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ORIGINAL CONTRIBUTION

Pediatric adiposity stabilized in Switzerland between 1999 and 2012

Stefanie B. Murer · Siret Saarsalu · Michael B. Zimmermann · Isabelle Aeberli

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Abstract
Purpose Several countries have recently reported stabilization and/or a decrease in the prevalence of pediatric obesity. However, systematic, repeated national monitoring studies are scarce, and it is unclear whether this trend would be sustained. The objective was to present the latest overweight and obesity prevalence in Swiss children and to investigate trends in prevalence from 1999 to 2012.
Methods Using probability-proportionate-to-size cluster sampling, nationally representative samples of children aged 6–12 years were recruited in 1999 ($n = 594$), 2002 ($n = 2{,}493$), 2004 ($n = 328$), 2007 ($n = 2{,}218$), 2009 ($n = 907$), and 2012 ($n = 2{,}963$). Height and weight were measured to calculate BMI (kg/m^2). BMI cutoffs proposed by the Centers for Disease Control and Prevention (CDC) and by the International Obesity Task Force were used to determine the prevalence of overweight (excluding obesity) and obesity. Waist circumference was measured in 2007 and 2012, and multiple skinfold thicknesses assessed in 2002 and 2012.
Results Using the CDC criteria, prevalences of overweight and obesity in 2012 were 11.9 % (95 % CI 10.7–13.1) and 7.1 % (95 % CI 6.2–8.0), respectively, and did not change between 1999 and 2012 ($\beta = -0.144$, $p = 0.293$ and $\beta = -0.063$, $p = 0.552$, respectively). Boys had significantly higher obesity prevalence than girls in 2007 (5.6 vs. 3.4 %) and 2012 (8.1 vs. 5.9 %). Percentage of children with excess waist circumference and body fat percentage did not differ between 2007 and 2012, and 2002 and 2012, respectively.
Conclusion Our data indicate the prevalence of childhood adiposity in Switzerland stabilized between 1999 and 2012, but ≈ 1 in 5 children remain overweight or obese and further efforts are needed to control the epidemic.

Keywords Obesity · Overweight · Children · Trends · Body fat percentage · Waist circumference

Abbreviations

%BF	Body fat percentage
BMI-SDS	BMI standard deviation scores
CDC	Centers for Disease Control and Prevention
D	Body density
IOTF	International Obesity Task Force
PPS	Probability-proportionate-to-size
SFT	Skinfold thicknesses

S. B. Murer · S. Saarsalu · M. B. Zimmermann · I. Aeberli
Human Nutrition Laboratory, Institute of Food, Nutrition and Health, Swiss Federal Institute of Technology (ETH) Zurich, Zurich, Switzerland

S. B. Murer (✉)
Schmelzbergstrasse 7, LFV D27.2, 8092 Zurich, Switzerland
e-mail: stefanie.murer@hest.ethz.ch

I. Aeberli
Division of Endocrinology, Diabetes, and Clinical Nutrition, University Hospital Zurich, Zurich, Switzerland

Introduction

The prevalence of childhood overweight and obesity is increasing worldwide [1, 2]. Obesity during childhood is linked to both direct, short-term health consequences [3] as well as indirect consequences through tracking of obesity into adulthood and later associated morbidities [4]. Prevalence continues to increase in developing and transition countries [5], but recent evidence from several industrialized countries has suggested a leveling off or a decrease in childhood obesity [6, 7].

In Switzerland, the first national study determining prevalence of overweight and obesity among 6–12-year-old children was conducted in 2002. At that time, more than 13 % of Swiss children were overweight (excluding obesity) and an additional 6 % classified as obese [8]. Compared to regional data assessed in the 1960s and 1980s, this represented a fivefold increase in prevalence [9]. In 2007, in a second national study, a decrease in overweight in girls and of obesity in both genders was reported [10]. This pattern was attributed to an increased public awareness on the importance of this health issue and to the success of various health campaigns and interventions aimed at promoting healthy eating and physical activity in general and specifically during childhood [10]. However, additional factors such as an alteration in immigration, sociodemographic shifts, or self-selection bias might explain those results. As this is the first evidence of a change in tendency, it is also unclear whether the decrease in prevalence from 2002 to 2007 would be sustained.

BMI is widely used as a surrogate measure of adiposity [11]; however, it does not distinguish between lean body mass and fat mass and provides no indication on fat distribution [12]. Multiple skinfold thicknesses (SFT) provide valid estimates of the amount of subcutaneous body fat [13, 14] and substantially improve the prediction of adiposity [15]. Central distribution of body fat is associated with a higher risk of the metabolic syndrome [16]. Waist circumference serves as a proxy for estimating visceral adipose tissue [17] and has consistently been associated with components of the metabolic syndrome in children [18–20].

