International Journal of Public Health (2020) 65:607–616
https://doi.org/10.1007/s00038-020-01342-1

ORIGINAL ARTICLE

Trends in social inequality in overweight and obesity among adolescents in Denmark 1998–2018

Mette Rasmussen[1] · Mogens Trab Damsgaard[1] · Camilla Schmidt Morgen[1] · Lene Kierkegaard[1] · Mette Toftager[1] · Stine Vork Rosenwein[1] · Rikke Fredenslund Krølner[1] · Pernille Due[1] · Bjørn Evald Holstein[1]

Received: 16 November 2019 / Revised: 16 January 2020 / Accepted: 12 February 2020 / Published online: 20 February 2020

Abstract

Objectives The aim was to analyze trends in overweight and obesity in relation to socioeconomic position among Danish adolescents in the 20-year period 1998–2018.

Methods The study used data on self-reported height and weight and parents' occupational social class (OSC) from 11-, 13- and 15-year-old schoolchildren in 1998, 2002, 2006, 2010, 2014 and 2018, n = 22,177. The analyses included absolute social inequality in overweight/obesity (prevalence difference between low and high OSC) and relative social inequality (OR for overweight/obesity).

Results In the total sample, the prevalence of overweight and obesity was 9.7% and 1.4%, respectively, with significantly higher prevalence in low than high OSC. There were significantly increasing trends in both overweight and obesity 1998–2018 in low OSC and no significant increase in high OSC. The OR for overweight was 1.59 (1.42–1.74) in middle and 2.16 (1.89–2.46) in low OSC, OR for obesity 1.74 (1.29–2.34) in middle and 2.97 (2.15–4.11) in low OSC. Associations were not modified by survey year.

Conclusions There was a persistent absolute and relative social inequality in overweight and obesity 1998–2018 among Danish adolescents.

Keywords Adolescents · HBSC · Obesity · Overweight · Social inequality · Socioeconomic status · Trend study

Introduction

In many countries, overweight and obesity is now one of the most significant public health problems (Ng et al. 2014; Seidell and Halberstadt 2015). Studies over time show that trends in overweight and obesity vary across national settings (Ahluwalia et al. 2015). It is important to monitor developments in prevalence levels over time so that changes in the magnitude of the problem can be estimated, and to evaluate whether national level health promotion initiatives have reached the intended effect. However,

✉ Bjørn Evald Holstein
bho@sdu.dk

Mette Rasmussen
mera@sdu.dk

Mogens Trab Damsgaard
trab@sdu.dk

Camilla Schmidt Morgen
casm@sdu.dk

Lene Kierkegaard
leki@sdu.dk

Mette Toftager
mtoftager@health.sdu.dk

Stine Vork Rosenwein
stvr@sdu.dk

Rikke Fredenslund Krølner
rikr@sdu.dk

Pernille Due
pdu@novo.dk

[1] National Institute of Public Health, University of Southern Denmark, Studiestræde 6, 1455 Copenhagen, Denmark

overweight and obesity do not occur evenly within populations, and trends at the general population level may not reflect patterns in subgroups. Monitoring trends in overweight and obesity therefore needs to differentiate between groups of varying risk.

Many studies show that low socioeconomic position (SEP) is a key risk factor, not only among adults (e.g., Jaacks et al. 2019), but also in child and adolescent populations (Shrewsbury and Wardle 2008; Wang and Lim 2012). Still, varying socioeconomic patterns of child and adolescent overweight and obesity are observed across different national settings. A cross-national study of social inequalities in adolescent overweight in 35 countries found higher overweight prevalence levels among children from less affluent families in most Western European countries and many Central European countries. In Croatia, Estonia and Latvia and among boys in Poland, Lithuania, Macedonia and Finland, the overweight prevalence was highest among adolescents living in more affluent families (Due et al. 2009). Data from the WHO European Childhood Obesity Surveillance Initiative collected in 2008 among children aged 6.5 to 7.5 in five countries showed that in Sweden and Portugal the prevalence was highest in children living in low SEP families, while in Bulgaria and Lithuania the highest prevalence levels were observed in high SEP families. In the Czech Republic, no clear association was seen (Lissner et al. 2016). These national variations highlight the need for monitoring developments in overweight prevalence by SEP and at the national level.

A review by Chung et al. (2016) summarized 30 studies on trends in social inequality of overweight and obesity from 15 economically advanced countries and regions. Based on absolute measures of inequality they found that around half of the studies indicated widening social inequalities in overweight and obesity among children and adolescents. Chung et al. (2016) also found that less than ten percent of the studies reported after 2000 showed an overall increase in overweight and obesity but one-third demonstrated an increase in overweight and obesity prevalence among low SEP children and adolescents. They also conclude that socially differentiated trends in overweight and obesity may be masked in studies reporting trends for whole populations not stratifying by SEP. Studies published later than Chung et al. (2016) show varying findings. Based on measures of relative social inequality, two other studies confirm the finding of increasing social inequality in overweight among adolescents (Hardy et al. 2017; Elgar et al. 2015). Sigmund et al. (2018) finds increasing absolute social inequality in overweight among boys 2002–2014 and decreasing absolute social inequality among girls but no change in relative social inequality. A study by Inchley et al. (2017) demonstrated that the trend in social inequality in overweight varied by country.

Over the latest years, a levelling-off in overweight and obesity in children and adolescents has been observed in Denmark (Pearson et al. 2010; Morgen et al. 2013) as in other countries (NCD Risk Factor Collaboration 2017; Inchley et al. 2017; Ahluwalia et al. 2015; Chung et al. 2016). Only few Danish studies have examined trends by SEP. Møller et al. (2007) studied trends in BMI and overweight in 8–10-year-old Danish children from the community of Odense from 1997/98 to 2003/04 by parental occupation. They applied relative estimates of inequality and found a less favorable trend in BMI and overweight among children in low compared to high SEP families. Matthiessen et al. (2014) presents trends in overweight and obesity among a national sample of 4–14-year-old Danish children over the period 2000–2008. They found an increase in overweight prevalence among boys over the study period, while no significant changes were observed among girls and for obesity. The increase in overweight among boys covered an increase among boys of parents with low educational level and stable prevalence among boys of parents with medium and high educational level. To our knowledge, no trend studies based on more recent and longer spanning Danish data on child and adolescent overweight and obesity across SEP have been conducted.

