Public Health in Practice 7 (2024) 100510

Contents lists available at ScienceDirect

Public Health in Practice

journal homepage: www.sciencedirect.com/journal/public-health-in-practice

# Impact of a nationwide school policy on body mass index in Danish school children: An interrupted time series analysis

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## ABSTRACT

*Objectives:* A new school policy mandating 45 min physical activity daily during school was introduced in Denmark in 2014. We aimed to evaluate the effect of this policy on BMI in school-aged children. It was hypothesized that the school policy would decrease BMI, especially in the obese fraction of the population (90th percentile BMI).

*Study design:* This register-based study was conducted as a natural experiment.

*Methods:* Analyses were based on data from The National Child Health Register that contains nationwide data on height and weight from mandatory preventive health examinations completed by school nurses or medical doctors during pre-preparatory classes (0th-3rd grade) and lower secondary education (7th-9th grade). A total of 401,517 children were included in the analyses with annual repeated cross-sectional data covering the period from 2012 to 2018. The effect of the school policy was evaluated using an interrupted time series approach comparing pre- and post-policy slopes in BMI, stratified by sex and age-group.

*Results:* In boys, no significant differences were observed in mean BMI slopes from pre-to post-policy in either age-group. In girls, post-policy slopes were significantly higher compared to pre-policy in both age-groups (0th-3rd grade: β:0·034 kg/m2, 95%-CI: (0·024; 0·043), p-value: <0·001; 7th-9th grade: β:0·066 kg/m2, 95%-CI: (0·028; 0·103), p-value: 0·001). No significant differences in slopes were observed in BMI at the 90th percentile from pre-to post-policy for both sexes and across both age-groups. Adjustment for leisure-time physical activity as a potential time-varying confounder did not alter the findings.

*Conclusions:* In conclusion, we did not detect a significant decrease in BMI levels among school-aged children following the introduction of a nationwide school policy specifying daily physical activity in school. If anything, a small positive change in BMI was observed in girls. More research is needed to understand whether structural changes similar to this requirement are able to prevent overweight and obesity in children and adolescents.

## 1. Introduction

Mean body mass index (BMI) and prevalence of overweight and obesity in children and adolescents aged 5–19 have been rising between 1975 and 2016 [1]. Overweight and obese children face a greater risk of various health issues throughout life [2]. Moreover, obesity poses an economic burden and drains societal resources [3]. Since childhood obesity often persists into adulthood and weight loss is challenging [4], early prevention is crucial.

Overweight and obesity are most likely caused by complex interactions between genetics, environmental, and behavioral factors [5]. Even though individuals may respond differently to physical activity (PA) and diet, an imbalance in energy intake and expenditure over time still appears to be the primary driver for obesity [6]. Consequently, PA and diet are important tools in preventing childhood obesity. In Denmark, a new school policy prioritizing PA was introduced in all

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https://doi.org/10.1016/j.puhip.2024.100510
Received 23 April 2024; Accepted 8 May 2024
Available online 17 May 2024

public schools in 2014 [7]. The policy aimed to ensure student well-being, minimize impact of socioeconomic background, and create optimal conditions for every child to reach their full learning potential. Different structural changes came with this policy (e.g. a longer school day), but a distinctive feature in a health promotion perspective was a requirement of an average of 45 min PA daily integrated in the ordinary school curriculum [8]. No requirement on PA (besides requirements on physical education) existed before the policy. Moreover, no details were introduced on when, where and how, and the municipalities and schools met the requirement in different ways. In a recent study, we found that the school policy significantly increased PA during school hours, but no clear effect was evident for total PA [9]. The study was not powered to study the effect of the school policy on PA in subgroups of the population. It is possible and not unlikely that children who tend to be physically inactive or overweight may have increased their daily energy expenditure due to the school policy, although no clear effect on total PA was observed at the population level [9]. This could potentially result in reductions in BMI, particularly among subgroups of the population.

Few countries have implemented policies mandating PA during school time [10–12], but none have evaluated their impact on BMI using interrupted time-series (ITS) analysis. In the absence of a control group, ITS is a suitable statistical alternative [13] that has been used to assess nationwide policy changes in real-world settings [14,15] by comparing trends (in outcome) before and after policy introduction [13]. Thus, the primary aim of this study was to examine the effect of the Danish school policy mandating 45 min of daily PA on nationwide mean BMI in school children using the ITS approach. Also, we examined differences in the 90th percentile BMI to explore if effects varied between the most overweight segment and the remainder of the population. It was hypothesized that increased PA levels during school hours would lead to a decrease in BMI, especially among the most obese. In addressing the primary aim, this study also provides secular trends in BMI for Danish school children between 2012 and 2018.

## 2. Methods

### 2.1. Study design

A natural experiment design was used including nation-wide routine data collected annually.

