Evaluations of school-based and fiscal efforts on diet-related behaviors and weight, emphasizing fruit, vegetables, candy, and soda

Bente Øvrebø

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–Bente Øvrebø

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Summary

Background

A healthy diet includes high intake of fruit and vegetables and low intake of unhealthy products high in energy density, added sugars, and/or saturated fats. Many individuals consume low amounts of fruit and vegetables, and high quantities of unhealthy products associated with increased risk of overweight and noncommunicable diseases. The World Health Organization recommends school-based and fiscal efforts to promote a healthy diet and weight. Studies of short- and long-term effects from such real-life large-scale efforts are warranted.

This thesis is based on three separate Norwegian initiatives implemented during the 21st century. First, the Fruit and Vegetables Make the Marks (FVMM) project was a school-based intervention study that aimed to increase fruit and vegetable intake among children. Second, a nationwide free school fruit and vegetable policy, provided pupils with a daily piece of fresh fruit or vegetables. Third, taxes on candy and soda were raised abruptly, effective January 1, 2018. The overall aim of this thesis was to evaluate the effects from these school-based and fiscal efforts on diet-related behaviors and weight, with a particular emphasis on fruit, vegetables, candy, and soda.

Methods and findings

Three papers were included in this thesis. Paper I focused on the FVMM project, a cluster-randomized study initiated in 2001. The sample comprised 38 schools (1,950 pupils) from two Norwegian counties. Eighteen schools were randomized to the intervention, and 20 served as controls. The intervention comprised a multicomponent school-based educational program administered for one school year in an effort to increase fruit and vegetable intake. Furthermore, nine of the intervention schools in one county were given free fruit at school, resulting in a subgroup receiving the multicomponent educational program and free school fruit and vegetables. Data were collected in 2001 (baseline: mean age of 11.8 years) and in four additional follow-up collections before the final one in 2016, when the pupils were adults (mean age: 26.5). Linear mixed models were used to estimate differences in fruit and vegetable intake during adulthood between groups. The analyses found no differences in fruit or vegetable intake among adults who in

childhood had received the multicomponent educational program compared with the controls. Among the subgroup of individuals who received free school fruit and vegetables, no synergistic effect from the multicomponent educational program on adult fruit and vegetable intake was found.

An evaluation of the nationwide free fruit and vegetable policy (Paper II), implemented from 2007 to 2014, was possible due to the policy's rollout, in which some schools were exposed, while others were not. By utilizing cross-sectional and longitudinal anthropometric data from four national representative cohorts from the Norwegian Childhood and Youth Growth studies, a quasi-natural experimental design was used to evaluate the effects from policy exposure on weight outcomes at ages 8.5 and 13. Heterogeneity was examined in effects across exposure duration, sex, and socioeconomic status. Pooled models indicated no consistent beneficial or unintended effects from 1–2.5 years of exposure to the policy on weight outcomes at age 8.5 or at age 13, with up to four years of exposure.

The abrupt increases in candy and soda taxes – 80% and 40%, respectively – were evaluated using a quasi-experimental design (Paper III). By accessing retail sales data from nearly all Norwegian grocery stores, sales of candy and soda during the season with the tax increases were compared with sales during the season before the tax hikes (control season). Two models were used to evaluate the effects from the tax increases on volume sales of candy and soda, with one estimating the immediate effect on sales and another estimating average changes in sales. The analyses revealed no detectable reductions in sales of the taxed products that coincided with the tax increases.

Conclusion

The school-based and fiscal efforts evaluated in this thesis did not yield detectable or consistent effects on diet-related behaviors and weight, emphasizing fruit, vegetables, candy, and soda. Overall, the findings indicate the need for adapted and/or additional efforts to improve diet and reduce overweight and obesity in Norway.

Sammendrag [in Norwegian]

Bakgrunn

Et sunt kosthold inkluderer et høyt inntak av frukt og grønnsaker, og et begrenset inntak av usunne produkter med et høyt innhold av energi, tilsatt sukker og/eller mettet fett. Mange individer spiser likevel lite frukt og grønnsaker og har et høyt inntak av usunne produkter, som er assosiert med økt risiko for overvekt og ikke-smittsomme sykdommer. Verdens helseorganisasjon anbefaler skolebaserte og fiskale tiltak for å fremme et sunt kosthold og redusere overvekt og fedme. Det er behov for studier som evaluerer kort- og langtidseffekter av slike tiltak som er gjennomført i en naturlig setting.