Therefore, the aim of the present study is to analyze trends in overweight and obesity across SEP among 11–15-year-old Danish adolescents over a 20-year long period from 1998 to 2018 using parental occupational social class (OSC) as indicator of SEP. When the overall prevalence either increases or decreases over time, conclusions on changes in inequalities between subgroups may be in the opposite directions when based on absolute and relative measures (Harper et al. 2008; Houweling et al. 2007; Moonesinghe and Beckles 2015; Rasmussen et al. 2009). Both measures are important and should be addressed in studies of changing social inequality. In the current study, trends in social inequalities in overweight and obesity are therefore assessed on both absolute and relative measures. From a public health point of view, absolute social inequality in overweight may be more relevant than relative social inequality. Absolute social inequality reflects the excess number of adolescents from lower socioeconomic strata who are overweight. A high relative social inequality in overweight may not be that important in a public health perspective if the prevalence of overweight and obesity is low.

Methods

Design and study population

Data come from the Danish contribution to the international Health Behaviour in School-aged Children (HBSC) study (Inchley et al. 2016). The study design was repeated,

comparable cross-sectional studies with similar procedures for sampling, data collection and measurements. Each survey selected a random sample of schools drawn from complete lists of all public and private schools in Denmark. Each survey included schoolchildren in the fifth, seventh and ninth grade, corresponding to the age groups 11-, 13- and 15-year-olds. The current study comprised data from the HBSC surveys in 1998, 2002, 2006, 2010, 2014 and 2018. The response rate for the full study population was 87.7%, N = 30,068. After exclusion of participants with missing data on weight status and OSC, the final N was 22,177 (Table 1).

Data collection and measurements

The students completed the internationally standardized HBSC questionnaire in the classroom (Roberts et al. 2009). Weight status was based on self-reported weight and height measured by the items: "How much do you weigh without clothes?" and "How tall are you without shoes?" Body mass index (BMI = kg/m^2) was estimated and the international standardized age- and sex-specific BMI cutoff points proposed by Cole and Lobstein (2012) to define weight status into overweight (overweight and obesity combined, hereafter labeled overweight) and obesity. Self-reports of height and weight may result in misclassification of BMI and overweight (e.g., Elgar et al. 2005; Pérez et al. 2015). A previous validation study among 11-, 13- and 15-year-olds was conducted as a supplement to the Danish HBSC study. This documented an underestimation of weight among both boys and girls and an overestimation of height among boys, resulting in an underestimation of the overweight prevalence of 4.67 and 6.64 percentage points among boys and girls, respectively (Rasmussen et al. 2013).

Parents' OSC was measured by the items: "Does your father (mother) have a job?" "If yes, please write exactly what job he (she) does." "Please say in what place he (she) works." We coded the responses according to the Danish Occupational Social Class measurement from I (high) to V (low). A category VI was added, including parents outside the labor market who receive unemployment benefits, disability pension or other kinds of transfer income (Christensen et al. 2014). Each participant was categorized by the highest ranking parent into high (I–II), middle (III–IV) and low (V–VI) OSC. The coding procedure was similar in all six surveys. Jobs change over time but the applied OSC measure categorized occupations by two general features which are more stable than occupations, namely required educational qualifications and the control (over capital or people) connected with the occupation. Several studies have demonstrated that adolescents in the age group included in this study are able to report their parents' occupation with a fair validity (Lien et al. 2001; Pu et al. 2011; Pueyo et al. 2007; West et al. 2001) and that OSC is an appropriate SEP indicator in studies of adolescents (Pförtner et al. 2015).

Statistical analyses

Initial analyses separated boys and girls. The prevalence of overweight and the association between OSC and overweight were so similar that we decided to pool boys and

Table 1 Study population by survey year, sex, age group, occupational social class (OSC), overweight and obesity

	1998	2002	2006	2010	2014	2018	Total
Response rate[a] (%)	89.9	89.3	88.8	86.3	85.7	84.8	87.7
N	5205	4824	6269	4922	4534	4314	30,068
N included in this study	4193	3828	4264	3454	3687	2751	22,177
Percent boys	49.6	47.9	48.8	48.2	48.4	49.7	48.7
Percent girls	50.4	52.1	51.2	51.9	51.6	50.4	51.3
Percent 11-year-olds	32.4	34.1	34.5	34.5	29.5	33.6	33.6
Percent 13-year-olds	35.0	33.2	36.3	33.5	35.3	34.8	34.8
Percent 15-year-olds	32.6	32.7	29.2	32.0	35.2	31.6	31.6
Percent high OSC	28.5	25.4	28.8	40.0	42.7	43.7	34.1
Percent middle OSC	49.6	54.2	48.9	42.3	41.2	44.4	47.1
Percent low OSC	21.9	20.4	22.2	17.7	15.8	11.9	18.8
Percent overweight[b,c]	7.6	11.3	10.1	9.7	8.9	10.9	9.7
Percent obese[b]	0.8	1.3	1.8	1.8	1.4	1.3	1.4

Data from the Health Behaviour in School-aged Children study in Denmark 1998, 2002, 2006, 2010, 2014 and 2018

[a]Number of participants as percentage of schoolchildren enrolled in the participating classes

[b]Sex- and age-standardized prevalences

[c]Overweight including obese

girls. The reported prevalence levels of overweight and obesity are standardized by sex and age groups. We used chi-square test for differences among groups and Cochran–Armitage test for trend to study time trends in prevalence of overweight and obesity. We analyzed social inequality in two ways: (1) Absolute social inequality calculated as prevalence difference in overweight and obesity between low and high OSC. (2) Relative social inequality, i.e., odds ratio (OR) for overweight and obesity from multilevel logistic regression analysis with high OSC as reference group, adjusted for sex, age group and survey year and a final model with inclusion of an interaction product (survey year * OSC). The multilevel models accounted for the applied cluster sampling (PROC GLIMMIX in SAS). The first regression analyses were conducted for boys and girls separately. These showed similar associations for boys and girls, so all subsequent analyses combined boys and girls.