### 2.2. The National Child Health Register (Børnedatabasen)

In Denmark, all children are offered preventive health examinations completed by school nurses or medical doctors during the early years of a child's life and during school attendance. Children attend primary school (0$^{th}$ grade) in August the year they turn 6 unless circumstances postpone school start. The first health examination is completed during 0$^{th}$-3rd grade (6-9y) and the last during 7th-9th grade (13-15y). Measurements obtained from these two age-groups are included in this study. Measurements are performed across the whole year. The National Child Health Register is a national database based on health data from these examinations. It includes data on background, height, weight, breast-feeding, and passive smoking. The register was established in 2009. Since 2011 municipalities have been obligated to report data to the register. From 2012 and onwards, data are considered complete. Data access was given in 2022. However, data registered after 2018 were incomplete due to long-lasting technical updates. Therefore, population representative data in this study covered the period between 2012 and 2018.

### 2.3. Study population

This study is based on data from every Danish child and adolescent aged 6–9 and 13–15 who is registered in the National Child Health Register with a valid measurement in the period between 2012 and 2018 (n = 401,517). Children without a school code were excluded from analyses (n = 177,845), and since the school policy only applies to public schools (fully tax-funded), children attending private- and boarding schools were excluded from analyses.

The National Child Health Register does not include information on response rates (coverage). However, The Ministry of Children and Education (Børne-og Undervisningsministeriet) have publicly available data on the number of students in all public schools at each grade and for each year. These were compared to student numbers in the National Child Health Register. To avoid selection bias due to low school-level coverage, children in a specific age-group (grade) on a specific school were only included in analyses if the database contained information on at least 70 % of the expected number of children in this age-group according to the Ministry for Children and Education.

### 2.4. Socioeconomy

In a secondary analysis, the school policy evaluation (mean BMI) was divided into socioeconomic groups for children in 7th-9th grade. Data on the highest educational level of parents at each school were extracted from The Ministry for Children and Education and combined with data from The National Health Register. Initially, the percentage of parents with low education (above secondary and vocational education) at each school was calculated each school year. These percentages were ranked and divided into tertiles determining low, middle, and high socioeconomic schools. If the socioeconomic category changed for a school during the study period, the predominant category was used for categorization.

### 2.5. Time-varying confounding

The ITS method is robust towards confounding factors changing steadily over time, but vulnerable to time-varying confounding variables that change fast or coincide with policy introduction [13]. During the study period, leisure-time sedentary behaviour among school-aged children has increased in Norway (similar to Denmark) [16], and leisure PA decreased in Denmark [9]. The steadiness of these potential changes is unclear, but they may have affected BMI trends between 2012 and 2018. Information on leisure time activity was not available in the National Child Health Register, and therefore no adjustments were made in main analyses. Therefore, data from a sub-population deriving from The PHASAR study (Physical Activity in Schools after the Reform) and data from three historical studies were included to explore this [17]. From the historical studies, data from 581 children aged 6–16 from 32 schools collected between 2009 and 2012 were included in this analysis [18–20] (i.e. pre-policy data). The post-policy study population was matched with pre-policy study populations, and data were collected at the same schools and age-groups during the same seasons. The post-policy dataset comprised PA data from 29 schools collected in 2017 and 2018 (i.e. post-policy data), on a total sample of 1793 Danish children aged 6–17 [17]. In all studies, PA was measured by accelerometry. A child was included if he/she did not suffer from any physical disabilities and if valid accelerometer measurements were obtained (a minimum of 3 valid weekdays and 1 valid weekend day). Anthropometric data were collected objectively in all studies. More information on data collection, recruitment, methods, and study population is described in The PHASAR study protocol [17].

### 2.6. Ethical considerations

In Denmark, informed consent and approval from the Regional Scientific Ethical Committee are not required in studies based on register data. The approval for the PHASAR study was waived, as it does not include an intervention or biological material (S-20170031). This project and the PHASAR study (secondary analysis) were notified and approved by the Danish Data Protection Agency (2015-57-0008). All data are stored and treated in accordance with the Danish Protection Act and the General Data Protection Regulation.

### 2.7. Statistical methods

All analyses were completed in StataBE 17 (StataCorp). A statistical analysis plan was pre-registered at Open Science Framework (https://osf.io/etr7x/) before initiating analyses.

BMI (kg/m$^2$) was calculated using height and weight data, serving as primary outcome. BMI trends were initially presented via a plot of marginal means. The plot was based on a mixed-effect regression model stratified into two age-groups (0$^{th}$-3rd grade and 7th-9th grade). Covariates used were time (categorical school year variable) and sex including their interaction. Analyses were further adjusted for age, school code and individual identifier.