Denne avhandlingen tar utgangspunkt i tre separate tiltak som ble iverksatt i Norge på 2000-tallet. Først «Frukt og grønt i sjette» som var et forskningsprosjekt bestående av et multikomponent skolebasert undervisningsopplegg med hensikt å øke frukt- og grønnsaksinntaket til skolebarn. Deretter den nasjonale skolefruktordningen, som var et tiltak der skoleelever fikk én porsjon frukt eller grønnsaker i løpet av skoledagen gratis. Siste tiltak inkludert i avhandlingen er økningen av de eksisterende avgiftene på sjokolade og sukkervarer (søtsaker) og alkoholfrie drikkevarer (brus), som fant sted 1. januar 2018. Det overordnede målet i avhandlingen er å evaluere effektene av disse skolebaserte og fiskale tiltakene på ernæringsrelatert atferd og vektstatus, med fokus på frukt, grønnsaker, søtsaker og brus.

Metode og funn

Tre vitenskapelige artikler presenteres i denne avhandlingen. «Frukt og grønt i sjette» var en klynge-randomisert intervensjonsstudie igangsatt i 2001 (artikkel I). Utvalget besto av 38 skoler (1950 elever) fra to fylker i Norge, hvor atten skoler ble tilfeldig fordelt til å motta intervensjonen og 20 skoler utgjorde kontrollskoler. Intervensjonen besto av et multikomponent skolebasert undervisningsopplegg som ble gitt over ett skoleår, med formål om å øke inntak av frukt og grønnsaker. Ni intervensjonsskoler i ett av fylkene ble i tillegg gitt gratis frukt på skolen, som resulterte i at en undergruppe fikk både undervisningsopplegget og gratis skolefrukt. Opplysninger ble samlet inn i 2001 (utgangsnivå ved gjennomsnittsalder på 11,8 år), og i fem oppfølgingsrunder med siste innsamling i

2016, da elevene var blitt voksne (26,5 år). Blandede lineære modeller ble brukt til å estimere gruppeforskjeller i frukt- og grønnsaksinntak i voksen alder. Analysene viste ingen forskjeller i hverken frukt- eller grønnsaksinntak mellom gruppen som i barndommen hadde mottatt undervisningsopplegget og kontrollgruppen. Det ble heller ikke observert forsterkende effekter av gratis skolefrukt i undergruppen som fikk dette i tillegg til undervisningsopplegget.

Gjennomføringen av den nasjonale skolefruktordningen (artikkel II) i 2007 til 2014 førte til at noen skoler var omfattet av ordningen, mens andre ikke var det. Dette resulterte i et kvasieksperiment. Tverrsnitt- og longitudinelle antropometriske målinger fra fire nasjonalt representative kohorter i Barne- og Ungvekststudiene ble brukt til å vurdere effekten av skolefruktordningen på vektutfall ved 8- og 13-års alder. Effekter av ordningen ble også vurdert etter eksponeringstid og mellom kjønn og sosioøkonomisk gruppe. Samlede analyser viste ingen konsistente fordeler eller utilsiktede konsekvenser av 1-2,5 år med eksponering for skolefruktordningen på vektutfall ved 8,5 år eller ved 13-års alder hvor elevene var eksponert i opptil fire år.

Økningene i de eksisterende avgiftene på søtsaker og brus på henholdsvis 80- og 40% ble evaluert ved bruk av et kvasieksperimentelt design (artikkel III). Volumsalget av søtsaker og brus fra nesten alle norske dagligvarehandler i sesongen med avgiftsøkningene ble sammenliknet med salg av disse varene i forrige sesong (kontrollsesong). To modeller ble brukt til å evaluere effektene av avgiftsøkningene på volumsalg av søtsaker og brus. Den ene modellen estimerte den umiddelbare effekten på salg, mens den andre estimerte gjennomsnittsendringen i salg. Ingen av modellene ga påviselige reduksjoner i salg av de avgiftsbelagte produktene.

