European Journal of Nutrition
https://doi.org/10.1007/s00394-022-02851-w

ORIGINAL CONTRIBUTION

Long-term trends in the consumption of sugary and diet soft drinks among adolescents: a cross-national survey in 21 European countries

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Received: 13 January 2021 / Accepted: 22 February 2022

Abstract

Purpose To assess country-level trends in the prevalence of daily consumption of sugary (2002–2018) and diet (2006–2018) soft drinks among European adolescents, overall and by family material affluence.

Methods We used 2002, 2006, 2010, 2014 and 2018 data from the 'Health Behaviour in School-aged Children' survey. Nationally representative samples of adolescents completed a standardised questionnaire at school, including a short food frequency questionnaire ($n = 530{,}976$ and 21 countries for sugary soft drinks; $n = 61{,}487$ and 4 countries for diet soft drinks). We classified adolescents into three socioeconomic categories for each country and survey year, using the Family Affluence Scale. Multilevel logistic models estimated time trends, by country.

Results Sugary soft drinks: the prevalence of daily consumption (≥ 1×/day) declined in 21/21 countries ($P_{\text{linear trends}} \leq 0.002$). Absolute [range − 31.7 to − 3.4% points] and relative [range − 84.8 to − 22.3%] reductions varied considerably across countries, with the largest declines in Ireland, England and Norway. In 3/21 countries, the prevalence of daily consumption decreased more strongly in the most affluent adolescents than in the least affluent ones ($P \leq 0.002$). Daily consumption was more prevalent among the least affluent adolescents in 11/21 countries in 2018 ($P \leq 0.002$). Diet soft drinks: overall, daily consumption decreased over time in 4/4 countries ($P_{\text{linear trends}} \leq 0.002$), more largely among the most affluent adolescents in 1/4 country ($P \leq 0.002$).

Conclusions Daily consumption of sugary and diet soft drinks in European adolescents decreased between 2002 (2006 for diet drinks) and 2018. Public health interventions should continue discouraging daily soft drink consumption, particularly among adolescents from lower socioeconomic groups.

Keywords Trend analysis · Sugary soft drinks · Sugar-sweetened beverages · Sodas · Diet soft drinks · Artificially sweetened beverages · Adolescents · Health Behaviour in School-aged Children study · Socioeconomic inequalities in health

Background

Sugar-sweetened beverages (SSBs) include sugary soft drinks (or regular sodas), fruit drinks, sports/energy drinks, and all other beverages with added sugar [1]. Sugary soft drinks are the most consumed type of SSBs [1, 2], with high intake contributing to childhood obesity [3, 4] and dental caries [5]. Adolescents and young adults are the largest consumers of SSBs worldwide [1, 6–9]. Recent research in the U.S. suggested that the intake of SSBs, especially sugary soft drinks, has been declining since the 2000s in almost all age groups, including adolescents [1, 10, 11]. The National Health and Nutrition Examination Survey also showed a decrease in the prevalence of young high SSB consumers (> 12 oz/day ≈ 350 mL) as well as an increase in non-consumers [10]. In Europe, the consumption of sugary soft drinks [12] and SSBs [12, 13] in adolescence varies considerably between western, northern, and southern regions, with information on time trends being limited: i.e. Nordic countries (decline between 2002 and 2010) [14] and Great Britain (rise between 1997 and 2008–2009) [15]. In addition, the comparability of European data is limited due to different periods of analysis and methodology in the assessment of SSB consumption. It also remains unclear

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Published online: 15 March 2022

whether changes in European adolescents' consumption of SSBs are also happening in high (daily) consumers.

The socioeconomic gradient in adolescent diets is more sizeable for SSBs than for other food groups [16]. In several European countries, adolescents with a lower parental socioeconomic position (SEP) are more likely to consume SSBs than those with a higher parental SEP [17–21]. In the U.S., large and persistent socioeconomic inequalities in SSB consumption have been documented in children aged 2 to 18 years [22]. In Europe, few studies have investigated how socioeconomic differences in SSB consumption have changed over time [14, 23]. In addition, cross-national comparisons are limited due to heterogenous SEP indicators between studies (e.g. education vs. income). Yet, assessing trends in SSB consumption by SEP groups is needed as socioeconomic inequalities in diet and obesity have persisted or even risen in the last decades [24–26].

Investigating whether sugary soft drinks have been replaced by diet soft drinks, also called artificially sweetened or sugar-free beverages (< 1 kcal/100 mL), is useful because there is no clear evidence that replacing sucrose with low-calorie sweeteners has a beneficial impact on appetite regulation, weight management nor glucose homeostasis in children [27, 28]. Sales and consumption of diet soft drinks have increased globally [29, 30]. However, little is known about European trends in diet soft drink consumption [15, 30], especially among children and adolescents [15]. In addition, data on potential associations between SEP and diet soft drink consumption in Europe are scarce and inconsistent [20, 31–33].

In its reports 'Ending childhood obesity' [34] and 'Closing the gap in a generation' [35], the World Health Organization (WHO) recommends a large set of actions to reduce SSB consumption and promote health equity. Comparing cross-national trends in consumption of sugary and diet soft drinks is thus relevant for policy stakeholders, whereby variations in trends might reflect national differences in public health interventions [36]. Analyses of trends in high-risk and vulnerable populations (e.g. adolescents, large consumers, lower SEP groups) may also provide valuable knowledge on the possible influence of implemented policies or programs, and whether specific additional efforts are needed for these populations. The present study aims to assess time trends in the prevalence of daily consumption of sugary (2002–2018) and diet (2006–2018) soft drinks among adolescents in Western, Northern and Southern Europe, overall and according to family material affluence.

Methods

Study design, sampling and database

The 'Health Behaviour in School-aged Children' study (HBSC) is a large repeated cross-national survey developed under the aegis of the WHO Regional Office for Europe (http://www.hbsc.org/). HBSC aims at obtaining insights into health behaviours and well-being of adolescents aged 11, 13 and 15 years. Since 1986, the school-based survey has been conducted every 4 years [37]. The most recent survey (2018) involved 47 countries or regions of Europe and Canada. Samples were nationally representative: national teams conducted sampling stratification by geo-political units and/or school type and randomly selected one or several classes by school [37]. Data were collected via self-administered anonymous questionnaires, standardised across countries, and translated into national language(s). Pupils completed the questionnaire in the classroom after receiving standardised instructions from teachers or research assistants [37]. Participation rates varied across countries and were higher at the pupil than at the school levels (e.g. 2018 school rates: ≥ 60% in 9/21 countries and pupil rates: ≥ 80% in 12/20 countries, no data in Iceland) [38]. HBSC data managers check data quality and merge national files into international datasets [37].