The aim of the present study was to update the prevalence of overweight and obesity in a cross-sectional, nationally representative sample of 6–12-year-old Swiss children in 2012, and to investigate trends in overweight and obesity prevalence from 1999 to 2012. In addition, children with excess body fat percentage (%BF) and waist circumference were compared among selected surveys.

Methods

Population

Data were obtained from 6 cross-sectional, nationally representative school-based health surveys. Detailed methods of the 1999, 2002, 2004, 2007, and 2009 surveys have been previously published [8, 10, 21–25]. The 3 larger surveys (2002, 2007, and 2012) specifically aimed to monitor trends in prevalence of overweight and obesity in Swiss primary school children at 5-year intervals. The 3 smaller surveys (1999, 2004, and 2009) were done using the same sampling scheme, but were smaller in size, designed to assess iodine status; weights and heights were assessed for subject characterization.

Sampling scheme

In all 6 surveys, an identical stratified probability-proportionate-to-size (PPS) cluster design was used to obtain a representative national sample of Swiss children aged 6–12 years. Based on current census data, the Swiss Federal Office of Statistics divided Switzerland into five geographic regions: west (French language), north-west (German language), north-east (German language), central east (German language), and south (Italian language). Each of these regions was divided into three strata by population size of the communities (i.e., small communities: <10,000 inhabitants; middle-sized communities: 10,000–100,000 inhabitants; large communities >100,000 inhabitants). Then, a two-stage PPS random cluster sampling was used to obtain independent national samples of the population groups. For the 3 larger surveys, 60 communities and per community 1 school across Switzerland were identified by stratified random selection. Schools that declined participation were systematically replaced by another randomly selected school from the same strata (sampling stage 1). Per school, 3–4 classrooms were randomly selected and all students from these classrooms were invited to participate (sampling stage 2). For the 3 smaller surveys, 30 communities/schools (1999/2009) and 20 communities/schools (2004) were selected according to the same principle (Table 1).

Information about the size of residential community (i.e., large, middle sized, and small) of each school visited was noted only in the 3 larger surveys.

Enrollment and participation

Participation was voluntary in 1999, 2002, 2004, 2007, and 2009; written informed consent was obtained from all parents or legal guardians of the participating children [8, 10, 21–25]. The enrollment process was slightly altered in 2012, as written informed consent was no longer necessary, but parents had the possibility to withdraw their child from the survey by letter. An information letter describing the study and the examination process was sent to the school principal, teachers, parents, and children two weeks prior to the measurement day in order to give parents/children sufficient time to consider participation. For the 2012 survey, data were collected from February to June 2012, and ethical approval was obtained from the Ethical Commission of the Swiss Federal Institute of Technology

Table 1 Study population characteristics of national samples of Swiss children aged 6–12 years in 1999, 2002, 2004, 2007, 2009, and 2012

	Year of survey					
	1999	2002	2004	2007	2009	2012
n	594	**2,493**	328	**2,218**	907	**2,963**
Sex (n (%))						
Boys	296 (49.8)	**1,231 (49.4)**	160 (48.8)	**1,082 (48.8)**	455 (50.2)	**1,499 (50.6)**
Girls	298 (50.2)	**1,262 (50.6)**	168 (51.2)	**1,136 (51.2)**	452 (49.8)	**1,464 (49.4)**
Age (y)[a]	10.5 (6.5–12.5)[b]	**9.9 (6.2–13.0)**	10.5 (6.5–12.5)	**10.1 (6.3–13.0)**[f]	10.5 (6.5–12.5)	**9.9 (6.3–13.0)**
Weight (kg)	33.2 (15.6–77.5)	**32.7 (17.7–94.4)**	32.9 (19.1–63.7)	**33.2 (15.9–83.3)**	33.2 (17.2–77.0)	**32.7 (16.7–132.3)**
Height (m)	1.392 ± 0.116[c]	**1.387 ± 0.120**	1.389 ± 0.102	**1.400 ± 0.116**[g]	1.396 ± 0.1135	**1.389 ± 0.117**
BMI (kg/m^2)	17.0 (10.9–31.5)	**17.1 (12.5–35.0)**	16.8 (12.5–27.6)	**16.9 (12.3–34.7)**	16.9 (12.3–29.2)	**16.9 (12.4–42.7)**
BMI-SDS[d]	0.16 ± 0.97	**0.19 ± 0.94**	0.03 ± 0.99	**0.06 ± 0.91**[g]	0.09 ± 0.96	**0.15 ± 0.98**
Number of schools	30	**57**	20	**60**	28	**58**
Participation rate (%)	n.a.[e]	**76.4**	n.a.	**72.5**	n.a.	**94.5**