BMI was expected to change gradually, since implementation of the PA requirement (and its potential effect on BMI) takes time. Two types of main analyses were performed: I) examining the effect of the school policy on mean BMI, and II) on the 90th percentile BMI.

The first part was completed using linear mixed-effect regression. This analysis was also stratified into two age-groups. The effect of time onto BMI was modelled as piecewise linear function with two pieces corresponding to pre- and post-policy periods (separated by August 1, 2014). For this purpose, an additional post-policy time-variable was created corresponding to time from policy change onwards such that its effect represented the change in slope compared to the pre-time interval. The two piece-wise time-variables were included in the model as fixed effects. An interaction term between sex and the post-policy time variable was included due to the assumption that policy effects may be different for boys and girls. Furthermore, the analysis was adjusted for age. School codes and individual identifiers were included as random effects to take correlations between repeated measurements within the same child as well as between measurements from different children within the same school into account. The model included a term for change in slope post-policy, and this term was tested against zero to test the null hypothesis of no difference in slopes.

To further unfold the policy's effect on BMI, an additional quadratic post-policy time-variable was included in analyses to relax the assumption that the policy's effect on BMI is linear, and account for the possibility, that it may take time before increases in PA during school hours influence BMI. The significance of the quadratic variable was tested. If it was significant and relevant (based on plots), tests were conducted on pre-specified data-points, 2·5 and 3·5 year after policy introduction. The (local) slopes from the two time-points (first derivatives) were tested against the linear pre-policy slope to test the null-hypothesis of no difference in slopes.

Furthermore, quantile regression (qreg2 in Stata) was used to estimate potential changes in the 90th percentile of BMI post-policy. The same fixed effects as in the mixed-effect regression model was included in the quantile analysis. Since quantile regression does not incorporate random effects structures, only 0$^{th}$ and 8th graders were included in these analyses (assuring that no individual was included with more than one measurement). School codes were included as a cluster-variable together with cluster robust estimates for standard errors. Again, using post-estimation pre- and post-policy slopes were tested against each other to test the null hypothesis of no difference in slopes. The quantile regression was also conducted with a quadratic time-variable as explained above.

The last analysis conducted was completed on a smaller sub-population in which data on leisure time PA were available pre- (2009–2012) and post-policy (2017–2018). A linear mixed-effect regression approach was used, and the effect of time was assumed to be piecewise linear with the two pieces corresponding to pre- and post-policy periods (i.e. quadratic effects were excluded). The model was adjusted for age, sex, and leisure time PA as fixed effects and individual identifiers and schools as random effects. Analyses were not stratified by sex and age to preserve statistical power. In a post-estimation analysis, pre- and post-policy slopes were tested against each other to test the null hypothesis of no difference in slopes.

The threshold level for significance was alpha = 0·05, however, emphasis was also placed on clinical relevance as sample sizes were large in this study.

Data was checked for statistical assumptions underlying the mixed-effect regression models: normality and homoscedasticity of residuals and linearity between dependent and independent variables.

## 3. Results

Characteristics of the study population are presented in Table 1. After data cleaning, 279,184 primary school children and 122,333 children from lower secondary education were included in analyses. The fewest number of observations were obtained in 2012/13 and 2017/18. Boys and girls were equally distributed across the study period.

In addition, number of schools included in analyses by school year are presented in Table 1; these account for about 60 % of all public schools in Denmark with a total of 1339 (in 2012) to 1280 (in 2018) [21].

Crude means and standard deviations (SD) or medians and inter-quartile ranges are presented by age-group and sex in Table 1. In both age-groups in girls, median BMI increased with time (visual statement). No clear pattern in the development of BMI was present in the boys. These trends were also apparent in the adjusted mean BMI trends (Fig. 1). Table 1 also shows that the proportion of overweight and obese children increased over time, especially in girls.

### 3.1. Interrupted time series analyses

#### 3.1.1. Mean BMI

No significant changes in slope were observed in boys in neither age-group (Fig. 2, Table 2). In girls, post-policy slopes increased significantly compared to the pre-policy slopes in both age-groups (Fig. 2, Table 2).

The quadratic time-variable was significant in both age-groups suggesting that BMI developed non-linearly during the post-policy period (Supplement, Fig. 2). No significant differences in slopes were observed in boys 2.5 years after policy introduction (Supplement, Table 1). A small but significant decrease in slope was observed in the youngest boys 3.5 years after policy introduction, whereas no significant difference was observed in boys in grades 7–9 (Supplement, Table 1). In girls, a positive change in slope was observed 2.5 years after policy introduction in both age-groups, and post-policy slopes were not significantly different 3.5 years after (Supplement, Table 1).

#### 3.1.2. The 90th percentile BMI

No significant changes between pre- and post-policy slopes in 90th percentiles BMI were observed in boys or girls in neither age-group (Fig. 3, Table 3).