Selection of countries

For this study, we used data from the five most recent surveys: 2002, 2006, 2010, 2014 and 2018. The question on sugary soft drinks was mandatory in all countries, whereas the question on diet soft drinks was optional and introduced as of 2006 [37]. We included 21 countries from Western ($n = 12$), Northern ($n = 5$) and Southern ($n = 4$) Europe (classification from [39]) with data on sugary soft drink consumption available for at least four consecutive years. Among them, four countries also had data over three consecutive years on diet soft drinks: Belgium (Flemish), Belgium (French), Ireland and Wales. Sizes and characteristics (i.e. % girls, mean age) of samples with available data on sugary and diet soft drinks are presented by country and survey year in Supplementary Files 1 and 2, respectively.

Consumption of soft drinks

The consumption of sugary and diet soft drinks was assessed via a validated food frequency questionnaire (FFQ), including 4 mandatory items (i.e. vegetables, fruit, sugary soft drinks and sweets) and up to 15 additional optional items [40]. The general question was 'How many times a week do you usually eat or drink …?' and the food items analysed in this study were: 'Coke® or other soft drinks that contain sugar' and 'Diet Coke® or diet soft drinks?'. Local examples of common brands could be added in brackets to enhance question understanding. Thus, the HBSC FFQ focussed on soft drinks (carbonated and noncarbonated sodas) and not on other types of SSBs (e.g. fruit drinks, sports/energy drinks). Pupils could tick one possible answer among 'never', 'less than once a week', 'once a week', '2–4 days a week', '5–6 days a week', 'once a day, every day', and 'every day,

more than once' [37]. For this study, daily consumers were defined as those who ticked one of the last two answers. In the validation study among a similar sample of adolescents (aged 11 to 14 years, $n = 101$) in Belgium, agreement and gross misclassification for three weekly consumption frequency categories (i.e. 'once a week or less', '2–4 days a week' and '5 or more days a week') between the HBSC FFQ and a 7-day food diary were as follows: 50% and 10% for sugary soft drinks, and 65% and 21% for diet soft drinks [40].

Socioeconomic position

The Family Affluence Scale (FAS) is a validated proxy measure of household's material affluence [41–43]. During survey years 2002 to 2010, FAS consisted of the following four scored items: (1) 'Does your family own a car, van or truck?' (no = 0; 1 = 1; ≥ 2 = 2), (2) 'Do you have your own bedroom for yourself?' (no = 0; yes = 1), (3) 'How many computers do your family own (including laptops and tablets)?' (none = 0; 1 = 1; 2 = 2; > 2 = 3), (4) 'During the past 12 months, how many times did you travel away on vacation with your family?' (never = 0; 1× = 1; 2× = 2; ≥ 3 = 3). In 2014 and 2018, the question on holidays was refined to focus on abroad holidays and two questions were added: (5) 'How many bathrooms (room with a bath/shower or both) are in your home?' (none = 0; 1 = 1; 2 = 2; > 2 = 3), and (6) 'Does your family have a dishwasher at home?' (no = 0; yes = 1). To estimate the relative SEP of adolescents across different cross-national contexts and periods, totals of the individual FAS responses were ridit-transformed [37, 44]. Adolescents were ranked within each country, survey year, sex and age group to draw their ridit-score, ranging from 0 (lowest affluence) to 1 (highest affluence). Ridit-scores, previously applied in social inequality studies [45, 46], are based on cumulative probabilities. The ridit of the category i is the sum of the proportions (π) of individuals in each category below the category i (i.e. all having lower untransformed FAS) plus half the proportion of individuals in the category i itself [37, 44, 47]: $\text{Ridit}_i = \sum_{0 \le k < i} \pi_k + \frac{\pi_i}{2}$. To illustrate, if 2% of girls aged 11 years scored 0 in FAS (absolute affluence), their range would, therefore, be 0–0.02, and the ridit-score assigned would be 0.01 (= 0 + 0.02/2). Girls with a score of 1 comprising 6% of the population would result in a ridit-score of 0.05 (0.02 + 0.06/2), and so on. This procedure sets the mean score of ridit-transformed FAS at 0.5 (SD 0.28) in each country and survey year, disregarding cross-national and temporal differences in absolute material standards of living. We then classified participants into the lowest 20%, medium 60% and highest 20% affluent groups.

Statistical analysis

We excluded participants with missing data on sugary (0.9%, Supplementary File 3) or diet soft drinks (2.5%, Supplementary File 4). To correct for uneven sample distributions across survey years, the prevalence (%) of daily soft drink consumption (= proportion of daily consumers) was standardised for sex and age group, assuming a reference population of 50% of boys and girls and 33.3% of participants aged 11, 13 and 15 years, respectively. Absolute 16-year [12-year for diet soft drinks] differences in prevalence were calculated as follows: value in 2018–value in 2002 [2006]. Relative differences were computed as the absolute difference divided by the 2002 value [2006]. Geographical variations of these relative prevalence differences were mapped using the software QGIS® 3.10.7 (https://www.qgis.org/en/site/).

The dependent variable was daily consumption of sugary and diet soft drinks (coded 1 if frequency ≥ 1×/day and 0 if < 1×/day). Using the whole dataset (all countries together), we assessed whether the time trend was linear, quadratic or cubic and found that the overall trend was linear, despite a slightly larger decline between 2002 and 2006 than between 2006 and 2018. We eventually modelled a linear trend in the prevalence of daily consumption within each country to compare the overall national trends between 2002 and 2018. We applied multilevel logistic regressions, adjusting for sex and age groups, and using time as a continuous independent variable, scaled 1 to 5 [4 for diet soft drinks] to model the constant slope of change over time [48]. To assess how the socioeconomic differences in soft drink consumption have evolved over time (between 2002 [2006] and 2018, and not between each survey year), we computed multilevel logistic regressions applying an interaction term between FAS categories (lower, medium, higher affluence) and time (continuous). Models were adjusted for sex, age groups, survey years and FAS categories (all as dummy variables). After computing predictive margins, we plotted trends in prevalence (95% CI) of daily consumers by FAS categories and survey years [49]. For all multilevel models, we used a hierarchical two-level structure with a random intercept: the class of survey participants or the school when no data were available at the class level (median cluster size: 17). All statistical analyses were performed at the country level using STATA® version 15 (Stata Corp., College Station, TX, USA) and the commands *melogit* and *xtmelogit* (for *margins*). Statistical significance was set at $P \le 0.002$ due to multiple testing (Bonferroni correction: 0.05/21 for 21 countries).

Results

Sample characteristics

Table 1 shows an overview of the sample description across the five survey years and in total. Overall, age group and sex distributions were comparable across survey years for the 530,976 participants (21 countries) with available data on sugary soft drinks: 50.7% girls, and 33.4%, 34.6%, and 32.0% of 11-, 13-, and 15-year-olds. FAS was missing among 5.0% of participants (excluded from socioeconomic analyses). Similar characteristics were observed for the participants with data on diet soft drinks ($n = 61{,}487$, 4 countries, 50.1% girls, 33.8%, 33.9%, and 32.3% of 11-, 13-, and 15-year-olds, 7.8% missing FAS).