Sensitivity analyses

The HBSC study includes one other indicator of socioeconomic background, the Family Affluence Scale (FAS) (Currie et al. 2008). FAS summarizes data on four kinds of consumer goods: family cars, child having own bedroom, and number of computers and family vacations, range 0–7 points categorized as low (0–3 points), medium (4–5 points) and high (6–7 points). As a sensitivity analysis, we studied the association between FAS and overweight.

Ethical issues

The international HBSC research protocol specifies ethical principles for data collection and protection. There is a request for careful information of participating schools, parents and children, for securing the participating children's confidentiality and for parental and child consent. Further, the study should follow national guidelines on these issues. In Denmark, there is no formal agency for approval of questionnaire-based surveys. In order to obtain approval and consent, we asked the school board as the parents' representative, the headmaster, and the students' council in each of the participating schools to approve the study. The participants received oral and written information that participation was voluntary, and that data were treated confidentially. The study complies with national standards for data protection. From 2014, the Danish Data Protection Authority has requested notification of such studies and has granted acceptance for the 2014 survey (Case No. 2013-54-0576) and the 2018 survey (Case 10 622, University of Southern Denmark).

Results

The combined study population from all years included 48.7% boys and 51.3% girls. The age groups were almost equally distributed with 33.6% 11-year-olds, 34.8% 13-year-olds and 31.8% 15-year-olds. The proportions of high, middle and low OSC were 34.1%, 47.1% and 18.8%. The sex- and age-standardized prevalence of overweight in the total sample was 9.7% and the prevalence of obesity was 1.4% (Table 1). The prevalence of overweight was slightly higher among boys than girls (10.4 vs. 8.9%), and the prevalence of obesity was similar (1.4%) among boys and girls (not shown in table).

Table 2 shows the sex- and age-standardized prevalence of overweight by OSC in the entire study population: 6.7% in high, 10.3% in middle and 13.4% in low OSC (chi^2-test, $p < 0.001$). This social gradient was similar among boys and girls. The prevalence of overweight among 3198 students with missing information about OSC was 10.3% (not shown in table, not included in the analyses). Separately for each survey year, Table 2 also presents the prevalence of overweight in high, middle and low OSC and the absolute social inequality in overweight by percent point difference between low and high OSC. The absolute social inequality in overweight was statistically significant in all survey years. The changes in overweight prevalence over time are illustrated in Fig. 1. Analyses of trends in overweight by the three occupational classes showed no significant trend in high OSC ($p = 0.256$) but significantly increasing trends in middle OSC ($p = 0.006$) and low OSC ($p = 0.006$). The prevalence differences between low and high OSC suggest that there was a persistent absolute social inequality in overweight of 1998–2018 of about 6.6%.

Table 2 also shows the relative measures of inequality as OR for overweight by OSC for the entire study population and by survey year. In the entire study population, the OR for overweight was 1.59 (1.42–1.74) in middle versus high OSC and 2.16 (1.89–2.46) in low OSC versus high OSC. The corresponding OR estimates for boys were 1.51 (1.30–1.75) and 2.04 (1.71–2.43) and for girls 1.68 (1.43–1.99) and 2.20 (1.82–2.66). The analyses stratified by survey year showed a similar pattern, suggesting no modifying effect of survey year. This was supported by a nonsignificant statistical interaction term between OSC and survey year ($p = 0.320$).

Table 3 presents the results for obesity. In the entire study population, the prevalence of obesity in high, middle and low OSC was 0.9%, 1.4% and 2.4% ($p < 0.001$). This social gradient was similar among boys and girls. The prevalence of obesity among 3198 participants with missing information about OSC was 2.0% (not shown in Table 3, not included in the analyses). The prevalence of

Table 2 *Overweight (including obesity)* by occupational social class; sex- and age-standardized percentage and adjusted OR (95% CI) for overweight

Survey year	Absolute social inequality described by sex- and age-standardized percent (95% CI) with overweight					Relative social inequality described by OR (95% CI) for overweight[b]		
	Occupational social class					Occupational social class		
	High	Middle	Low	Total	Prevalence difference[a] (95% CI)	High	Middle	Low
1998 (n = 4193)	5.5	7.7	10.2	7.6	*4.7*	1	*1.42*	*2.05*
	(4.2–6.8)	(6.6–8.8)	(8–3–12.2)	(6.8–8.4)	*(2.4–7.1)*		*(1.06–1.92)*	*(1.47–2.86)*
2002 (n = 3828)	7.6	12.0	13.9	11.3	*6.3*	1	*1.65*	*1.93*
	(6.0–9.3)	(10.6–13.4)	(11.5–16.3)	(10.3–12.3)	*(3.3–9.2)*		*(1.26–2.17)*	*(1.40–2.64)*
2006 (n = 4264)	6.8	10.5	13.7	10.1	*6.9*	1	*1.57*	*2.12*
	(5.4–8.2)	(9.2–11.8)	(11.5–15.8)	(9.2–11.0)	*(4.3–9.5)*		*(1.20–2.05)*	*(1.57–2.84)*
2010 (n = 3454)	6.9	10.1	15.2	9.7	*8.3*	1	*1.52*	*2.39*
	(5.5–8.2)	(8.6–11.7)	(12.3–18.00)	(8.7–10.7)	*(5.1–11.4)*		*(1.16–1.99)*	*(1.75–3.27)*
2014 (n = 3687)	6.1	9.8	13.9	8.9	*7.8*	1	*1.59*	*2.34*
	(4.9–7.3)	(8.3–11.3)	(11.1–16.7)	(8.0–9.8)	*(4.7–10.8)*		*(1.21–2.08)*	*(1.70–3.23)*
2018 (n = 2751)	7.8	12.7	16.0	10.9	*8.1*	1	*1.67*	*2.20*
	(6.3–9.3)	(10.8–14.5)	(12.0–20.0)	(9.8–12.1)	*(3.9–12.4)*		*(1.27–2.21)*	*(1.50–3.21)*
All years	6.7	10.3	13.4	9.7	*6.6*	1	*1.59*	*2.16*
(n = 22,177)	(5.6–7.9)	(9.5–11.2)	(12.4–13.5)	(9.3–10.1)	*(5.5–7.8)*		*(1.42–1.74)*	*(1.89–2.46)*