The quadratic term for time was non-significant in both age-groups suggesting that the 90th percentile BMI followed a linear trend post-policy. No further quadratic analyses were performed.

#### 3.1.3. Mean BMI in socio-economic groups

When examining whether pre- and post-policy mean BMI changes differed between socioeconomic groups (based on parental educational level) in 7th–9th graders, no significant post-policy changes were observed in the medium or high socioeconomic groups (Supplement, Table 2). However, we observed a significant increase in mean BMI in boys and especially girls from low socioeconomic families (boys: β: 0·091 kg/m$^2$, 95%CI: 0·002; 0·179, P-value:0·045; girls β: 0·160 kg/m$^2$, 95%CI: 0·070; 0·249, P-value:<0·001).

**Table 1**
Characteristics of population by school year.

| | 2012/13 | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 |
|---|---|---|---|---|---|---|
| Schools | | | | | | |
| n | 840 | 895 | 872 | 869 | 820 | 756 |
| Median coverage* | | | | | | |
| % | 84·6 (77·8–91·3) | 85·7 (78·8–92·0) | 85·9 (79·3–92·8) | 86·2 (78·8–92·7) | 86·7 (80·0–93·0) | 86·8 (80·0–92·86) |
| Sex | | | | | | |
| Boys, n (%) | 51,009 (50·8 %) | 70,266 (50·5 %) | 69,337 (51·1 %) | 70,791 (51·0 %) | 63,343 (50·8 %) | 55,888 (51·1 %) |
| Girls, n (%) | 49,484 (49·2 %) | 68,959 (49·5 %) | 66,464 (48·9 %) | 68,082 (49·0 %) | 61,393 (49·2 %) | 53,432 (48·9 %) |
| Age-group | | | | | | |
| $0^{th}$-3rd grade, n (%) | 63,829 (79·3 %) | 80,018 (74·3 %) | 79,310 (76·7 %) | 77,054 (74·6) | 70,644 (77·1 %) | 61,497 (76·1 %) |
| 7th-9th grade, n (%) | 16,661 (20·7 %) | 27,688 (25·7 %) | 24,154 (23·3 %) | 26,256 (25·4 %) | 21,002 (22·9 %) | 19,337 (23·9 %) |
| Mean height (cm) | | | | | | |
| $0^{th}$-3rd grade boys | 127·9 (8·3) | 128·2 (8·4) | 128·2 (8·5) | 128·3 (8·6) | 128·4 (8·6) | 128·7 (8·5) |
| $0^{th}$-3rd grade girls | 126·6 (8·4) | 127·00 (8·5) | 126·92 (8·6) | 127·08 (8·7) | 127·15 (8·7) | 127·32 (8·7) |
| 7th-9th grade boys | 172·2 (9·0) | 173·01 (8·8) | 172·86 (8·9) | 173·36 (8·8) | 172·91 (9·0) | 173·26 (8·7) |
| 7th-9th grade girls | 165·1 (6·5) | 165·29 (6·5) | 165·47 (6·5) | 165·55 (6·5) | 165·39 (6·5) | 165·58 (6·5) |
| Median weight (kg) | | | | | | |
| $0^{th}$-3rd grade boys | 25·5 (22·8–29·3) | 25·8 (23·0–29·6) | 25·7 (22·9–29·8) | 25·7 (22·9–29·9) | 25·8 (22·9–30·0) | 26·0 (23·0–30·0) |
| $0^{th}$-3rd grade girls | 25·0 (22·0–29·0) | 25·1 (22·3–29·4) | 25·2 (22·2–29·4) | 25·3 (22·3–29·6) | 25·3 (22·3–29·9) | 25·5 (22·4–30·0) |
| 7th-9th grade boys | 59·9 (52·3–68·0) | 60·5 (53·1–69·0) | 60·5 (53·0–69·0) | 61·1 (53·7–69·8) | 60·5 (53·0–69·0) | 61·0 (53·7–69·4) |
| 7th-9th grade girls | 55·3 (49·7–62·5) | 55·9 (50·1–63·4) | 56·0 (50·1–63·4) | 56·4 (50·6–63·5) | 56·7 (50·7–64·0) | 56·8 (50·8–64·1) |
| Median BMI ($kg/m^2$) | | | | | | |
| $0^{th}$-3rd grade boys | 15·79 (14·91–16·90) | 15·81 (14·96–16·95) | 15·82 (14·95–16·95) | 15·81 (14·93–16·96) | 15·79 (14·90–16·94) | 15·80 (14·90–16·97) |
| $0^{th}$-3rd grade girls | 15·73 (14·73–17·02) | 15·75 (14·78–17·07) | 15·77 (14·78–17·10) | 15·77 (14·78–17·13) | 15·80 (14·79–17·16) | 15·81 (14·79–17·20) |
| 7th-9th grade boys | 19·73 (18·13–21·84) | 19·81 (18·21–22·01) | 19·76 (18·19–21·96) | 19·89 (18·30–22·07) | 19·79 (18·19–21·97) | 19·85 (18·25–22·04) |
| 7th-9th grade girls | 20·18 (18·44–22·39) | 20·21 (18·51–22·46) | 20·27 (18·50–22·55) | 20·38 (18·65–22·63) | 20·47 (18·69–22·72) | 20·44 (18·66–22·72) |
| 90th percentile BMI | | | | | | |
| $0^{th}$-3rd grade boys | 18·64 | 18·81 | 18·93 | 19·04 | 19·13 | 19·29 |
| $0^{th}$-3rd grade girls | 19·17 | 19·29 | 19·35 | 19·56 | 19·65 | 19·82 |
| 7th-9th grade boys | 25·31 | 25·28 | 25·73 | 25·76 | 25·64 | 25·53 |
| 7th-9th grade girls | 25·27 | 25·78 | 25·78 | 25·83 | 26·15 | 26·00 |
| Overweight/obesity (%) | | | | | | |
| $0^{th}$-3rd grade boys | 9·42/2·79 | 9·89/2·89 | 9·99/3·39 | 10·07/3·57 | 10·27/3·71 | 10·41/4·20 |
| $0^{th}$-3rd grade girls | 12·57/3·71 | 13·03/4·00 | 13·22/4·28 | 13·72/4·66 | 14·26/4·71 | 14·52/5·07 |
| 7th-9th grade boys | 14·33/4·15 | 14·61/4·39 | 14·83/5·11 | 14·67/5·04 | 14·70/4·79 | 14·52/4·78 |
| 7th-9th grade girls | 14·30/3·19 | 14·66/3·98 | 14·91/3·92 | 15·40/4·01 | 16·76/4·20 | 16·27/4·10 |

