (0.97–1.31)	NA
Spain	NA	4.4 (2.9–5.6)	3.9 (3.2–4.9)	NA	NA	1	0.93 (0.74–1.18)	NA

NA, data not available.
[1] Adjusted ORs were estimated through country-specific logistic models that included child's sex and COSI rounds of data collection as covariates.

Table 5. Prevalence of severe obesity based on the WHO definition by mothers' education level and country in COSI round 1 (2007/2008), round 2 (2009/2010), and round 3 (2012/2013) – rounds combined

Country	Included number of children	Low-medium level of education[3]		High level of education[3]	
		children, %	prevalence of severe obesity, %	children, %	prevalence of severe obesity, %
Bulgaria	5,562	64.3	4.0	35.7	4.3
Czech Republic[2]	6,250	69.6	3.0	30.4	0.7
Italy[1]	82,691	83.5	4.2	16.5	1.9
Lithuania	7,470	57.5	2.7	42.4	2.0
Malta	1,499	64.9	6.4	35.1	4.6
Portugal	2,964	82.6	3.8	17.4	3.2
Spain[2]	3,175	57.1	5.1	42.9	2.9
Turkey	4,337	89.2	2.4	10.8	2.1

[1] Statistically significant difference of proportions between children with low-medium educated mothers and highly educated mothers for severe obesity (based on the WHO definition) – Pearson's χ^2 corrected using the Rao-Scott method <0.001.
[2] Statistically significant difference of proportions between children with low-medium educated mothers and highly educated mothers for severe obesity (based on the WHO definition) – Pearson's χ^2 corrected using the Rao-Scott method <0.05.
[3] Low-medium level of education – primary or secondary school; high level of education – undergraduate/bachelor's degree or master's degree or higher.

CI 0.97–1.14 in 2009/2010, and OR_{adj} = 1.11; 95% CI 1.02–1.20 in 2012/2013), even though their values remained low. As for Bulgaria, Greece, Lithuania, Latvia, and Spain, the differences were not statistically significant.

Multivariate regression analysis did not identify an association between age groups and severe obesity among Greek, Slovenian, and Spanish children (Table 4). In Italy, 9-year-old children were at lower risk than 8-year-old children (OR_{adj} = 0.77; 95% CI 0.70–0.84); while in Belgium children aged 7 and 9 years old were at higher risk compared to children aged 6 years old (OR_{adj} = 1.81; 95% CI 1.72–1.92, and OR_{adj} = 1.31; 95% CI 1.24–1.39, respectively).

Finally, the association between severe obesity and education level of children's mothers was assessed for 8 countries (Table 5). Severe obesity was generally more common among children whose mother's level of education was low or medium compared to those with higher education.

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Discussion

Due to the adoption of a common methodology, the direct measurement of children by trained staff and the selection of a nationally representative sample of children, COSI is an important source of data for estimating childhood obesity, comparing the levels among countries, and looking at trends over time. In particular, this study provides the first analysis of the prevalence of severe obesity in measured school-age children living in 21 European countries. The first three rounds of COSI – which took place in 2007/2008, 2009/2010, and 2012/2013 – showed that the prevalence of childhood severe obesity varied greatly among countries, as has been seen for childhood overweight and obesity [42, 45, 47, 48]. More specifically, there were countries which were less affected by severe obesity (namely Moldova, Albania, and those of Northern Europe), and countries in which it was a more important public health problem (in Southern Europe, Bulgaria, and Republic of Macedonia). Although in the first 3 rounds of data collection of COSI some of the most populous European countries, such as Russia, Germany, France, and the UK, were not included, still almost 400,000 children aged 6–9 years could be expected to be severely obese in the participating 21 European countries in 2013 based on the prevalence calculated using 2007 WHO growth curves. This will doubtlessly impose a great burden on the health care systems of these countries.

The presence of higher prevalence rates of severe obesity in the south is in line with previous studies of obesity and overweight among European children [47, 48, 52], adolescents [53], and adults [54]. The explanation for it remains elusive, but some possible reasons can be suggested. For example, studies of European children and adolescents suggest that the lower height-for-age found in Southern European countries may be one explanation [55]. Other explanations may be linked to birth weight [56, 57], sleep duration [58, 59], and dietary or physical activity patterns [60]. Relatively low prevalence rates of overweight and obesity were observed in countries that are experiencing a nutrition transition (e.g., Albania and Moldova) [61]. Without timely, appropriate, and effective policy measures to prevent obesity [62], there is a risk that prevalence rates in these countries will eventually match the levels seen in other European countries.