Data from the Health Behaviour in School-aged Children study in Denmark 1998, 2002, 2006, 2010, 2014 and 2018

Estimates in italics are statistically significant

[a]Prevalence difference: percent point difference between low and high occupational social class, standardized by sex and age

[b]Multilevel logistic regression analyses adjusted by sex and age group; all years combined also adjusted for survey year

obesity in high, middle and low OSC is shown separately for each survey year, and the absolute social inequality in obesity is presented by percent point difference between low and high OSC. The absolute social inequality in obesity was statistically significant in 2006, 2010 and 2014. Figure 2 shows the changes in obesity prevalence over time in the three occupational classes. There were no significant trends for high OSC (p = 0.349) or middle OSC (p = 0.109) but an increasing trend in low OSC (p = 0.012). The prevalence differences between low and high OSC suggest that there was a persistent absolute social inequality in obesity 1998–2018 of about 1.5%.

The relative measures of inequality are shown as OR for obesity by OSC. In the full sample, the OR for being obese was 1.74 (1.29–2.34) in middle versus high OSC and 2.97 (2.15–4.11) in low versus high OSC. The corresponding OR estimates for boys were 1.54 (1.03–2.33) and 2.43 (1.55–3.81) and for girls 1.85 (1.19–2.86) and 3.24 (2.10–5.31). In the analyses stratified by survey year, the associations showed the same pattern. The findings suggest that the relative social inequality in obesity did not change from 2002 to 2018. This was supported by a nonsignificant statistical interaction term between OSC and survey year (p = 0.459).

Sensitivity analyses

The sex- and age-standardized prevalence of overweight was 8.4% in high, 11.8% in middle and 14.5% in low FAS families ($p < 0.001$) and the prevalence of obesity was 1.2% in high, 1.9% in middle and 2.6% in low FAS families ($p < 0.001$). The sex-, age- and survey year-adjusted OR (95% CI) for overweight was 1.46 (1.31–1.62) in middle and 1.86 (1.55–2.23) in low compared to high FAS families. The corresponding estimates for obesity were 1.81 (1.39–2.37) and 2.62 (1.72–3.98) (data not shown in table).

Discussion

Main findings

The prevalence of overweight and obesity increased with decreasing socioeconomic background in the total study population, among boys and girls, in all survey years, and regardless of indicator of socioeconomic background. The results of the present study add to the previous Danish findings of stagnating or slightly increasing prevalence

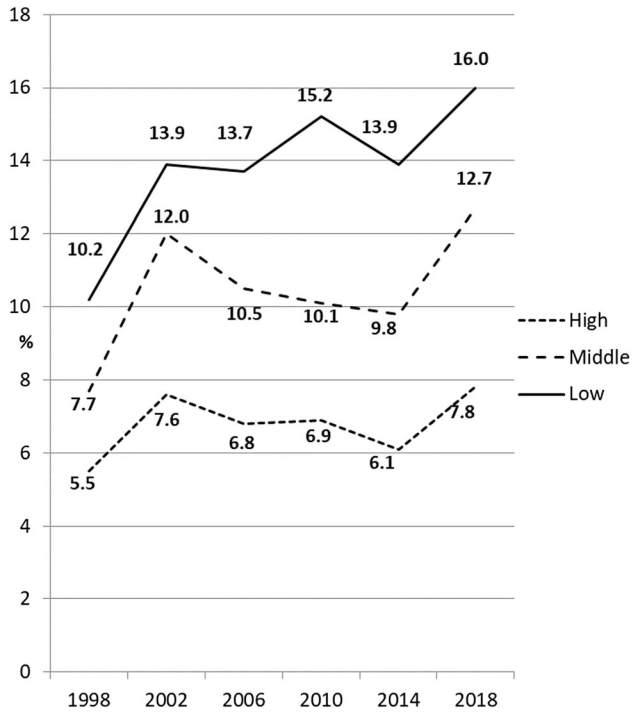

Fig. 1 Percent overweight by year and occupational social class. Data from the Health Behaviour in School-aged Children study in Denmark 1998, 2002, 2006, 2010, 2014 and 2018

levels of overweight and obesity among adolescents since the turn of the century. The presented findings suggest that the development from 1998 to 2018 is masking a slightly increasing trend among adolescents from low but not high SEP. The absolute social inequality (prevalence differences between low and high OSC) in overweight and obesity between 1998 and 2018 was persistent with no clear upward or downward trend. The relative social inequality (OR for overweight and obesity) showed no changes in social inequalities from 1998 to 2018.