Data are number of individuals (%), mean (standard deviation), median (interquartile range), 90th percentile and percentages of overweight or obesity using International Obesity Task Force (IOTF) cut offs.* Median coverage is based on coverage percentages from all classes included in analyses when compared to numbers obtained from the Ministry of Children and Education.

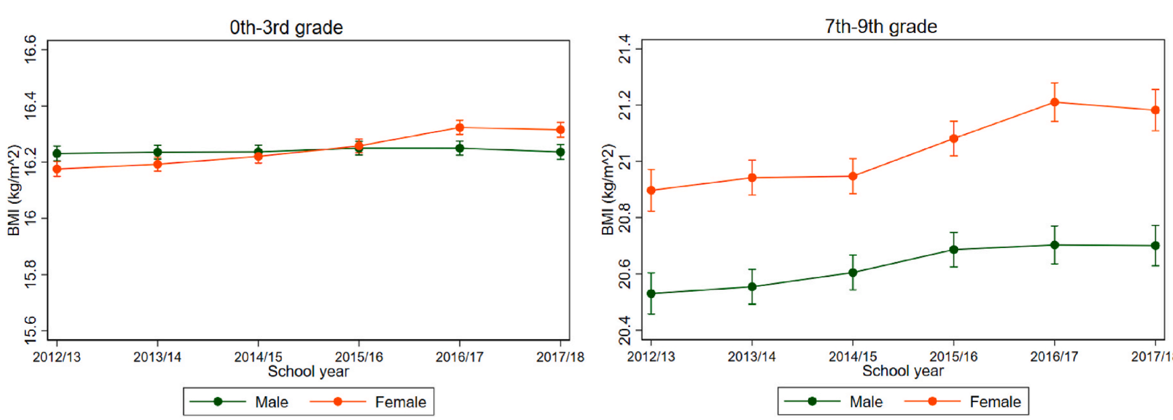


**Fig. 1.** Time trends in BMI by age-groups and sex
Estimates shown are mean BMI ($kg/m^2$) with 95 % CI by year and adjusted for age. The estimates were derived from a linear mixed model with random intercepts for school codes and individual identifiers. The model included main effects and an interaction term between time (categorical) and sex (fixed effects). In Fig. 2, time is treated continuous.

### 3.1.4. *Mean BMI adjusted for leisure time physical activity (sub-population)*

In a sub-population, a mixed-effect linear regression analysis was carried out to examine the effect of increased school time PA on BMI with adjustment for leisure time PA (n = 2374 from 35 schools). No change in post-policy slope was observed in this sub-population without adjusting for leisure time PA (β: −0·235 $kg/m^2$ per year, 95 % CI: −0·555; 0·085, P-value: 0·151)· Results only changed slightly when adjusting for leisure time PA, and no significant difference was observed (β: −0·224 $kg/m^2$ per year, 95 % CI: −0·541; 0·094, P-value: 0·167).