Bold values indicate the three large surveys

[a] Exact age values for 2002/2007/2012 (e.g., 6.2 years); mid-year age values for 1999/2004/2009 (e.g., 6.5 years)

[b] Median; range in parentheses (all such values)

[c] Mean ± SD (all such values)

[d] BMI standard deviation scores calculated using the Epi Info software from the Centers for Disease Control and Prevention

[e] Not assessed

[f] Different from 2002 and 2012, $p < 0.003$ (Mann-Whitney U test, Bonferroni correction)

[g] Different from 2002 and 2012, $p < 0.05$ (One-way ANOVA with Games-Howell post hoc test)

Zurich (Zurich, Switzerland) and the Cantonal Ethic Committee Vaud (Lausanne, Switzerland).

Anthropometric measures

Measuring methodologies were identical across the 6 surveys with detailed description of the 2012 survey as follows. Children left the classroom in pairs, and measurements were carried out in a separate room. For the measurements, subjects removed their shoes, emptied their pockets, and wore light indoor clothing. All measurements were conducted by two trained examiners (S.B.M. and S.S.). Height and weight were measured using standard anthropometric techniques [26]. Body weight was measured to the nearest 0.1 kg using a digital scale (PS22; Breuer, Ulm, Germany). Height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 214; Seca Medizinische Waagen und Messsysteme, Hamburg, Germany). Waist circumference was measured twice to the nearest 0.1 cm using a nonstretchable measuring tape (Seca 201; Seca Medizinische Waagen und Messsysteme, Hamburg, Germany) midway between the lowest rib margin and the iliac crest [27]. SFT were measured by using a Harpenden Skinfold Caliper (HSC-5; British Indicators, West Sussex, United Kingdom) with a constant spring pressure of 10 g/mm, a resolution of 0.2 mm, and a measuring range of 80 mm. SFT were measured at the triceps, biceps, subscapular, and suprailiac sites [27]. For the triceps, the midpoint of the back of the upper arm between the tip of the olecranon and acromial process was determined by measuring with the arm flexed at 90° and marked with a soft pen. With the arm hanging freely at the side, the caliper was applied vertically above the olecranon at the marked level. Over the biceps, the SFT were measured at the same level as the triceps, again with the arm hanging freely and the palm facing outward. At the subscapular site, the SFT were picked up just below the inferior angle of the scapula at 45° to the vertical along the natural cleavage lines of the skin. The suprailiacal SFT were measured above the iliac crest, just posterior to the midaxillary line and parallel to the cleavage lines of the skin, with the arm lightly held forward. All sites were measured on the left side of the body in duplicate. Gender and age (date of birth) were obtained from the school lists provided by each teacher. In the case of missing data, they were established at the time of examination.

In an identical manner, waist circumference was measured in 2007 [28], and 4 SFT assessed in 2002 [8]; however, those measurements were not available from the other surveys.

Data analysis

All data were thoroughly checked for data entry errors. Children <6.0 years and ≥13.0 years were excluded from the data analysis. In the 3 larger surveys, the exact age of the children was calculated from date of birth and date of measurement. In the 3 smaller surveys, the age parameters were known in full years (e.g., 6 or 7), and therefore, the mid-year value (e.g., age 7.5 for all children indicating to be 7 years old) was used.

BMI was calculated as weight (kg) divided by height squared (m^2). Overweight (excluding obesity) and obesity were defined according to the age- and sex-specific 85th and 95th BMI percentiles, respectively, of the Centers for Disease Control and Prevention (CDC) [29] and according to the age- and sex-specific BMI percentiles proposed by the International Obesity Task Force (IOTF), which have been extrapolated to the adult BMI cutoffs, passing through BMI 25 and 30 kg/m^2, respectively, at age 18 [30]. As there is no national growth reference for Swiss children, we previously validated the accuracy of the CDC and the IOTF criteria in classifying adiposity for Swiss children at this age [31]. The sensitivity and specificity of the CDC and IOTF overweight criteria and of the CDC obesity criteria were high, but the IOTF obesity criteria were found to be poor failing to identify one half of the children classified as obese on the basis of %BF from SFT [31]. Therefore, the IOTF values were only displayed to allow for international comparison [32], and if not clearly indicated, we referred to the estimation of prevalence rates obtained with the CDC reference throughout the text. To compare BMI values across different ages and by gender, individual BMI standard deviation scores (BMI-SDS) were calculated using the software Epi Info version 3.5.3 (Centers for Disease Control and Prevention, Atlanta, GA, USA).