The finding of the highest prevalence of overweight and obesity among the low SEP group is in line with previous findings from other Western European countries (Due et al. 2009; Lissner et al. 2016; Inchley et al. 2017; Shrewsbury and Wardle 2008; Wang and Lim 2012). Our study showed that the prevalence difference between low and high SEP families did not differ significantly across survey years. At the same time, there were slightly—although significantly—increasing prevalence of both overweight and obesity among adolescents from low SEP and stable prevalence among adolescents from high SEP families. The latter observation confirms the part of the literature that documents a widening absolute social inequality (Chung et al. 2016; Inchley et al. 2017; Matthiessen et al. 2014). The study by Matthiessen et al. (2014) included a national sample of 4–14-year-old Danish children over the period from 2000 to 2008 and showed that there was increasing prevalence of overweight among boys of parents with low educational level and stable trends among boys of parents with medium and high educational level.

Several studies document increasing relative social inequality in overweight (Hardy et al. 2017; Elgar et al. 2015), including a Danish study by Møller et al. (2007) among 8–10-year-old children from the community of Odense from 1997/98 to 2003/04. Our study did not confirm such increasing relative social inequality. The current study is not directly comparable to the previous Danish studies due to differences in age groups, sample representativeness, measure of SEP, time period, and length of time period. It is plausible that the differences in these parameters may explain the differences in findings across studies.

Following several decades of increasing prevalence of obesity and overweight, it is positive that stagnations and lower rates of increase have been observed across several countries (NCD Risk Factor Collaboration 2017; Ahluwalia et al. 2015) including Denmark (Pearson et al. 2010; Morgen et al. 2013). However, the findings of the present study reveal that there is still a substantial rate of increase among adolescents from low SEP groups. This finding suggests that low SEP groups may be more exposed to obesogenic environments and potentially also more vulnerable to such exposures. The finding of increasing prevalence in low SEP groups suggests that the presence and impact of these potentially underlying mechanisms may have strengthened over the study period. The findings also illustrate that obesity preventive initiatives are less effective in reaching low SEP groups. The current findings may constitute an example of the preventive paradox where preventive initiatives not only fail to reduce inequalities but in fact cause increasing inequalities. The findings therefore highlight the need for successful development and implementation of health promoting and preventive initiatives capable of specifically reaching low SEP populations.

It is difficult to explain the persistency in social inequality in overweight. The dataset includes data on what is usually considered determinants of overweight (physical activity, eating habits, general health status) but as adolescent overweight has its origin early in life. It is very likely that weight group also influence these variables. Inclusion of these variables in the analyses could therefore result in more confusion than clarity.

Limitations

Our data on weight status are based on adolescents' self-reported height and weight and calculation of body mass index (BMI). BMI is not a perfect measure of overweight or obesity, but rather a measure of relative weight. The study does not include anthropometric or other data which can enhance the confidence in the measurement of weight

Table 3 *Obesity* by occupational social class; sex- and age-standardized percentage and adjusted OR (95% CI) for overweight

Survey year	Absolute social inequality described by sex- and age-standardized percent (95% CI) with obesity					Relative social inequality described by OR (95% CI) for obesity[b]		
	Occupational social class					Occupational social class		
	High	Middle	Low	Total	Prevalence difference[a] (95% CI)	High	Middle	Low
1998 (n = 4193)	0.4	1.0	1.0	0.8	0.6	1	2.32[c]	2.50[c]
	(0.1–0.8)	(0.6–1.4)	(0.4–1.6)	(0.5–1.1)	(− 0.2 to 1.3)			
2002 (n = 3828)	1.2	1.0	2.1	1.3	1.0	1	0.91	1.90
	(0.5–1.8)	(0.6–1.5)	(1.1–3.2)	(0.9–1.6)	(− 0.2 to 2.2)		(0.44–1.91)	(0.88–4.13)
2006 (n = 4264)	0.9	1.8	2.8	1.8	*1.9*	1	*1.99*	*3.04*
	(0.4–1.4)	(1.3–2.4)	(1.7–3.8)	(1.4–2.2)	*(0.7–3.1)*		*(1.01–3.91)*	*(1.49–6.20)*
2010 (n = 3454)	0.9	2.0	3.6	1.8	*2.7*	1	*2.34*	*4.37*
	(0.4–1.4)	(1.3–2.7)	(2.1–5.1)	(1.4–2.2)	*(1.2–4.3)*		*(1.19–4.62)*	*(2.13–8.97)*
2014 (n = 3687)	0.8	1.3	2.9	1.4	*2.1*	1	1.60	*3.55*
	(0.4–1.3)	(0.8–1.9)	(1.6–4.3)	(1.0–1.8)	*(0.7–3.6)*		(0.79–3.21)	*(1.69–7.46)*
2018 (n = 2751)	1.0	1.4	2.2	1.4	1.1	1	1.52	2.43
	(0.5–1.6)	(0.8–2.1)	(0.6–3.7)	(0.9–2.8)	(− 0.6 to 2.8)		(0.71–3.26)	(0.93–6.36)
All years	0.9	1.4	2.4	1.4	*1.5*	1	*1.74*	*2.97*
(n = 22,177)	(0.5–1.3)	(0.9–1.9)	(1.9–2.8)	(1.2–1.6)	*(1.0–2.0)*		*(1.29–2.34)*	*(2.15–4.11)*

Data from the Health Behaviour in School-aged Children study in Denmark 1998, 2002, 2006, 2010, 2014 and 2018

Estimates (95% CI) in italics are statistically significant

[a]Prevalence difference: percent point difference between low and high occupational social class, standardized by sex and age

[b]Multilevel logistic regression analyses adjusted by sex and age group; all years combined also adjusted for survey year

[c]Model does not converge, 95% CI cannot be estimated

status. Many previous studies have documented that self-reported weight and height may be exposed to information bias which may result in misclassification, in this case underestimation of the prevalence of overweight (Elgar et al. 2005; Pérez et al. 2015). This has also been documented by Rasmussen et al. (2013) who found that BMI based on self-reported data caused an underestimation of weight among both boys and girls and an overestimation of height among boys. These errors resulted in an underestimation of the overweight prevalence (Rasmussen et al. 2013). The prevalence of overweight and obesity in the present study is therefore likely to be underestimated. Furthermore, there was a higher prevalence of obesity among participants without data about parents' OSC which also contributes to an underestimation of the prevalence of obesity.