16-year trends in sugary soft drink consumption

In 2018, the age- and sex-standardised prevalence of daily sugary soft drink consumption (≥ 1×/day) ranged from 4.2% in Finland to 29.4% in French-speaking Belgium (Table 2). Overall, Northern Europe had lower proportions of daily consumers than Southern Europe and Western Europe. Between 2002 and 2018, proportions of daily consumers declined in all 21 countries with regards to absolute differences [range − 31.7 to − 3.4% points], relative differences [range − 84.8 to − 22.3%], and OR [range 0.57 to 0.96] (P for trends ≤ 0.002). Ireland underwent the sharpest decline, going from 37.4 to 5.7% of daily consumers (− 84.8%), followed by England (− 74.9%) and Norway (− 72.1%). Countries with the smallest decline between 2002 and 2018 were Austria (− 22.9%), French-speaking Belgium (− 22.6%), and France (− 22.3%). In the five Northern European countries, the prevalence of daily soft drink consumers was already low in 2002 (≤ 12.9%, except in Norway: 20.5%). Still, all five Northern countries experienced a large decline (relative differences: − ≥ 45.3%, except for Denmark: − 34.9%). As for Southern Europe, all four countries underwent a steady decrease in daily consumption, ranging from relative differences of − 47.6% in Italy to − 67.8% in Greece. Figure 1

Table 1 Description of all participants included in the analyses (daily consumers: ≥ 1×/day and non-daily consumers: < 1×/day), by survey year and overall, Health Behaviour in School-aged Children' study (2002–2018)

	2002	2006	2010	2014	2018	Total
Sugary soft drinks						
Included countries (*n*)	19	21	21	21	21	21
Included adolescents (*n*)	89,530	110,206	110,514	113,668	107,058	530,976
Sex (%)						
Girls	50.9	50.5	50.8	50.8	50.8	50.7
Age groups (%)						
11 years old	35.2	33.0	32.1	32.1	35.1	33.4
13 years old	34.1	34.7	34.3	34.8	35.0	34.6
15 years old	30.7	32.3	33.5	33.0	29.9	32.0
Family Affluence Scale (%)						
Lower	21.1	20.7	20.1	19.2	20.4	20.3
Middle	58.2	57.6	57.5	54.2	58.3	57.1
Higher	18.1	17.6	17.6	17.2	17.8	17.6
Missing	2.6	4.0	4.7	9.4	3.6	5.0
Diet soft drinks						
Included countries (*n*)		3	4	4	3	4
Included adolescents (*n*)		12,927	17,767	19,046	11,747	61,487
Sex (%)						
Girls		49.3	49.3	51.2	50.6	50.1
Age groups (%)						
11 years old		32.1	31.6	32.4	41.5	33.8
13 years old		34.5	36.2	33.6	30.2	33.9
15 years old		33.4	32.3	34.0	28.4	32.3
Family Affluence Scale (%)						
Lower		20.2	19.2	19.6	20.1	19.7
Middle		55.4	52.9	56.3	57.7	55.4
Higher		16.5	16.4	17.7	18.0	17.1
Missing		7.8	11.6	6.4	4.2	7.8

Table 2 Age- and sex-standardised prevalence of daily consumption of sugary soft drinks (≥ 1×/day), by survey year and by country, and linear trend between 2002 and 2018, by country

Country	Age- and sex-standardised prevalence of daily consumption					Difference between 2002 and 2018		Linear trend between 2002 and 2018[a]		
	2002 (%)	2006 (%)	2010 (%)	2014 (%)	2018 (%)	Absolute difference (% points)	Relative difference (%)	OR	95% CI	*P*-value (trend)
Western										
Austria	21.8	20.9	21.2	15.9	16.8	− 5.0	− 22.9	0.90	(0.87, 0.94)	< 0.001
Belgium (Flemish)	39.8	40.0	32.8	28.7	24.0	− 15.8	− 39.7	0.80	(0.78, 0.82)	< 0.001
Belgium (French)	38.0	30.8	28.5	36.3	29.4	− 8.6	− 22.6	0.96	(0.94, 0.98)	0.002
England	38.3	21.8	37.7	13.7	9.6	− 28.7	− 74.9	0.65	(0.62, 0.68)	< 0.001
France	29.0	26.7	26.7	26.0	22.5	− 6.5	− 22.3	0.92	(0.90, 0.94)	< 0.001
Germany	30.1	19.0	20.3	19.7	14.1	− 16.0	− 53.3	0.91	(0.88, 0.95)	< 0.001
Ireland	37.4	23.4	19.8	11.1	5.7	− 31.7	− 84.8	0.57	(0.54, 0.59)	< 0.001
Luxembourg		27.4	29.6	27.5	22.6	− 4.8[b]	− 17.5[b]	0.91	(0.88, 0.95)	< 0.001
Netherlands	43.8	36.2	30.2	25.6	17.4	− 26.4	− 60.3	0.72	(0.70, 0.74)	< 0.001
Scotland	47.2	28.4	21.3	22.5	16.6	− 30.6	− 64.8	0.70	(0.67, 0.72)	< 0.001
Switzerland	32.4	25.2	26.9	26.7	20.2	− 12.2	− 37.6	0.88	(0.86, 0.90)	< 0.001
Wales	36.6	28.7	23.8	19.8	18.0	− 18.6	− 50.8	0.78	(0.76, 0.80)	< 0.001
Northern										
Denmark	9.9	9.4	7.5	5.9	6.4	− 3.4	− 34.9	0.86	(0.82, 0.90)	< 0.001
Finland	7.6	5.3	4.4	2.7	4.2	− 3.5	− 45.3	0.78	(0.74, 0.82)	< 0.001
Iceland		11.6	8.4	4.6	4.0	− 7.6[b]	− 65.3[b]	0.65	(0.62, 0.68)	< 0.001
Norway	20.5	12.4	10.1	6.0	5.7	− 14.8	− 72.1	0.67	(0.64, 0.70)	< 0.001
Sweden	12.9	6.5	6.3	5.0	4.8	− 8.1	− 62.7	0.75	(0.72, 0.79)	< 0.001
Southern										
Greece	18.4	15.0	9.7	4.8	5.9	− 12.5	− 67.8	0.67	(0.64, 0.70)	< 0.001
Italy	24.4	28.4	19.3	16.2	12.8	− 11.6	− 47.6	0.79	(0.76, 0.82)	< 0.001
Portugal	33.4	26.0	21.8	17.1	14.8	− 18.6	− 55.7	0.76	(0.73, 0.78)	< 0.001
Spain	30.1	22.9	21.5	19.3	13.2	− 16.9	− 56.2	0.80	(0.78, 0.82)	< 0.001