Using the mean of the 4 repeated SFT measurements, body density (D) and %BF were calculated according to the following equations by Deurenberg et al. [33]:

$$D(\text{boys})(\text{g/ml}) = 1.1690 - 0.0788 \times \text{Log}(\text{sum of four SFT})$$

$$D(\text{girls})\ (\text{g/ml}) = 1.2063 - 0.0999 \times \text{Log}\ (\text{sum of four SFT})$$

$$\%\text{BF} = ((562 - 4.2 \times (\text{age} - 2))/D) - (525 - 4.7 \times (\text{age} - 2))$$

Prevalence estimates of children above the age- and sex-specific 85th and the 95th percentile values for %BF and for waist circumference were calculated. The %BF and waist circumference percentiles derived from the national samples of Swiss children in the 2002 [8] and the 2007 survey [28], respectively.

Statistical analysis was done using IBM SPSS Statistics version 20 (IBM Company, Armonk, NY, USA) and Excel (Microsoft Office 2010; Microsoft Corporation, Redmond, WA, USA). All data were checked for normal distribution using Kolmogorov–Smirnov test and graphically by evaluating histograms and Q–Q plots. Normally distributed data were expressed as mean ± SD. Nonnormally distributed data were log-transformed before data analysis and expressed as median (Min–Max). No suitable transformation could be found for age, BMI, %BF, and waist circumference, and therefore, nonparametric testing was applied for these variables. One-way ANOVA followed by Games-Howell post hoc test, which does not require homogeneity of variances, was performed to check for significant differences among the population characteristics for normally distributed continuous variables. For the comparison of several continuous nonparametric data, Kruskal–Wallis test followed by Mann-Whitney U group comparison (Bonferroni correction) was conducted. Two continuous nonparametric variables were compared by Mann-Whitney U test. Linear regression models on trends in overweight and obesity prevalence between 1999 and 2012 were conducted with survey year as a continuous variable. Prevalence of overweight and obesity between the 6 surveys and gender was compared using the chi-square test, followed by the z test to check for significant differences between the individual values (Bonferroni correction). Prevalence estimates of children above the age- and sex-specific 85th and the 95th percentiles values for %BF and waist circumference were also compared using the chi-square test and z test (Bonferroni correction). Trends in overweight (including obesity) prevalence between 2002, 2007, and 2012 by size of residential community were analyzed using a logistic regression with weight category as binary outcome, survey year and residential community as factors treated both as discrete variables.

Results

Obesity Survey 2012

In total, 3239 children attending the consenting schools were invited to participate in the study. Of those, 177 children did not take part (77 children/parents declined participation, and 100 children were absent on the day of measurement due to illness or other reasons), resulting in an overall participation rate of 94.5 %. Fifteen children were excluded because of missing age, and 84 children because they were either <6.0 or ≥13.0 years of age. The final sample size consisted of 2963 children, representing approximately 1 in 185 children in this age group in Switzerland.

Study population characteristics

Basic characteristics of the children from all 6 surveys did not differ, except for a significant difference ($p < 0.05$) in age, height, and BMI-SDS in 2007 compared to 2002 and 2012 (Table 1).

Table 2 Prevalence (%) of overweight (excluding obesity) and obesity in national samples of Swiss children aged 6–12 years in 1999, 2002, 2004, 2007, 2009, and 2012 by gender, using the CDC and the IOTF references