What is specifically relevant for the presented results is whether the anticipated misclassification has changed over time and across OSC. Previous studies among adult populations on the influence of time on the magnitude of underreporting of BMI show varying results with some documenting a decreasing underreporting (Hayes et al. 2011) and others identifying increasing underreporting (Shiely et al. 2013). Unfortunately, no data are available for exploring differential weight status misclassification over time and by OSC. Therefore, there is a risk that part of the observed changes in prevalence levels over time in the full populations and in the OSC strata may be due to changes in the magnitude of misclassification.

OSC appears to be a valid and appropriate indicator of socioeconomic background. OSC is closely linked to parents' educational attainment which probably comes before the development of the children's weight status. FAS is less appropriate for trend studies because the affluence value of the single components of the measure, like computers, may change considerable over time. Further, FAS may not be a genuine independent variable in the analyses because the family's possession of consumer goods may appear after the establishment of children's weight status.

Implications

Trends in overweight and obesity vary across countries and so does the social inequality in overweight and obesity. For this reason, it is important to monitor such trends. It is also important to get more insight into the processes which

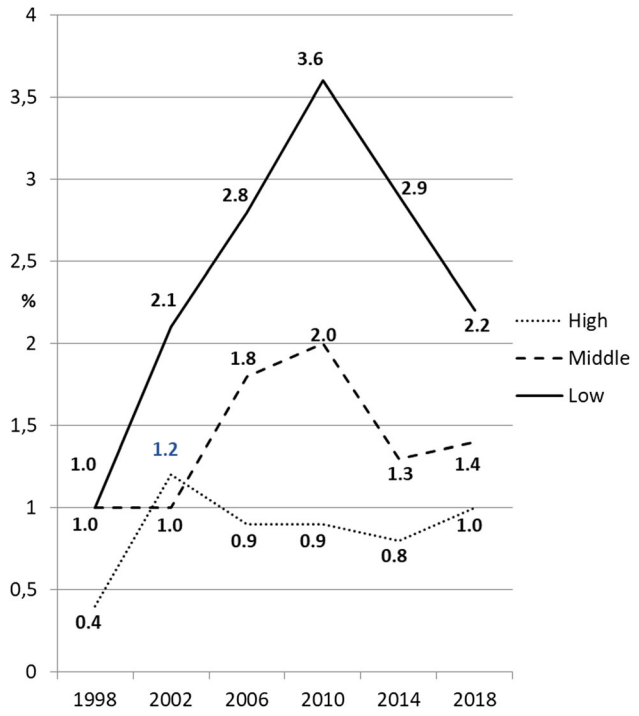

Fig. 2 Percent obese by year and occupational social class. Data from the Health Behaviour in School-aged Children study in Denmark 1998, 2002, 2006, 2010, 2014 and 2018

cause high and increasing prevalence of obesity and overweight among low SEP adolescents. It is worthwhile to conduct further studies in the entire HBSC database with data from many European and North American countries. We also recommend studies which apply parental education as SEP measure because education may tap the cultural capital in the family better than occupation. Unfortunately, data on parental education were not included in our study.

From a practice point of view, it is important to develop interventions and health education efforts to fight not only overweight but specifically obesity in low SEP families. Many intervention studies address obesity prevention with specific interest in whether the intervention reduces social inequality in obesity among children and adolescents (see reviews in Beauchamp et al. 2014; Boelsen-Robinson et al. 2015; Hillier-Brown et al. 2014; Olstad et al. 2016). Most of these interventions failed in reducing social inequality in obesity, but some did. Educational intervention strategies to change individual behaviors are generally not very effective in reduction of obesity (Beauchamp et al. 2014), whereas community-based interventions and interventions which apply structural changes in the environment (Beauchamp et al. 2014; Boelsen-Robinson et al. 2015; Hillier-Brown et al. 2014) often succeed in reducing social inequality in obesity, or at least prevent widening of such social inequalities among children and adolescents. Olstad et al. (2016) focused on policies rather than specific interventions and concluded that interventions which address environmental barriers seem to have an equal or greater benefit on obesity rates for disadvantaged groups. Further, they suggest that fiscal measures with free or subsidized fruit or healthy meal measures may have better chances of reducing social inequality in obesity. It is important to get more insight into processes which facilitate prevention of obesity and it is promising that community-based interventions and interventions which apply structural changes in the environment may be effective.

Conclusion

The proportion of overweight and obese schoolchildren was increasing in lower socioeconomic strata in Denmark 1998–2018. The social inequality in overweight and obesity was persistent in absolute as well as in relative terms from 1998 to 2018. Intervention research suggests that structural and fiscal interventions at school and community level may be effective in reducing the social inequality in obesity.

Author contributions All authors have contributed substantially to the conception and design of the paper and to the interpretation of data. MTD, PD, BEH, LK, RFK, MR, SVR and MT collected the data. RFK and BEH developed the protocol for coding of occupational social class. BEH and MTD performed the analyses. MR and BEH wrote the first draft of the manuscript. All authors contributed to the writing of the manuscript and a critical revision of the intellectual content. All authors have approved the final version of the manuscript and are accountable for all aspects of the work.

Funding The Nordea foundation (Grant No. 02-2011-0122) provided economic support for the 2010 study and The Danish Health Authority (Grant No. 1-1010-274/13) for the 2018 survey. The funding agencies did not interfere in the study design, data collection, and analysis, interpretation, writing of this article or the decision to submit the manuscript for publication. None of the authors received any honorarium, grant or other form of payment to produce the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that there is no potential, perceived, or real conflict of interest.