[a]Time trends estimated by multilevel logistic models adjusted for sex and age groups. The presented odds ratios are for the variable time, coded as a continuous variable to assess linear trends between 2002 and 2018

[b]Differences between 2006 and 2018 (no data in 2002)

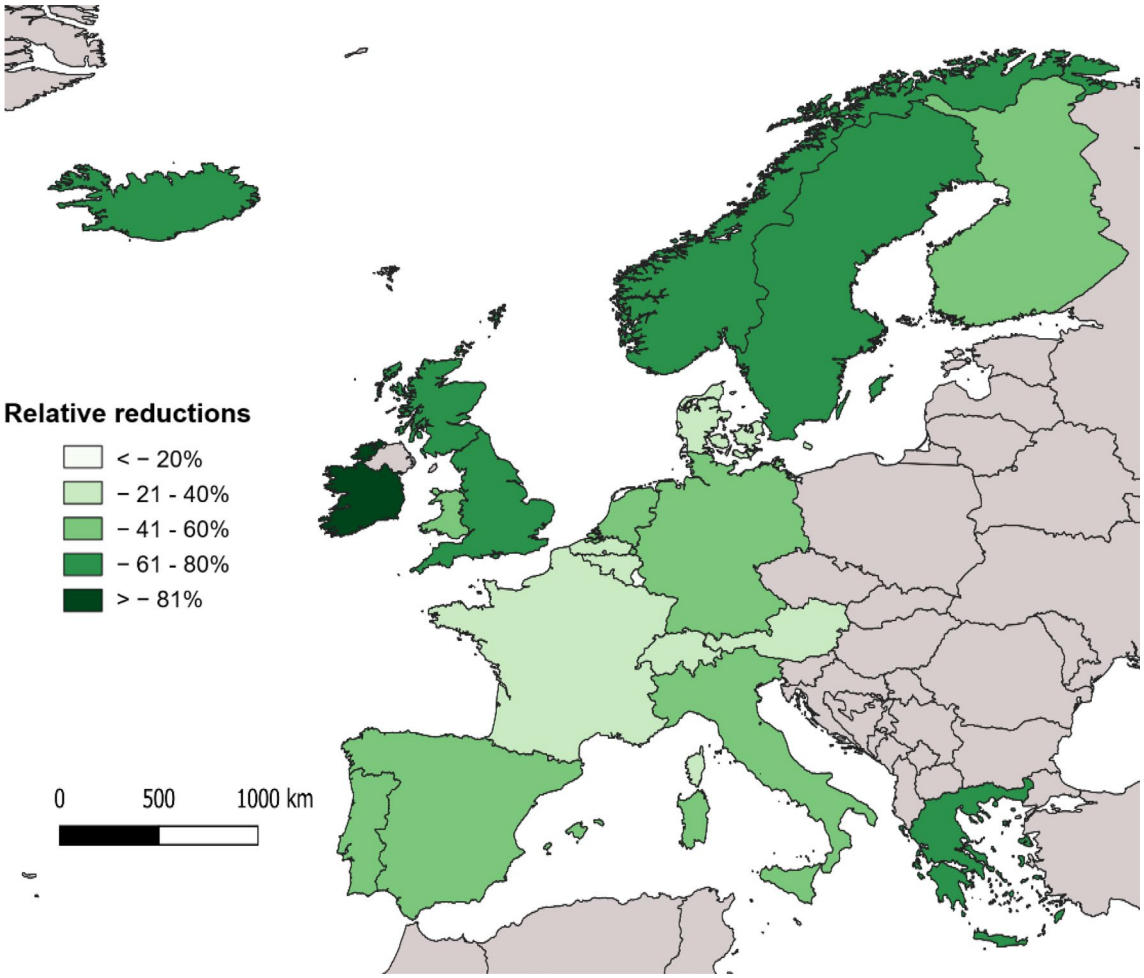


Fig. 1 Map of Europe showing the relative declines in the prevalence of daily consumers of sugary soft drinks between 2002 (2006 for Luxembourg and Iceland) and 2018. Sharper declines are in darker green

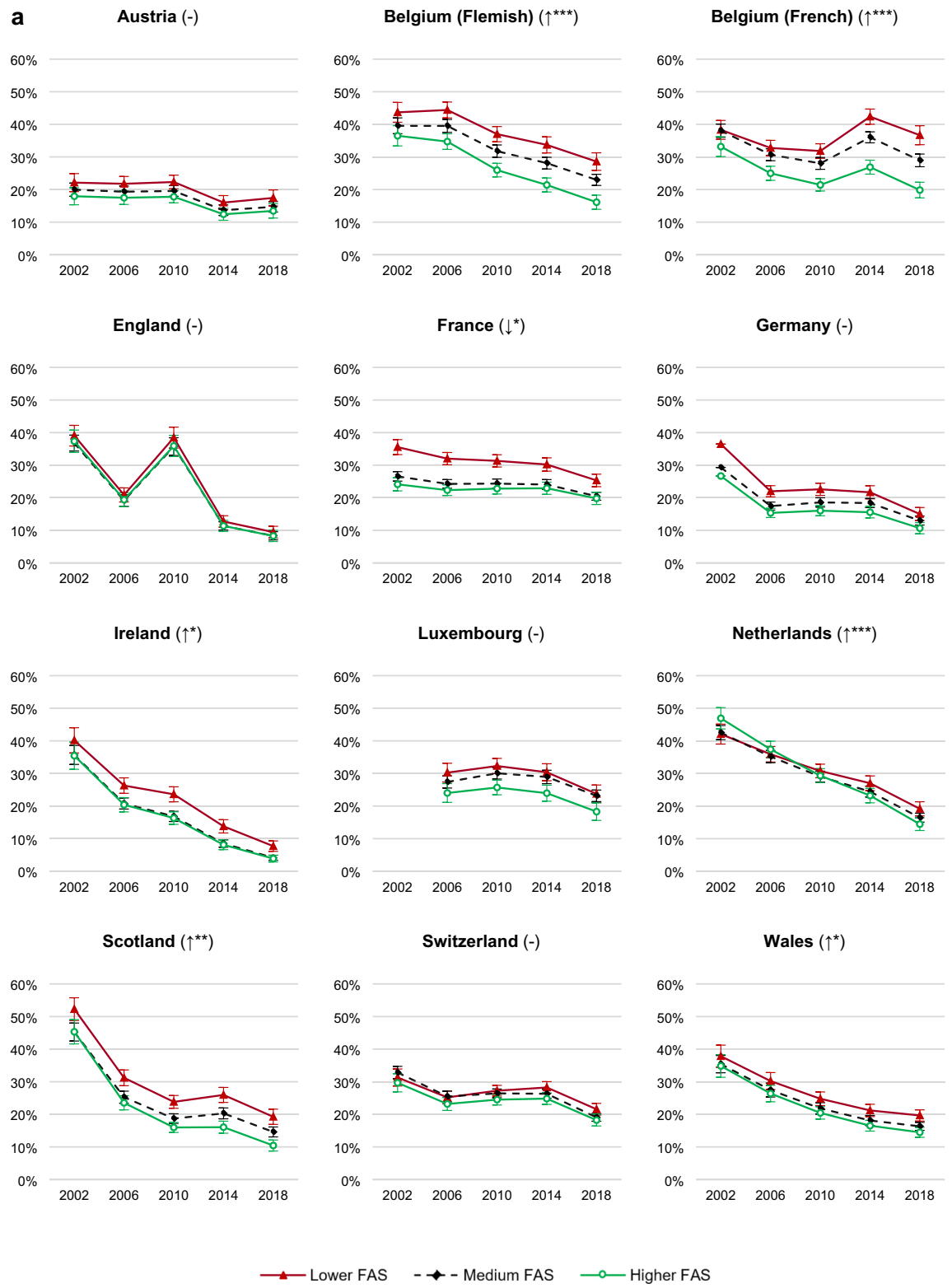
summarises cross-national variations in the relative reductions of daily consumers of sugary soft drinks.