	Year of Survey													
	1999		2002		2004		2007		2009		2012		β[a]	*p* value
	N	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)	*N*	% (95% CI)		
Overweight														
Total														
CDC reference	82	13.8 (11.0–16.6)	**335**	**13.4 (12.1–14.7)**	36	11.0 (7.6–14.4)	**230**	**10.4 (9.1–11.7)**[b]	113	12.5 (10.4–14.6)	**353**	**11.9 (10.7–13.1)**	−0.144	0.293
IOTF reference	85	14.3 (11.5–17.1)	**349**	**14.0 (12.6–15.4)**	39	11.9 (8.4–15.4)	**246**	**11.1 (9.8–12.4)**[c]	119	13.1 (10.9–15.3)	**416**	**14.0 (12.7–15.3)**	−0.056	0.700
Boys														
CDC reference	40	13.5 (9.9–17.4)	**167**	**13.6 (11.7–15.5)**	22	13.8 (8.5–19.1)	**117**	**10.8 (8.9–12.7)**	57	12.5 (9.5–15.5)	**179**	**11.9 (10.3–13.5)**	−0.165	0.147
IOTF reference	37	12.5 (8.7–16.3)	**162**	**13.2 (11.3–15.1)**	17	10.6 (5.8–15.4)	**121**	**11.2 (9.3–13.1)**	57	12.5 (9.5–15.5)	**207**	**13.8 (12.1–15.5)**	0.061	0.646
Girls														
CDC reference	42	14.1 (10.1–18.1)	**168**	**13.3 (11.4–15.2)**	14	8.3 (4.1–12.5)	**113**	**9.9 (8.2–11.6)**	56	12.4 (9.4–15.4)	**174**	**11.9 (10.2–13.6)**	−0.133	0.576
IOTF reference	48	16.1 (11.9–20.3)	**187**	**14.8 (12.8–16.8)**	22	13.1 (8.0–18.2)	**125**	**11.0 (9.2–12.8)**	62	13.7 (10.5–16.9)	**209**	**14.3 (12.5–16.1)**	−0.165	0.364
Obesity														
Total														
CDC reference	31	5.2 (3.4–7.0)	**163**	**6.5 (5.5–7.5)**	17	5.2 (2.8–7.6)	**100**	**4.5 (3.6–5.4)**[c]	48	5.3 (3.8–6.8)	**209**	**7.1 (6.2–8.0)**	0.063	0.552
IOTF reference	12	2.0 (0.9–3.1)	**95**	**3.8 (3.0–4.6)**	6	1.8 (0.3–3.3)	**49**	**2.2 (1.6–2.8)**[b]	25	2.8 (1.7–3.9)	**102**	**3.4 (2.7–4.1)**	0.055	0.553
Boys														
CDC reference	17	5.7 (3.0–8.4)	**90**	**7.3 (5.8–8.8)**	8	5.0 (1.6–8.4)	**61**	**5.6 (4.2–7.0)**	28	6.2 (4.0–8.4)	**122**	**8.1 (6.7–9.5)**	0.111	0.364
IOTF reference	5	1.7 (0.2–3.2)	**46**	**3.7 (2.6–4.8)**	4	2.5 (0.1–4.9)	**26**	**2.4 (1.5–3.3)**	13	2.9 (1.4–4.4)	**51**	**3.4 (2.5–4.3)**	0.071	0.349
Girls														
CDC reference	14	4.7 (2.3–7.1)	**73**	**5.8 (4.5–7.1)**	9	5.4 (2.0–8.8)	**39**	**3.4 (2.3–4.5)**[e]	20	4.4 (2.5–6.3)	**87**	**5.9 (4.7–7.1)**[d,e]	−0.001	0.993
IOTF reference	7	2.3 (0.6–4.0)	**49**	**3.9 (2.8–5.0)**	2	1.2 (−0.4–2.8)	**23**	**2.0 (1.2–2.8)**	12	2.7 (1.2–4.2)	**51**	**3.5 (2.6–4.4)**	0.042	0.700

Bold values indicate the three large surveys

CDC Centers for Disease Control and Prevention [29], *IOTF* International Obesity Task Force [30]

[a] Unstandardized regression coefficient

[b] Different from 2002, $p < 0.05$ (z test, Bonferroni correction)

[c] Different from 2002 and 2012, $p < 0.05$ (z test, Bonferroni correction)

[d] Different from 2007, $p < 0.05$ (z test, Bonferroni correction)

[e] Different from that of boys (in the same year), $p < 0.05$ (z test, Bonferroni correction)

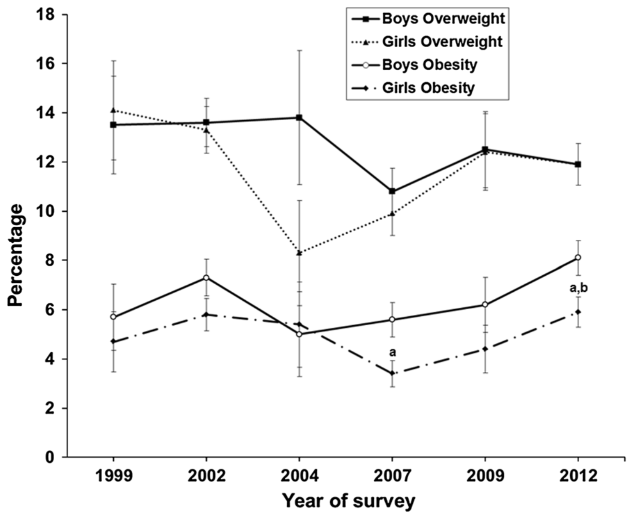

Fig. 1 Trends in prevalence (%) ± SE of overweight (excluding obesity) and obesity in Swiss children aged 6–12 years from 1999-2012 by gender, using the Centers for Disease Control and Prevention (CDC) reference. [a]Gender difference in obesity prevalence in 2007 and 2012, $p < 0.05$ (z test, Bonferroni correction); [b]different from obesity prevalence in 2007, $p < 0.05$ (z test, Bonferroni correction)