Ethical approval and informed consent There is no formal agency for approval of questionnaire-based surveys in Denmark. Therefore, we asked the school board as the parents' representative, the headmaster, and the students' council in each of the participating schools to approve the study. The participants received oral and written information that participation was voluntary, and that data were treated confidentially. The study complies with national standards for data protection. From 2014 the Danish Data Protection Authority has requested notification of such studies and has granted acceptance for

the 2014 survey (Case No. 2013-54-0576) and the 2018 survey (Case 10 622, University of Southern Denmark).

References

Ahluwalia N, Dalmasso P, Rasmussen M, Lipsky L, Currie C, Haug E, Kelly C, Damsgaard MT, Due P, Tabak I, Ercan O, Maes L, Aasvee K, Cavallo F (2015) Trends in overweight prevalence among 11-, 13- and 15-year-olds in 25 countries in Europe, Canada and USA from 2002 to 2010. Eur J Public Health 25(Suppl 2):28–32. https://doi.org/10.1093/eurpub/ckv016

Beauchamp A, Backholer K, Magliano D, Peeters A (2014) The effect of obesity prevention interventions according to socioeconomic position: a systematic review. Obes Rev 15:541–554. https://doi.org/10.1111/obr.12161

Boelsen-Robinson T, Peeters A, Beauchamp A, Chung A, Gearon E, Backholer K (2015) A systematic review of the effectiveness of whole-of-community interventions by socioeconomic position. Obes Rev 16:806–816. https://doi.org/10.1111/obr.12297

Christensen U, Krølner R, Nilsson CJ, Lyngbye PW, Hougaard CØ, Nygaard E, Thielen K, Holstein BE, Avlund K, Lund R (2014) Addressing social inequality in aging by the Danish occupational social class measurement. J Aging Health 26:106–127. https://doi.org/10.1177/0898264314522894

Chung A, Backholer K, Wong E, Palermo C, Keating C, Peeters A (2016) Trends in child and adolescent obesity prevalence in economically advanced countries according to socioeconomic position: a systematic review. Obes Rev 17:276–295. https://doi.org/10.1111/obr.12360

Cole TJ, Lobstein T (2012) Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes 7:284–294. https://doi.org/10.1111/j.2047-6310.2012.00064.x

Currie C, Molcho M, Boyce W, Holstein BE, Torsheim T, Richter M (2008) Researching health inequalities in adolescents: the development of the Health Behaviour in School-aged Children (HBSC) Family Affluence Scale. Soc Sci Med 66:1429–1436. https://doi.org/10.1016/j.socscimed.2007.11.024

Due P, Damsgaard MT, Rasmussen M, Holstein BE, Wardle J, Merlo J, Currie C, Ahluwalia N, Sørensen TIA, Lynch J (2009) Socioeconomic position, macroeconomic environment and overweight among adolescents in 35 countries. Int J Obes (London) 33:1084–1093. https://doi.org/10.1038/ijo.2009.128

Elgar FJ, Roberts C, Tudor-Smith C, Moore L (2005) Validity of self-reported height and weight and predictors of bias in adolescents. J Adolesc Health 37:371–375

Elgar FJ, Pförtner TK, Moor I, De Clercq B, Stevens GW, Currie C (2015) Socioeconomic inequalities in adolescent health 2002-2010: a time-series analysis of 34 countries participating in the health behaviour in school-aged children study. Lancet 385(9982):2088–2095. https://doi.org/10.1016/S0140-6736(14)61460-4

Hardy LL, Mihrshahi S, Gale J, Drayton BA, Bauman A, Mitchell J (2017) 30-year trends in overweight, obesity and waist-to-height ratio by socioeconomic status in Australian children, 1985 to 2015. Int J Obes (Lond) 41:76–82. https://doi.org/10.1038/ijo.2016.204

Harper S, Lynch J, Meersman SC, Breen N, Davis WW, Reichman ME (2008) An overview of methods for monitoring social disparities in cancer with an example using trends in lung cancer incidence by area-socioeconomic position and race-ethnicity, 1992–2004. Am J Epidemiol 167:889–899. https://doi.org/10.1093/aje/kwn016

Hayes AJ, Clarke PM, Lung TW (2011) Change in bias in self-reported body mass index in Australia between 1995 and 2008 and the evaluation of correction equations. Popul Health Metr 9:53. https://doi.org/10.1186/1478-7954-9-53

Hillier-Brown FC, Bambra CL, Cairns JM, Kasim A, Moore HJ, Summerbell CD (2014) A systematic review of the effectiveness of individual, community and societal level interventions at reducing socioeconomic inequalities in obesity amongst children. BMC Public Health 14:834. https://doi.org/10.1186/1471-2458-14-834

Houweling TA, Kunst AE, Huisman M, Mackenbach JP (2007) Using relative and absolute measures for monitoring health inequalities: experiences from cross-national analyses on maternal and child health. Int J Equity Health 6:15

Inchley J, Currie D, Young T, Samdal O, Torsheim T, Augustson L, Mathison F, Aleman-Diaz A, Molcho M, Weber M, Barnekow V (eds) (2016) Growing up unequal: gender and socioeconomic differences in young people's health and well-being. World Health Organization, Copenhagen

Inchley J, Currie D, Jewell J, Breda J, Barnekow V (eds) (2017) Adolescent obesity and related behaviours: trends and inequalities in the WHO European Region, 2002–2014. World Health Organization, Copenhagen

Jaacks LM, Vandevijvere S, Pan A, McGowan CJ, Wallace C, Imamura F, Mozaffarian D, Swinburn B, Ezzati M (2019) The obesity transition: stages of the global epidemic. Lancet Diabetes Endocrinol 7:231–240. https://doi.org/10.1016/S2213-8587(19)30026-9