Socioeconomic differences in sugary soft drink consumption

Figure 2a shows 16-year cross-national trends in the prevalence of daily consumption of sugary soft drinks according to material affluence in Western Europe. Proportions of pupils reporting daily consumption decreased more sharply among pupils living in the 20% most affluent families than among those living in the 20% least affluent ones in Flemish Belgium, French-speaking Belgium, and the Netherlands ($P<0.001$). The widening of socioeconomic differences in daily soft drink consumption was of a lower extent in Scotland ($P=0.004$), Ireland, and Wales ($P<0.05$). By contrast, most improvements between 2002 and 2018 tended to be observed among adolescents of lower affluence in France ($P<0.05$). In Austria,

Fig. 2 **a** Trends in prevalence (95% CI) of daily consumers of sugary soft drinks, by country and by Family Affluence Scale (FAS) category in Western European countries (↓/↑ = decrease/increase in socioeconomic differences over time between the 20% most affluent vs. the 20% least affluent adolescents; interaction terms FAS × time: $^{*}P\leq0.05$, $^{**}P\leq0.01$, $^{***}P\leq0.001$, multilevel logistic models adjusted for sex, age groups, survey years and FAS categories; Germany 2002: 95% CI could not be established as no data available on clustering at the class nor school levels). **b** Trends in prevalence (95% CI) of daily consumers of sugary soft drinks, by country and by Family Affluence Scale (FAS) category in Northern and Southern European countries (↑ = increase in socioeconomic differences over time between the 20% most affluent vs. the 20% least affluent adolescents; interaction terms FAS × time: $^{*}P\leq0.05$, $^{**}P\leq0.01$, $^{***}P\leq0.001$, multilevel logistic models adjusted for sex, age groups, survey years and FAS categories) ▶

England, Germany, Luxembourg, and Switzerland, no widening or narrowing of socioeconomic differences was seen. In 2018, socioeconomic inequalities were observed in 8/12 countries in Western Europe: Flemish Belgium, French-speaking


a
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Netherlands (↑***)
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Switzerland (-)
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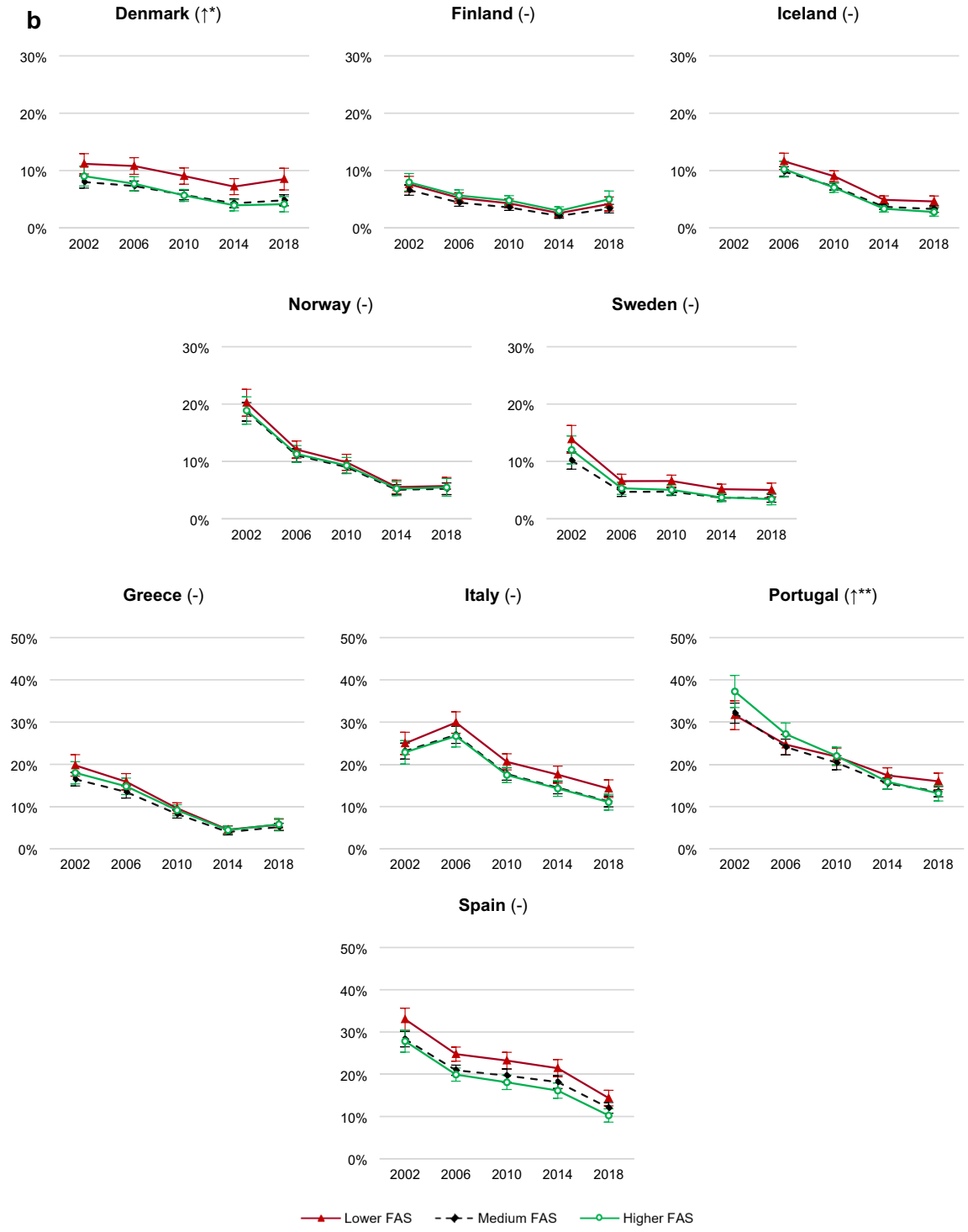

Fig. 2 (continued)

Belgium, France, Germany, Ireland, the Netherlands, Scotland, and Wales, where the 20% least affluent adolescents were more likely to report drinking sugary soft drinks daily than their most affluent pairs ($P \leq 0.002$, data not shown).