## 4. Discussion

This study aimed to investigate the effect on BMI of a new school policy requiring 45 min daily PA during school time. We found no significant decreases in slope in mean BMI or the 90th percentile BMI after

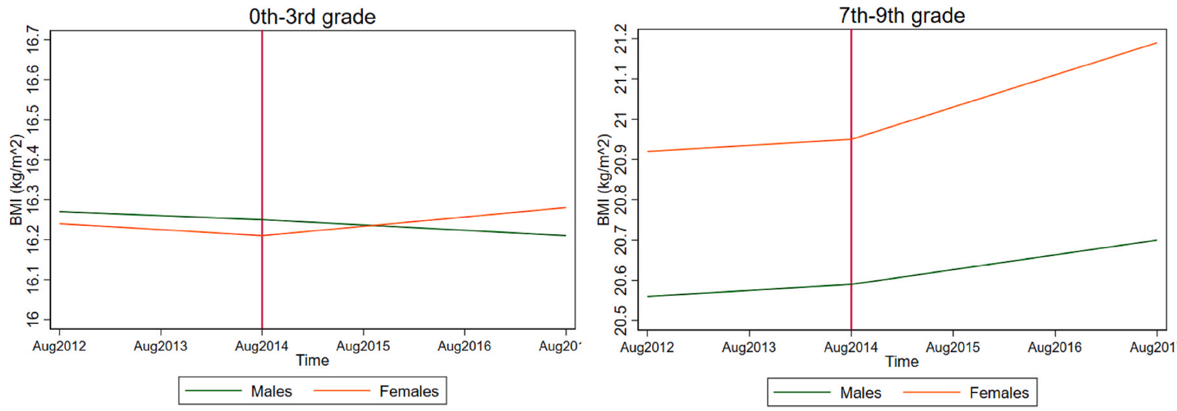


**Fig. 2.** BMI pre- and post-policy slopes by age-groups and sex. Pre- and post-policy trends based on marginal means of BMI (kg/m$^2$) from mixed-effects linear regression analyses adjusted for age with random intercepts for school codes and individual identifiers. Analyses included main effects for sex and time (continuous) and an interaction term between post-policy time (continuous) and sex. In Fig. 1, time is treated categorical. The red line marks the introduction of the school policy.

**Table 2**
Estimated difference in pre- and post-policy BMI slopes by age-group and sex.

| Age-group | Sex | β (95 % confidence interval) | P-value |
|---|---|---|---|
| 0$^{th}$-3rd grade (n = 449,660) | Boys | −0·002 (−0·011; 0·007) | 0·677 |
| | Girls | 0·034 (0·024; 0·043) | <0·001 |
| 7th-9th grade (n = 141,731) | Boys | 0·022 (−0·016; 0·059) | 0·252 |
| | Girls | 0·066 (0·028; 0·103) | 0·001 |

The difference in pre- and post-policy slopes are expressed as BMI points (kg/m$^2$) per year. n = number of observations (not individuals).

the school policy was introduced. On the contrary, mean BMI analyses suggested a small significant increase in post-policy slopes in girls in 0$^{th}$-3rd grade and 7th-9th grade. No significant changes were observed between pre- and post-policy slopes in the 90th percentile BMI.

Countless studies have examined the effectiveness of various school-based interventions including PA in preventing overweight and obesity in children, and meta-analyses found no to small reductions in BMI in favour of the intervention group [22–24]. Only a few studies have examined the effect of nationwide physical education policies on BMI [25–27]. To our knowledge, this is the first study to evaluate the impact of a nationwide school-based PA requirement on BMI using ITS. Contrary to the hypothesis, we observed an increase in mean BMI post-policy slope in girls. This increase could either indicate that the school policy, contrary to expectations, had a disadvantageous effect on BMI in girls or alternatively that the analyses are confounded by time-varying confounders, which is a risk with the repeated cross-sectional design. Since obesity is caused by complex interaction between genetics, behavioral and environmental factors many potential confounding factors exist (e.g. diet, physical activity etc.). Moreover, another relevant structural change occurred simultaneously with the PA requirement as the school day became longer. Previous studies have found that longer school days and increased PA during school hours reduce leisure time PA and engagement in sports activities [28,29], which could influence total PA. Post-policy increases in BMI slopes could also be caused by confounding factors changing between 2012 and 2018. Unfortunately, registry data did not allow for adjustment for these confounders. Screen use and sedentary behavior during leisure time have increased from 2012 and onwards [16,30]. It is plausible that this development has accelerated post-policy. Awareness of this potentially

**Table 3**
Estimated difference in pre- and post-policy 90th percentile BMI slopes by age-group and sex.

| Age-group | Sex | β (95 % CI) | P-value |
|---|---|---|---|
| 0$^{th}$ grade (n = 196,048) | Boys | 0·034 (−0·023; 0·091) | 0·239 |
| | Girls | 0·057 (−0·001; 0·115) | 0·053 |
| 8th grade (n = 73,399) | Boys | −0·105 (−0·359; 0·149) | 0·418 |
| | Girls | −0·008 (−0·251; 0·235) | 0·946 |

The difference in pre- and post-policy slopes are expressed as BMI points (kg/m$^2$) per year. n = number of observations (not individuals).