Lien N, Friedstad C, Klepp K-I (2001) Adolescents' proxy reports of parents' socioeconomic status: how valid are they. J Epidemiol Community Health 55:731–737

Lissner L, Wijnhoven TMA, Mehlig K, Sjöberg A, Kunesova M, Yngve A, Petrauskiene A, Duleva V, Rito AI, Breda J (2016) Socioeconomic inequalities in childhood overweight: heterogeneity across five countries in the WHO European Childhood Obesity Surveillance Initiative (COSI-2018). Int J Obes (Lond) 40:796–802. https://doi.org/10.1038/ijo.2016.12

Matthiessen J, Stockmarr A, Biltoft-Jensen A, Fagt S, Zhang H, Groth MV (2014) Trends in overweight and obesity in Danish children and adolescents: 2000-2008—exploring changes according to parental education. Scand J Public Health 42:385–392. https://doi.org/10.1177/1403494813520356

Møller NC, Wedderkop N, Kristensen PL, Andersen LB, Froberg K (2007) Secular trends in cardiorespiratory fitness and body mass index in Danish children: the European Youth Heart Study. Scand J Med Sci Sports 17:331–339

Moonesinghe R, Beckles GLA (2015) Measuring health disparities: a comparison of absolute and relative disparities. Peer J 3:e1438. https://doi.org/10.7717/peerj.1438

Morgen CS, Rokholm B, Sjøberg CS, Schou Andersen C, Geisler Andersen L, Rasmussen M, Nybo Andersen AM, Due P, Sørensen TI (2013) Trends in prevalence of overweight and obesity in Danish infants, children and adolescents—are we still on a plateau? PLoS ONE 8:e69860. https://doi.org/10.1371/journal.pone.0069860

NCD Risk Factor Collaboration (NCD-RisC) (2017) Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. Lancet 390(10113):2627–2642. https://doi.org/10.1016/S0140-6736(17)32129-3

Ng M, Fleming T, Robinson M et al (2014) Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 384:766–781

Olstad DL, Teychenne M, Minaker LM, Taber DR, Raine KD, Nykiforuk CI, Ball K (2016) Can policy ameliorate socioeconomic inequities in obesity and obesity-related behaviours? A

systematic review of the impact of universal policies on adults and children. Obes Rev 17:1198–1217. https://doi.org/10.1111/obr.12457

Pearson S, Hansen B, Sørensen TI, Baker JL (2010) Overweight and obesity trends in Copenhagen schoolchildren from 2002 to 2007. Acta Paediatr 99:1675–1678. https://doi.org/10.1111/j.1651-2227.2010.01897.x

Pérez A, Gabriel K, Nehme EK, Mandell DJ, Hoelscher DM (2015) Measuring the bias, precision, accuracy, and validity of self-reported height and weight in assessing overweight and obesity status among adolescents using a surveillance system. Int J Behav Nutr Phys Act 12(Suppl 1):S2. https://doi.org/10.1186/1479-5868-12-S1-S2

Pförtner TK, Günther S, Levin KA, Torsheim T, Richter M (2015) The use of parental occupation in adolescent health surveys. An application of ISCO-based measures of occupational status. J Epidemiol Community Health 69:177–184. https://doi.org/10.1136/jech-2014-204529

Pu C, Huang N, Chou YJ (2011) Do agreements between adolescent and parent reports on family socioeconomic status vary with household financial stress? BMC Med Res Methodol 11:50. https://doi.org/10.1186/1471-2288-11-50

Pueyo M-J, Serra-Sutton V, Alonso J, Starfield B, Rajmil L (2007) Self-reported social class in adolescents: validity and relationship with gradients in self-reported health. BMC Health Serv Res 7:151

Rasmussen M, Due P, Damsgaard MT, Holstein BE (2009) Social inequality in adolescent daily smoking: has it changed over time? Scand J Public Health 37:287–294. https://doi.org/10.1177/1403494809102178

Rasmussen M, Holstein BE, Melkevik O, Damsgaard MT (2013) Validity of self-reported height and weight among adolescents: the importance of reporting capability. BMC Med Res Methodol 13:85. https://doi.org/10.1186/1471-2288-13-85

Roberts C, Freeman J, Samdal O, Schnohr CW, de Looze ME, Nic Gabhainn S, Iannotti R, Rasmussen M (2009) The Health Behaviour in School-aged Children (HBSC) study: methodological developments and current tensions. Int J Public Health 54(Suppl 2):140–150. https://doi.org/10.1007/s00038-009-5405-9

Seidell JC, Halberstadt J (2015) The global burden of obesity and the challenges of prevention. Ann Nutr Metab 66(Suppl 2):7–12. https://doi.org/10.1159/000375143

Shiely F, Hayes K, Perry IJ, Kelleher CC (2013) Height and weight bias: the influence of time. PLoS ONE 8:e54386. https://doi.org/10.1371/journal.pone.0054386

Shrewsbury V, Wardle J (2008) Socioeconomic status and adiposity in childhood: a systematic review of cross-sectional studies 1990-2005. Obesity (Silver Spring) 16:275–284. https://doi.org/10.1038/oby.2007.35

Sigmund E, Badura P, Sigmundová D, Voráčová J, Zacpal J, Kalman M, Pavelka J, Vokacová J, Hobza V Jr, Hamrik Z (2018) Trends and correlates of overweight/obesity in Czech adolescents in relation to family socioeconomic status over a 12-year study period (2002–2014). BMC Public Health 18:122. https://doi.org/10.1186/s12889-017-5013-1

Wang Y, Lim H (2012) The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. Int Rev Psychiatry 24:176–188. https://doi.org/10.3109/09540261

West P, Sweeting H, Speed E (2001) We really do know what you do: a comparison of reports from 11-year olds and their parents in respect of parental economic activity and occupation. Sociol 35:539–559