In Northern Europe (Fig. 2b), socioeconomic differences in daily sugary soft drink consumption tended to have increased between 2002 and 2018 only in Denmark ($P < 0.05$). In Southern Europe, socioeconomic differences in Italy and Spain persisted over time without widening

nor narrowing. Finally, in Portugal, social patterning has reversed over time: young people from higher affluence families were more likely to consume sugary soft drinks in 2002, but they tended to have reduced their consumption over time at a faster rate than those with lower affluence ($P = 0.003$). In 2018, socioeconomic inequalities in Southern and Northern Europe were observed in 3/9 countries: Denmark, Iceland, and Spain ($P \leq 0.002$ highest vs. lowest affluence, data not shown).

Analyses of trends in socioeconomic differences stratified by sex provided similar results (Supplementary File 5). Overall, increasing or decreasing differences were slightly more pronounced in boys than girls.

12-year trends in diet soft drink consumption

The prevalence of daily consumption of diet soft drinks ($\geq 1\times$/day) was lower than that of sugary soft drinks in all four countries (Table 3). All four countries experienced a decrease in the proportion of daily diet soft drink consumers [OR range 0.60 to 0.91] (P for trends < 0.001).

Socioeconomic differences in diet soft drink consumption

Figure 3 shows that socioeconomic differences in daily consumption of diet soft drinks increased in French-speaking Belgium ($P = 0.002$) and were likely to have increased in Ireland ($P = 0.011$). Pupils of higher affluent families were less likely to drink diet soft drinks over time than those of lower affluent families, leading to socioeconomic inequalities in 2018 in these two countries ($P \leq 0.001$, data not shown). In Flemish Belgium and Wales, the decline in daily consumption was similar among socioeconomic groups.

Discussion

Daily consumption of sugary soft drinks in adolescence declined between 2002 and 2018 in all 21 European countries. However, the extent of declines was heterogeneous across countries, and the prevalence of daily consumption of sugary soft drinks in 2018 remained elevated in Western Europe, compared to Southern and Northern Europe. A decline in daily consumption of diet soft drinks was also documented between 2006 and 2018 (four countries). Socioeconomic inequalities in sugary and diet soft drinks tended to increase over time in some countries.

Towards a reduction of SSB consumption

Our results indicating a decline in daily consumption of sugary soft drinks align with the overall decrease in SSB

Table 3 Age- and sex-standardised prevalence of daily consumption of diet soft drinks ($\geq 1\times$/day), by survey year and by country, and linear trend between 2006 and 2018, by country

Country	Age- and sex-standardised prevalence of daily consumption				Difference between 2006 and 2018		Linear trend between 2006 and 2018[a]		
	2006 (%)	2010 (%)	2014 (%)	2018 (%)	Absolute difference (% points)	Relative difference (%)	OR	95% CI	*P*-value (trend)
Belgium (Flemish)	16.9	13.1	12.0	11.6	− 5.3	− 31.5	0.85	(0.81, 0.89)	< 0.001
Belgium (French)	21.8	19.0	19.8	16.5	− 5.3	− 24.5	0.91	(0.87, 0.95)	< 0.001
Ireland		8.4	5.8	3.2	− 5.2[b]	− 62.3[b]	0.60	(0.54, 0.68)	< 0.001
Wales	19.1	13.9	11.7		− 7.3[c]	− 38.4[c]	0.74	(0.69, 0.79)	< 0.001

[a]Time trends estimated by multilevel logistic models adjusted for sex and age groups. The presented odds ratios are for the variable time, coded as a continuous variable to assess linear trends between 2006 and 2018

[b]Differences between 2010 and 2018 (no data in 2006)

[c]Differences between 2006 and 2014 (no data in 2018)