Konklusjon

De skolebaserte og fiskale tiltakene som ble evaluert i denne avhandlingen ga ingen påviselige eller konsistente effekter på ernæringsrelatert atferd eller vektstatus, med fokus på frukt, grønnsaker, søtsaker og brus. Generelt indikerer funnene behovet for modifiserte og/eller ytterligere tiltak for å forberede kostholdet og redusere overvekt og fedme i Norge.

List of Papers

Paper I

Øvrebø B, Stea TH, Te Velde SJ, Bjelland M, Klepp KI, Bere E. A comprehensive multicomponent school-based educational intervention did not affect fruit and vegetable intake at the 14-year follow-up. Prev Med. 2019 Apr;121:79-85.

Paper II

Øvrebø B, Stea TH, Bergh IH, Bere E, Surén P, Magnus PM, Juliusson PB, Wills AK. No strong evidence of benefits or unintended consequences on BMI or overweight from a nationwide school fruit and vegetable policy: a quasi-natural experimental study. PLoS Med. 2021 Sep (under revision).

Paper III

Øvrebø B, Halkjelsvik TB, Meisfjord JR, Bere E, Hart RK. The effects of an abrupt increase in taxes on candy and soda in Norway: an observational study of retail sales. Int J Behav Nutr Phys Act. 2020 Sep 14;17(1):115.

Abbreviations

ASBs	Artificially sweetened beverages
BMI	Body mass index
BMI_{SDS}	Body mass index standard deviation scores
CI	Confidence interval
cm	centimeter
COSI	The WHO European Childhood Obesity Surveillance Initiative
CVDs	Cardiovascular diseases
DALYs	Disability adjusted life years
dl	deciliter
DONE	Determinants of nutrition and eating
EUR	Euro (European currency)
FFV	Free fruit and vegetables
FVMM	Fruit and Vegetables Make the Marks
kg	kilogram
m	meter
MLMs	Multilevel models
OR	Odds ratio
OW/OB	Overweight and obesity
NA	Not applicable
NCDs	Noncommunicable diseases
NCGS	Norwegian Childhood Growth Study
NFFV	No free fruit and vegetables
NOK	Norwegian kroner (currency)
NYGS	Norwegian Youth Growth Study
QEs	Quasi-experiments
RCTs	Randomized controlled trials
SD	Standard deviation
SES	Socioeconomic status
SSBs	Sugar-sweetened beverages
WC	Waist circumference
WHtR	Waist-to-height ratio
WHO	World Health Organization

Contents

Acknowledgements v
Summary vii
Sammendrag [in Norwegian] ix
List of Papers xi
Abbreviations xiii
1 Introduction 1
1.1 Public health challenges 1
1.1.1 Noncommunicable diseases 1
1.1.2 Overweight and obesity 2
1.2 Diet 3
1.2.1 Dietary factors and health outcomes 3
1.2.2 Dietary recommendations 6
1.2.3 Dietary intake among adults and children in Europe and Norway 6
1.3 Promoting health and health-related behaviors 8
1.3.1 Determinants of health and health-related behaviors 8
1.3.2 Individual-level and structural efforts 10
1.3.3 Recommended efforts to promote a healthy diet and weight 12
1.3.4 Norwegian initiatives 13
1.4 Rationale for thesis 14
1.5 Overall research aim and specific objectives 15
2 Materials and methods 17
2.1 Fruit and Vegetables Make the Marks project (Paper I) 17
2.1.1 Study design 17
2.1.2 Sample 19
2.1.3 Intervention components 19
2.1.4 Data collection 21
2.1.5 Statistical methods 22
2.1.6 Ethics 23
2.2 The Childhood Growth study and Youth Growth study (Paper II) 23
2.2.1 Study design 23
2.2.2 Sample 25
2.2.3 Data collection and variables 27
2.2.4 Statistical methods 28