Trends in overweight and obesity prevalence from 1999 to 2012

Trends in overweight and obesity prevalence from 1999 to 2012 are shown in Table 2 and Fig. 1. Based on linear regression analyses, there was no significant change in the prevalence of overweight and obesity between 1999 and 2012 (Table 2). Time trends in prevalence estimated using the CDC and the IOTF references were similar; however, the IOTF [30] produced slightly higher estimates for overweight, but markedly lower estimates for obesity, especially in boys (Table 2).

When comparing prevalences among the 6 surveys, total overweight and obesity prevalence were significantly lower in 2007 than in 2002 and 2012 ($p < 0.05$), respectively (Table 2). In girls, prevalence of obesity was significantly higher in 2012 compared to 2007 ($p < 0.05$), but there was no difference in overweight prevalence. Both in 2007 and 2012, the prevalence of obese boys was significantly higher than the prevalence of obese girls ($p < 0.05$), however, only when using the CDC reference (Table 2).

Trends in overweight (including obesity) prevalence by size of residential community

Trends in overweight (including obesity) prevalence by size of residential community are shown in Fig. 2. Logistic regression revealed a strong interaction ($p = 0.013$) between the factors survey year and size of residential community, indicating that the trend in time was not the same for all community sizes or, equivalently, the effect of community size was not the same in all studies.

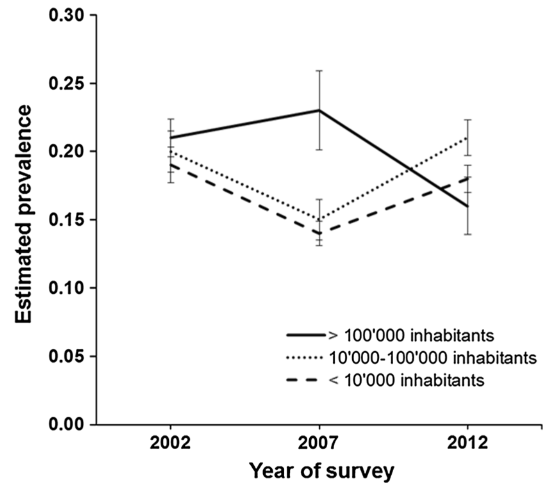

Fig. 2 Estimated prevalence ± SE of overweight (including obesity) in Swiss children aged 6–12 years in 2002, 2007, and 2012 by size of residential community, using the Centers for Disease Control and Prevention (CDC) reference

Comparison of %BF and waist circumference

The prevalence of children above the age- and sex-specific 85th and the 95th percentiles for waist circumference did not differ between 2007 and 2012 (Table 3). Furthermore, there was no difference in prevalence of children above the sex-specific 85th and the 95th percentiles for %BF for age between 2002 and 2012 (Table 3). Except for a higher prevalence of girls above the 85th percentile for waist circumference in 2007, there were no gender differences (Table 3).

Discussion

The analysis of data from 6 nationally representative cross-sectional studies carried out in Switzerland between 1999 and 2012 suggests a stabilization in the prevalence of childhood overweight and obesity over this period with significant fluctuations in-between. Contrasting to an earlier assumption, a decrease in the prevalence of overweight and obese Swiss children could not be confirmed [10]. In addition, there has been gender divergence in obesity prevalence, with boys at higher risk since 2007, and demographic shifts showing improvements in urban centers and a worsening in rural areas.

Comparing prevalence across countries is challenging, due to different assessment methods, especially because of several definitions of pediatric overweight and obesity that are used worldwide. However, comparisons between

Table 3 Prevalence (%) of children above the age- and sex-specific 85th and the 95th percentiles for waist circumference[a] and for body fat percentage[b] (estimated by measuring 4 skinfold thicknesses) in national samples of Swiss children aged 6–12 years in 2002, 2007, and 2012