COSI data also indicate that low and medium levels of parental education is a risk factor: in 6 out of 8 countries included in the analysis, children whose mothers had only a primary or secondary school education had a higher prevalence of severe obesity than children whose mothers had a higher education, but only in 3 cases was the difference statistically significant. Although it was not possible to assess properly the impact of family socioeconomic status on severe obesity, differences by mother's education level reinforce that a problem of inequality does exist and that it should be considered when devising strategies to tackle childhood severe obesity. School-based health promotion interventions have the potential to reach children from all socioeconomic backgrounds, and may, therefore, provide an important avenue for addressing health inequalities. Investments must be made to ensure that schools are health-promoting environments. Children also need to be protected from exposure to marketing for foods high in fat, salt, and sugar [62].

COSI was created with the aim of estimating childhood overweight and obesity prevalence across European countries over time through routine nationally representative surveys. The sample size suggested by the protocol [43] was established for producing estimates of overweight and obesity which are much more prevalent than severe obesity. Moreover, 6 countries had a sample size much lower than that suggested (approx. 2,800 measured children per age group). The number of measured children limits the precision of the investigation of childhood severe obesity. The sample size in some countries limited the possibility of producing robust and reliable estimates of the prevalence of childhood severe obesity by

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round of data collection and age group, especially when using the IOTF definition. Despite these limits, it was possible to assess changes over time for 9 countries, 3 slightly affected by childhood severe obesity (Belgium, Lithuania, and Latvia), and 4 with a high prevalence (Bulgaria, Greece, Italy, and Spain).

COSI data show a decrease of severe childhood obesity over time (starting from 2007/2008) in Italy, Portugal, and to a lesser extent in Slovenia, while the other countries do not show any great difference. The association between severe obesity and age is less clear; in Italy severe obesity is less common among children aged 9 compared to those aged 8, while in Belgium the prevalence for children aged 7 and 9 years compared to 6 and 8 years and in Greece, Slovenia, and Spain was not statistically significant.

An important limitation to all studies of severe obesity is that, due to early stigmatization, there might be a higher refusal to participate by the child or the parents if the child is severely obese [63, 64], which can produce an underestimate of the problem. The extent of this bias cannot be usefully estimated in a study of this design. Thus, the estimates reported in this study should be regarded as an underestimate of the true extent of the problem.

The application of different definitions of severe obesity leads to different estimates; prevalence values based on WHO cut-offs in all countries were notably higher than those based on IOTF cut-offs. The divergence mainly regarded the estimation of severe obesity prevalence among boys, which tended to be more than double using WHO growth curves compared with IOTF cut-offs. Despite this difference, the study confirms that, in several countries, childhood severe obesity should be tackled as an important health problem.

Conclusion

Acting on childhood obesity – including severe obesity – can have major benefits for child health and well-being, but also for national health care services and economies. When countries develop processes for monitoring childhood obesity like COSI, it ensures that national obesity strategies – both for prevention and treatment – can be evaluated. COSI also offers the unique possibility of comparing data of several European countries that share the same methodology to assess the weight status of school-aged children. This study is the first that investigates the prevalence of severe obesity in school children with a representative sample from 21 European countries. Severe obesity is a serious public health issue and the results of this study show that a large number of children in Europe suffer from it. Given its impact on education, health, social care, and the economy, obesity needs to be addressed via a range of approaches, from prevention to early diagnosis and treatment [65, 66].

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Statement of Ethics

Children and their parents gave their informed consent. The study protocol was approved by the research institute's committee on human research of the participating countries.

Disclosure Statement

The writing group takes sole responsibility for the content of this article and the content of this article reflects the views of the authors only. Dr. João Breda and Dr. Julianne Williams are staff members of the WHO and Dr. Marta Buoncristiano is a WHO consultant. The authors alone are responsible for the views expressed in this publication and they do not necessarily represent the decisions or the stated policy of the World Health Organization.

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Author Contributions

A.Sp. conceptualized and drafted the manuscript. M.B. conducted all analyses and made substantial contributions to the drafts of the paper. J.B. made substantial contribution to the conception and drafts of both the manuscript and the COSI study protocol as well as interpretation of the results. J.W. and P.G. were involved in critically reviewing the drafts of the manuscript. V.A.K., A.Y., I.S., G.O., G.S., N.P., A.I.R., M.K., V.F.S., J.M., I.H.B, P.N. commented on the draft of the paper and contributed with data collection and data cleaning. C.K., N.Y., I.Pu., A.P., V.D., A.Sj., A.G., M.Ha., J.H., G.B., C.H.P, M.He., H.T., H.Z., T.B.B., E.S., I.Pa. contributed with data collection and data cleaning. All authors contributed to and approved the report.

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