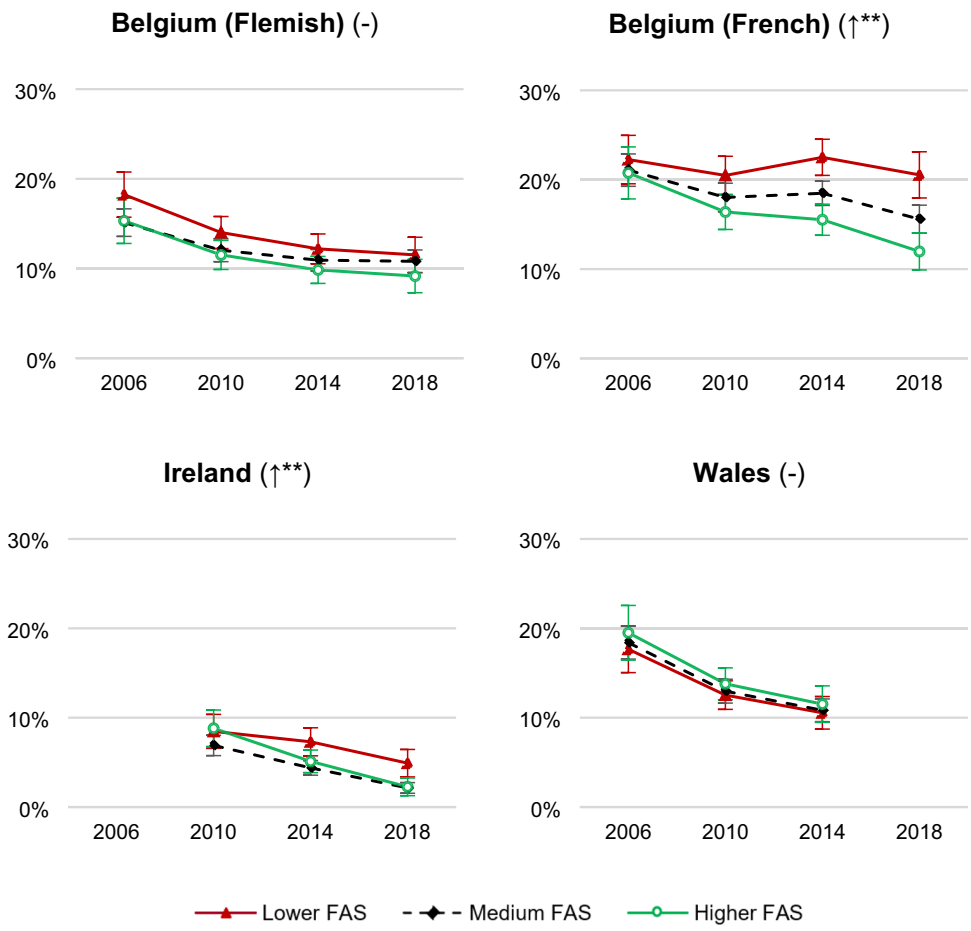

Fig. 3 Trends in prevalence (95% CI) of daily consumers of diet soft drinks, by country and by Family Affluence Scale (FAS) category in European countries (↑ = increase in socioeconomic differences over time between the 20% most affluent vs. the 20% least affluent adolescents; interaction terms FAS × time: $*P \leq 0.05$, $**P \leq 0.01$, $***P \leq 0.001$, multilevel logistic models adjusted for sex, age groups, survey years and FAS categories)

consumption observed in Western European adults between 1990 and 2010 (about − 10 mL/day) [1, 6]. Similarly, U.S. adolescents also reduced their consumption of sugary soft drinks (sodas): 2003–2004 mean intake was 169 kcal/day (representing 59% of calories from all types of SSBs) and went down to 76 kcal/day in 2013–2014 (43% of total SSBs) [1]. It is worthy to note that the intake of fruit drinks also linearly declined between 2003 and 2014 (17% of total SSBs in 2013–2014), conversely to sports drinks (11%) and other SSBs (29%, e.g. coffee and tea with added sugar, low-calorie SSBs) that remained relatively stable over time, despite some biennial fluctuations [1].

In European adolescents specifically, data are less detailed. The German DONALD study identified a decline in free sugar intake from SSBs between 1995 and 2016 [50]. In Great Britain, the average daily intake of SSBs in adolescents slightly increased between 1997 and 2008–2009 (from 119 to 131 kcal/day) [15] and then decreased between 2008–2009 and 2016–2017 (from 285 to 185 g/day) [21], according to the National Diet and Nutrition Survey. This indicates a potential turning point in SSB consumption that may have occurred in 2008–2009 and could reflect our data for English adolescents showing a drop in daily consumers of sugary soft drinks in 2006 followed by an increase in 2010 (Table 2). Importantly, all mentioned studies used quantitative intake data (in mL or kcal/day) derived from more robust dietary assessment methods than ours (i.e. consumption frequency with a focus on one type of SSBs).

The downward trend observed in sugary soft drink consumption is promising, considering food habits established in childhood tend to continue later in life [51]. Several hypotheses may explain this overall reduction in Europe. The implementation of school-based nutrition education programs and food policies (e.g. reduced availability of SSBs and facilitated access to water) have proven to be effective [52], in particular when they are combined [52, 53]. Other population-based interventions, such as media campaigns, traffic-light-labelling or taxation of SSBs, may have also played a role [36, 53]. Further analyses at the national level should be undertaken to better understand the reasons (1) for sharper declines in some countries (especially Ireland, England and Norway) and (2) for the continuous elevated consumption in nine countries, with one in six pupils still reporting drinking SSBs every day in 2018.

Increasing socioeconomic inequalities in SSB consumption

In the U.S., declines in sugary soft drink (soda) consumption were documented in non-Hispanic White, Black and Hispanic adolescents, with smaller reductions observed in Non-Hispanic Blacks, compared to Whites after 2009–2010 [22]. To our knowledge, no other studies in Europe investigated trends over time of socioeconomic differences in adolescent SSB consumption, except those using national HBSC data [14, 23]. In 2002, international HBSC data showed no associations between daily soft drink consumption and lower material affluence (untransformed FAS tertiles) in Western, Southern and Northern countries, except in France [17]. Sixteen years later, our study shows that socioeconomic inequalities in soft drink consumption were observed in 11/21 countries, including Belgium (French and Flemish), Germany and Spain, but not Italy nor Sweden. By comparison, 2007–2008 data of the international IDEFICS study among 2-to-9-year-olds documented a significant association between lower parental education level and larger weekly consumption frequency of SSBs also in Belgium, Germany and Spain (plus Italy) and no inequalities in Sweden either [54].

Increasing socioeconomic inequalities may indicate that public health interventions produced most benefits in families from higher socioeconomic levels. Literature shows that individuals with higher SEP tend to gain more from population-based interventions targeting individual behavioural change (e.g. education programs, media campaigns) [55–58]. By contrast, more recent structural efforts, such as limiting physical access to SSBs in schools or taxation of SSBs [52, 53, 59], may reduce socioeconomic inequalities in SSB intake among adolescents. Once again, further investigations at the country level are needed.

Trends in diet soft drink consumption

In a time of decreasing SSB intake, monitoring the consumption of possible substitution drinks is of great interest. As we documented a decline in daily consumption of diet soft drinks in the four countries, we can assume that in these countries, diet soft drinks did not particularly act as a substitute to sugary soft drinks. A decline in daily adolescent consumption of diet soft drinks was not anticipated. Popkin et al. found a steady increase in sales of diet (sugar-free) beverages in Western Europe between 2000 and 2014 [30]. This may suggest that consumption has grown in other populations than adolescents, possibly adults who are interested in healthy eating or weight control [32, 60–62]. European countries other than those analysed in this study may have also experienced a rise in diet soft drink consumption. To our best knowledge, data have only been published in Great Britain and demonstrated a decrease in mean diet soft drink intake per capita in 4- to 18-year-olds between 1997 (220 mL/day) and 2008–2009 (170 mL/day) [15]. A reduction in diet soft drink consumption was also observed in adults [1, 62] and children [1, 63] in the US after 2007–2010.

Associations between SEP and diet soft drink consumption

We found no other studies assessing trends in the associations between SEP and diet soft drink consumption in adults and children. Previous cross-sectional European data showed no consistent associations between artificially sweetened beverages consumption and SEP indicators in Norwegian adults in 2010–2011 [32], nor in Belgian young men in 2007 [33]. Negative associations between mother's education and diet soft drink consumption were documented in British 11-year-olds born in 2001 [31]. On the contrary, Drewnowski and Rehm found a positive association in U.S. adults: people with higher education or larger income drank more artificially sweetened beverages in 1999–2008 [62]. Such cross-national variations may be due to (1) differences in perceived costs of non-caloric drinks on a limited food budget or (2) differences in the perception of health benefits of consuming diet soft drinks instead of other caloric and non-caloric beverages [32, 60–62].