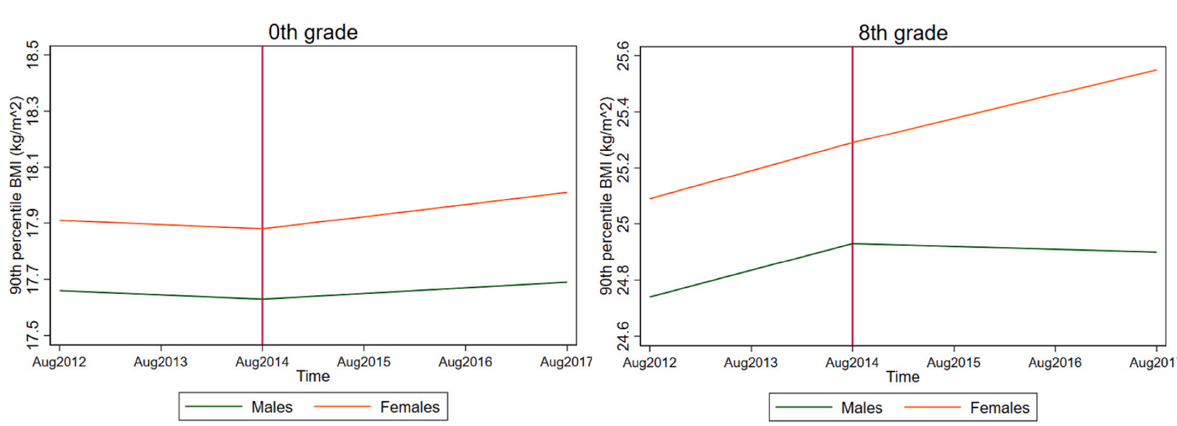


**Fig. 3.** 90th percentile BMI pre- and post-policy slopes by age-groups and sex
Pre- and post-policy trends in the 90th percentile BMI derived from quantile regression analyses adjusted for age. Analyses included main effects for sex and time (continuous) and an interaction term between post-policy time and sex. School code was included as a cluster variable. The red line marks the introduction of the school policy.

important confounder was the reason for including an analysis on a sub-sample, where it was possible to adjust for leisure time PA. No differences were observed in pre- and post-policy BMI slopes in this sub-population after adjustment for leisure time PA. The sub-population was smaller than the sample size in main analyses, which limits the power to detect small changes in BMI. Moreover, interaction term between time and sex was excluded to preserve power, which may have obscured any differences.

It is important to emphasize that the small increases observed in girls should be added to an already increasing BMI trend. When examining changes in mean BMI across the entire period between 2012 and 2018 (secular trends), significant yearly increases were observed in nearly all subgroups ($0^{th}$-3rd grade girls: β: 0·014 kg/m$^2$, 95%CI: 0·010; 0·019, P-value:<0·001; 7th-9th grade girls: β: 0·061 kg/m$^2$, 95%CI: 0·046; 0·076, P-value:<0·001; 7th-9th grade boys: β: 0·032 kg/m$^2$, 95%CI: 0·018; 0·047, P-value:<0·001). Changes were most pronounced in the oldest girls. In the 90th percentile BMI, no changes over time were observed in boys, but increased in girls in both age-groups ($0^{th}$ grade girls: β: 0·029 kg/m$^2$, 95%CI: 0·011; 0·048, P-value: 0·002; 8th grade girls: β: 0·095 kg/m$^2$, 95 % CI: 0·033; 0·157, P-value: 0·003). Even small yearly increases will accumulate over time. An increase among 7th-9th grade girls of 0·061 kg/m$^2$ yearly will result in a total increase of 0·6 kg/m$^2$ over a 10-year period.

Table 1 indicates that the prevalence of overweight and obesity is increasing in all subgroups. A study examined the prevalence of overweight in Europe between 2007 and 2017 identifying decreasing trends in Southern Europe, but unchanged or increasing trends in countries in Northern Europe [31]. A study conducted in Sweden revealed that the prevalence of overweight increased between 2004 and 2015, particularly among boys [32]. Furthermore, more recent data from Sweden covering the period of 2015 and 2021 for 6-9-year-olds also indicated a rising trend [33]. Therefore, the development does not seem to be restricted to Denmark.