	Year of survey												*p* value[c]
	2002				2007				2012				
	≥85th–94th percentile		≥95th percentile		≥85th–94th percentile		≥95th percentile		≥85th–94th percentile		≥95th percentile		
	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)	*N*	% (95% CI)	N	% (95% CI)	N	% (95% CI)	
Waist circumference[d]													
Total	–	–	–	–	208	9.4 (8.2–10.6)	129	5.8 (4.8–6.8)	266	9.0 (8.0–10.0)	187	6.3 (5.4–7.2)	0.692
Boys	–	–	–	–	88	8.1 (6.5–9.7)	70	6.5 (5.0–8.0)	129	8.6 (7.2–10.0)	94	6.3 (5.1–7.5)	0.897
Girls	–	–	–	–	120	10.6 (8.8–12.4)[f]	59	5.2 (3.9–6.5)	137	9.4 (7.9–10.9)	93	6.4 (5.1–7.7)	0.300
%BF[e]													
Total	285	11.7 (10.4–13.0)	152	6.2 (5.2–7.2)	–	–	–	–	365	12.4 (11.2–13.6)	219	7.4 (6.5–8.3)	0.135
Boys	145	12.1 (10.3–13.9)	70	5.9 (4.6–7.2)	–	–	–	–	198	13.3 (11.6–15.0)	115	7.7 (6.3–9.1)	0.087
Girls	140	11.3 (9.5–13.1)	82	6.6 (5.2–8.0)	–	–	–	–	167	11.5 (9.9–13.1)	104	7.2 (5.9–8.5)	0.832

[a] Waist circumference percentiles were constructed based on the national sample of Swiss children in 2007 [28]

[b] Body fat percentage percentiles were constructed based on the national sample of Swiss children in 2002 [8]

[c] Chi-square test

[d] Waist circumference was not measured in 2002

[e] Skinfold thicknesses were not measured in 2007

[f] Different from that of boys (in the same year), $p < 0.05$ (z test, Bonferroni correction)

countries reporting stabilization in nationally representative samples and using prevalence rates defined by the IOTF criteria indicate that stabilization has occurred at different levels in different countries: with a prevalence of overweight (including obesity) of 17.4 % in Switzerland, the stabilization has occurred at a slightly higher level than it did in France (15.8 %) [34], but markedly below the levels of stabilization in England (26.4 %) and in the USA (34.3 %). England and the USA reported stabilizing obesity rates of 7.4 and 15.7 %, respectively, which is 2–4.5 times higher than the obesity rates found in Swiss children (3.4 %) [7]. It is unclear why prevalences are stabilizing at different level across countries, but it is likely due to a combination of cultural and genetic factors [7].

Among countries whose data suggest stabilization, our study is the first to describe a small but significant fluctuation, with a lower overweight and obesity prevalence in 2007, compared to 2002 and 2012. In France, using annual data, the overweight prevalence in children aged 6–15 years increased between 1996 and 1998 and was stable between 1998 and 2006 [35]. Similarly, long-term trend analysis in Czech children showed an increasing trend since 1951 and a plateau since 2001 in girls but not in boys [36]. In 4-to-16-year-old German children, a significant upward trend was observed between 1999 and 2003, and a significant downward trend between 2004 and 2008 [37].

We have previously suggested a possible link between public health campaigns and the reduction in overweight and obesity prevalence in Switzerland between 2002 and 2007 [10]. Also, France and England have linked the implementation of national public health programs to the stabilization observed [35, 38]. The publication of the 2002 data [8] attracted significant media response in Switzerland. Numerous public health campaigns and programs were installed across the country in the following years. This most likely raised the general public's awareness of the childhood overweight problematic in Switzerland and also of the importance of healthy eating and the promotion of physical activity among children. Looking at the most recent prevalence data reported here, it can be speculated that after an initial uproar, the general interest in the topic has leveled off again and with this probably also the effort of the individual parents to try and motivate their children to be physically active and eat healthy foods. Another possibility could be that parents, or the general public, have become less receptive to public health campaigns, which might explain the increasing trend in prevalence rates between 2007 and 2012. The changes observed, however, might also simply reflect natural fluctuation within a population, which has been seen for pediatric obesity prevalence in other countries [35, 38]. On the other hand, there is evidence for a nonlinear, stepwise increase in the obesity epidemic over time, with periods of stable or decreasing prevalence rates followed by periods of increase [6].

The fluctuation may also be due to sampling bias differences across the surveys. Participation rate varied considerably among the 3 large surveys (2002, 2007, and 2012), which is likely attributed to the differences in the enrollment process (i.e., active parental consent in 2002/2007 vs passive parental consent in 2012). No information regarding participation rates was available for the 3 smaller surveys (1999, 2004, and 2009). In the 2012 survey, teachers estimated that 28 % of the nonparticipating children may have excess weight according to their subjective judgment. This figure, however, should be interpreted with caution as recognition rates of overweight children by adults are rather poor as proven in a study investigating the parents' weight perception of their own child as well as of unrelated children [39]. For the 2002 and 2007 surveys, no data regarding the weight status of the nonparticipating children are available. Although there is evidence that passive and active parental consents generate identical estimates of overweight and obesity prevalence, and BMI status of children does not influence the response to active parental consent procedures [40], we cannot completely rule out that different sampling biases existed among the studies which may have affected the outcome. As in the smaller surveys weight and height were solely assessed for better characterization of the subjects, it can be assumed that the sampling bias with regard to weight status was low. Those studies have confirmed the prevalence and trends found in the 3 large surveys, indicating that sampling bias due to different participation rates among the studies is small.