Strengths and limitations

The current study involved large nationally representative samples. HBSC methodology was standardised across survey years and countries, which allowed comparison of long-term trends in daily sugary and diet soft drink consumption in 21 countries. In addition, we used a cross-national homogeneous and validated indicator of SEP for adolescents [41–43].

The study also had some limitations. First, the HBSC FFQ focussed on soft drinks (sodas) without clearly mentioning other types of SSBs (e.g. fruit drinks, sports/energy drinks) and did not inform about the consumption of other drinks (e.g. water, 100% fruit juices). Second, there were no quantitative data on the usual intake of soft drinks (e.g. in mL/day). Of note, declines in the mean weekly frequency of sugary soft drink consumption were confirmed, with remarkably similar patterns (including peaks) observed. Absolute differences ranged from − 4.0×/week in Ireland to − 0.6×/week in Denmark (data not shown). Third, some countries collected data in different months across survey years. However, trends did not change after accounting for potential seasonal effects (data not shown), and observed peaks were not explained by seasonality, assuming larger consumption occurred in warmer months of data collection [64, 65]. Daily

consumers are probably less impacted by seasonality than occasional consumers, and data were primarily collected in cooler months of the school year: 71% of pupils were interviewed between October and April (only 6% between June and September). Fourth, the validity of the FFQ was moderate, with some risk of misclassification between daily and non-daily soft drink consumers [40]. We can, however, assume that misclassification remained constant over time. Fifth, although response rates at the pupil level remained high over time, response rates at the school level declined in some countries [14, 38, 66]. Supposing that schools already involved in health promotion actions are more likely to accept participating in HBSC surveys, there is a risk of overrepresenting pupils from the most favoured schools in the more recent samples. This could, in turn, have overestimated the reductions in daily soft drink consumers. Sixth, underreporting of sugary soft drink consumption might have risen over time due to increasing awareness of their implication in the obesity epidemic (increased risk of social desirability bias) [67, 68]. Finally, FAS only reflects one dimension of SEP, i.e. household material affluence. Socioeconomic differences might have been more pronounced if parental education or occupation were used instead of FAS, as previously shown in a study using both FAS and parental occupation in a limited number of countries from the 2002 HBSC international dataset [17]. Since parental education or occupation were not measured in HBSC every survey year and every country, trend analyses using these indicators were not possible for this study. FAS also changed between 2010 and 2014, increasing the risk of missing values with the addition of two new items. Furthermore, the material value of the single score components, such as computers, may have changed between 2002 and 2018 [69].

Conclusions

Since the 2000s, daily consumption of sugary and diet soft drinks among adolescents aged 11 to 15 years has declined in Western, Northern and Southern Europe. Particular attention should be made to public health policies and programs implemented in Ireland, England and Norway, as these countries experienced the largest declines. Another important finding from this study is that socioeconomic inequalities in the daily consumption of sugary soft drinks tend to have increased between 2002 and 2018. Understanding why Northern Europe has fewer daily adolescent consumers of sugary soft drinks and lower socioeconomic inequalities is essential in terms of policy implications and requires further investigation. In conclusion, this paper provides a valuable comparison of cross-national trends in sugary and diet soft drink consumption to evaluate the initiatives addressing adolescent nutrition over the last 2 decades and for future planning.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00394-022-02851-w.

Acknowledgements HBSC is an international study carried out in collaboration with World Health Organization Regional Office for Europe. The International Coordinator was Jo Inchley (University of Glasgow) for the 2018 survey and Candace Currie (Glasgow Caledonian University) for the 2002 to 2014 surveys. The Data Bank Manager was Professor Oddrun Samdal (University of Bergen). The survey data included in this study were conducted by the following principal investigators in the 21 countries or regions: Austria (Rosemarie Felder-Puig and Wolfgang Dür), Flemish Belgium (Maxim Dierckens, Bart De Clercq, Carine Vereecken, Anne Hublet, and Lea Maes), French-speaking Belgium (Katia Castetbon, Isabelle Godin and Danielle Piette), Denmark (Mette Rasmussen and Pernille Due), England (Fiona Brooks, Ellen Klemera, and Antony Morgan), Finland (Jorma Tynjälä), France (Emmanuelle Godeau), Germany (Matthias Richter, Petra Kolip, Ulrike Ravens-Sieberer, and Klaus Hurrelmann), Greece (Anna Kokkevi), Iceland (Arsaell M. Arnarsson and Thoroddur Bjarnason), Ireland (Saoirse Nic Gabhainn and Michal Molcho), Italy (Franco Cavallo and Alessio Vieno), Luxembourg (Helmut Willems, Bechara Ziade and Yolande Wagener), the Netherlands (Gonneke Stevens, Saskia van Dorsselaer, Wilma Vollebergh, and Tom de Bogt), Portugal (Margarida Gaspar de Matos), Scotland (Jo Inchley and Candace Currie), Spain (Carmen Moreno), Sweden (Petra Löfstedt, Lilly Augustine, and Ulla Marklund), Switzerland (Marina Delgrande-Jordan, Hervé Kuendig, Emmanuel Kuntsche, and Holger Schmid), and Wales (Chris Roberts). For details, see http://www.hbsc.org. We thank Pierre-Alexandre Fonta for his support in interpreting the ridit-transformation formula. We thank Emma Holmberg for proofreading the article and correcting English grammar.

Author contributions AC and KC conceived and designed the manuscript. AC defined the methodology, analysed the data, and drafted the manuscript under the supervision of KC. All the co-authors reviewed the manuscript, provided critical recommendations, and approved the final manuscript.

Funding HBSC is an international survey carried out in collaboration with the World Health Organization Regional Office for Europe. The data collection for each HBSC survey is funded at the national level. The work related to this paper was possible thanks to financial support by the University of Lausanne, Switzerland (UNIL/CHUV mobility fellowship) and academic support by the Université libre de Bruxelles, Belgium, for AC's postdoctoral fellowship. The funders had no role in the analysis, decision to publish, or preparation of the manuscript.

Availability of data and materials HBSC data and questionnaires can be accessed via a request to the HBSC Data Management Centre: dmc@hbsc.org. For further information, see http://www.uib.no/en/hbscdata.

Code availability Codes are available upon request.

Declarations

Conflict of interest AC, TL, MR, CK, ASF, MK, AD and KC declare no conflicts of interests.

Ethics approval/consent to participate Data collection was anonymous, and no directly identifiable information on pupils was collected. Ethical consent to conduct the HBSC survey was obtained by national teams

from the appropriate local/institutional ethics committee(s). In most countries, parental consent was passive. An information letter was sent out before data collection informing parents/carers about the survey and providing an opt-out response sheet if they did not want their child to take part in the study. Consent was also obtained by pupils, who were reminded verbally and in writing that participation was voluntary.

Consent for publication Not applicable.

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