The primary limitation of this study was the observational nature of the ITS approach. The gradual implementation of the school policy and the fact that BMI changes do not occur instantly make the ITS less reliable when compared to situations involving abrupt changes. Incorporating a control group was unfeasible due to the policy’s universal application across all Danish municipality schools. Private schools were also encouraged to adopt the policy changes. Thus, no suitable alternative controls were available within Denmark. Replicating the scale and methods outside the country, particularly the routine data collection through school nurses, would pose significant challenges. The absence of a control group introduces another limitation by elevating the risk of time-varying confounding, particularly concerning variables such as physical activity, screen time, diet, etc. Unfortunately, the unavailability of population-scale data on these factors precluded our ability to make the necessary adjustments. The possible increasing trend in obesity among Swedish 6-9-year-old children, based on routine surveillance data from 2015 to 2021 [33], may indicate that the rise observed in Danish children is not directly attributable to the school reform. However, comparing Denmark with Sweden is not without its challenges and does not offer an ideal control group due to differing national policies, cultural factors, and lifestyle behaviors.

An additional important limitation in this study is BMI’s limited ability to differentiate between gained lean mass and gained fat mass. The school policy focuses on physical activity, which is a crucial predictor of lean mass in children and adolescents. Thus, the BMI measurement may conceal important changes in body composition over time in this study. Nevertheless, the ability of the BMI outcome to be a surrogate for adiposity varies across the degree of fatness [34]. A study examining children and adolescents aged 5-18y found that above the 85th BMI percentile (BMI-for-age) BMI was highly associated with fat mass, but below the 50th percentile BMI was more related to fat-free mass [34]. This underpins the importance of the 90th percentile BMI analyses included in the present study, since BMI more accurately reflects adiposity at this percentile compared to the mean BMI.

Another limitation of the present study is the violation of the assumption about normality of residuals (Supplement, Fig. 1). Transparency and interpretation were prioritized, and data was not transformed.

We excluded school classes that did not have coverage of at least 70 % of the student population. No information existed that could be used to study whether the school classes that did not meet this criterion systematically differed from those that did. Thus, selection bias cannot be ruled out. We included all school grades with a coverage of at least 70 %, even if there were not complete data for the given grade and school across all school years. In post hoc sensitivity analyses, all main analyses were conducted again in a balanced design, where schools and grades were only included if there were complete data across all school years. The sample sizes in these analyses were substantially reduced. A positive change in BMI-slopes from pre-to post-policy were still observed in girls in both age-groups, but it was no longer significant in 7th-9th grade girls (Supplement, Table 3). This could be due to the reduced sample size in the balanced design. No relevant differences were observed between the balanced and unbalanced analyses in mean BMI for boys (Supplement, Table 3) and the 90th percentile BMI for boys and girls (Supplement, Table 4).

## 5. Conclusions

Results suggest that a school policy requiring 45 min of PA daily during school time was not able to reverse the trend of increasing mean BMI and BMI at the 90th percentile in Danish school children. A small increase in slope was observed post-policy in mean BMI in girls in both age-groups. When analyses on mean BMI were divided into socioeconomic groups in the 7th – 9th graders, a post-policy increase in mean BMI were observed in boys and girls from low socioeconomic schools. Whether the increase observed post-policy in mean BMI is due to an unexpected positive effect on BMI of the school policy among girls or due to unadjusted time-varying confounding is not possible to determine with this repeated cross-sectional design. It is important to emphasize that the increases in BMI should be added to an already increasing trend in mean BMI and the 90th percentile BMI.

Childhood and adolescent overweight and obesity pose a growing societal burden, which if unaddressed, escalates further into adulthood. Historically, structural changes have proven effective in health promotion and disease prevention, highlighting the significance of investigating the effectiveness of new initiatives like the present one. Despite the substantial effort dedicated to maintaining methodological rigor, the limitations identified in this study underscore the importance of national monitoring of health determinants and outcomes. This monitoring data becomes particularly valuable in situations where traditional control groups are not feasible, as is the case when an entire population, like the Danish population of school-aged children in our study, is exposed to a new structural intervention.

## Funding

The Danish Foundation TrygFonden has funded the project (ID 115606).

## Data sharing statement

This study is based on register data and data will not be publicly available after submission. Data was accessed by applying The Danish Health Data Authority (Sundhedsdatastyrelsen). A statistical analysis plan was pre-registered at Open Science Framework (https://osf.io/etr7x/).

## Acknowledgements

We thank all the schools, teachers, school leaders, children, and parents, who participated in PHASAR study, EYHS, SPACE, and the CHAMPS- study dk (secondary analyses). Also, a special thanks to all the researchers contributing to the historical studies. We also thank The Danish Foundation TrygFonden for funding the study (ID 115606).

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhip.2024.100510.

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