Using the CDC reference, we found a significant gender difference in obesity prevalence both in 2007 and 2012, but not in 2009. This is likely due to the smaller sample size in the 2009, making it difficult to detect statistical significances. However, when looking at the prevalences only, a gender divergence is apparent with boys at higher risk since 2007. In addition, the prevalence of boys with excess %BF is considerably higher (although not statistically significant) in 2012 as compared to 2002, whereas the prevalence of girls with excess %BF remained more or less unchanged during this time period. Similar to our results, other countries have found gender differences in prevalence and trends of obesity, generally showing higher rates in boys than in girls. In Portugal and Italy, countries known to have the highest prevalence of childhood adiposity in Europe, boys had a higher prevalence of obesity than girls [41, 42]. In Germany, the increase in childhood obesity between 1999 and 2006 was more pronounced in boys than in girls [43]. Trend analysis using data from the U.S. National Health and Nutrition Examination Surveys from 1999 to 2012 indicated a significant increase in obesity prevalence in boys, whereas stabilization was found in girls [44]. In Sweden [45], the Netherlands [46], and Czech Republic [36], there is evidence that the prevalence of overweight and/or obesity decreased in girls and stayed unchanged in boys. Those examples show that in future prevention programs, not only in Switzerland, it is important to target boys and girls separately as boys may, overall, be less perceptive to this topic.

We found certain shifts in sociodemographic distribution of overweight and obesity with a decline in urban centers and an increase in rural areas mainly taking place during the last 5 years. These findings are in line with BMI-SDS trends found in children from Czech Republic. There was an increase in BMI-SDS in children living in semi-urban and rural areas between 1951 and 2008, whereas BMI-SDS in urban girls but not boys decreased during that time period [36]. It is difficult to identify a clear reason for the observed demographic changes in Switzerland. On one hand, it is possible that prevention programs have been more widely spread or were more effective in urban areas. Furthermore, it is likely that the increasing living expenses in urban centers led to sociodemographic shifts. In a national study in Swedish school children, both a socioeconomic and an urban-rural gradient of overweight and obesity were found. The urban-rural gradient for overweight was attenuated when area education level was accounted for [47].

The present study has several strengths, including 6 large, nationally representative samples of school children, standardized measurement protocols throughout the studies, and the measurement of multiple SFT and waist circumference in selected surveys. Several issues, however, have to be considered when comparing the studies. Age parameters were known in full years only for the 3 smaller surveys, and thus, the respective mid-year age values were created to define overweight and obesity. This statistical assumption may have misclassified the weight status of some children. When estimating prevalence rates for the 3 larger surveys using full year instead of exact age parameters, however, prevalence estimates only differed by 0.2–0.6 % for overweight and by 0.1–0.2 % for obesity (data are not shown), indicating that no important bias was introduced by the imprecise age data. A further limitation is the relatively poor intra- and interobserver reliability of skinfold measurements [48]. Measurement errors are frequently proportional to the amount of subcutaneous body fat tissue [49], which may lead to larger measurement errors in the overweight and obese subgroup [15]. Hence, the %BF data should be interpreted with caution. A final point to consider is differences in body fat distribution between different ethnic groups. The large majority of the study population were of Caucasian origin. However, there were a small number of noncaucasian subjects in each of the surveys, which were treated using the same cutoff points as ethnicity was not recorded, and for children, no ethnicity-specific references exist. Thus, in this small minority, some misclassification with regard to the levels of adiposity may have occurred, even though the reference curves for %BF and waist circumference were based on the data from our own surveys [50–52].

In conclusion, our data suggest that the prevalence of childhood overweight and obesity in Switzerland has stabilized over the last 13 years, with ≈ 1 in 5 children affected. Future cross-sectional studies are needed to monitor this trend and to confirm stabilization. In addition, the present study emphasizes the importance to identify gender-specific risk factors for obesity in this age group in order to optimize the design of prevention programs. Stabilization has occurred at an unacceptably high level, and effective primary and secondary prevention programs have yet to be developed in order to truly improve the situation in Switzerland.

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Conflict of interest The authors declare that they have no conflict of interest.

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