2.2.5 Ethics 30
2.3 Retail data from Nielsen Company (Paper III)..................................30
2.3.1 Study design 30
2.3.2 Data and variables 30
2.3.3 Statistical methods..31
2.3.4 Ethics 33
3 Results..35
3.1 Effects from a multicomponent school-based educational program on long-term fruit and vegetable intake (Paper I) 35
3.2 Effects from a free school fruit and vegetable policy on weight (Paper II)..37
3.3 Effects from tax increases on sales of soda and candy (Paper III).......42
4 Discussion 45
4.1 Methodological considerations..45
4.1.1 Randomized controlled trials and quasi-experiments......................45
4.1.2 Internal validity associated with study design................................46
4.1.3 Confounding and information bias 49
4.1.4 Selection bias and external validity 50
4.1.5 Ethical considerations..52
4.2 Discussion of results..53
4.2.1 Why were there no effects from a multicomponent school-based intervention on fruit and vegetable intake in adulthood? 53
4.2.2 A free school fruit and vegetable policy as an effort to address childhood and adolescent overweight and obesity 57
4.2.3 Fiscal efforts that affect sales and possibly diet 60
4.2.4 General considerations 64
4.3 Implications 68
5 Conclusion 71
List of references 73
Appendices 89

1 Introduction

Dietary factors and overweight and obesity are some of the most influential risk factors for disease, disability, and premature death (1-3). Therefore, diet is important for health. To optimize dietary patterns, it is essential to implement efforts that promote a healthy diet.

1.1 Public health challenges

1.1.1 Noncommunicable diseases

Noncommunicable diseases (NCDs) are the main causes of death worldwide and are responsible for the greatest number of healthy life years lost (4). The World Health Organization (WHO) defines *NCDs* as chronic diseases, mainly including cardiovascular diseases (CVDs), cancers, chronic respiratory diseases, and diabetes (5). In 2019, NCDs accounted for 74% of all global deaths and were responsible for 64% of total disability adjusted life years (DALYs) (1, 6). Similar to global estimates, the main causes of death in Norway are NCDs, with cancer and CVDs as the top contributors (7), and approximately 87% of the Norwegian burden of disease attributed to NCDs in 2016 (8). In addition to causing death and disability, NCDs strain individual, family, and household finances (9, 10). Furthermore, treating NCDs is costly, as they negatively impact national income, socioeconomic development, and economic growth due to loss of productivity, prolonged disability, and increases in health and social care expenditures (9, 11). NCDs represent a public health concern, but can be prevented to some extent.

The development of NCDs is complex and caused by several factors (2). Some leading risk factors are linked to health-related behaviors and are preventable (1, 5). Health-related behaviors, often termed modifiable risk factors, include tobacco use, physical inactivity, a suboptimal diet, and alcohol intake, and they increase the risk of NCDs (5). These factors are associated with leading metabolic risk factors, such as high systolic blood pressure, high fasting plasma glucose, and overweight (body mass index [BMI] ≥ 25 kg/m^2) (1). Prevention and reduction of NCDs and their consequences depend on improving and limiting leading risk factors, such as diet quality and overweight (12).

1.1.2 Overweight and obesity

Overweight is a public health challenge in itself and one of the most important risk factors contributing to the global burden of disease (1, 13). In 2019, overweight and obesity were responsible for 160 million DALYs and more than 5 million deaths globally (1). Overweight can be described as a metabolic risk factor for NCDs and is associated with modifiable risk factors for NCDs, particularly diet quality and physical inactivity (1, 14). Some countries define *obesity* (BMI ≥ 30 kg/m^2) as a chronic disease outcome, not merely a risk factor for disease (15, 16). In this thesis, overweight and obesity will be referred to as both risk factors for disease and health outcomes.

Global prevalence of obesity has nearly tripled from 1975 to 2016, and in 2016, 39% of adults were categorized as overweight and 13% as obese (17). No single country has experienced a significant decline in the national proportion of overweight and obesity between 1990 and 2019 (1). Recent (2020) national self-reported data from Norway indicate that 47% of women and 59% of men are categorized with overweight or obesity (18). These numbers are about 10% lower for both sexes when compared with a regional sample with objective measures from 2017–2019 (19).

Global prevalence of childhood and adolescent overweight and obesity also has increased substantially, from 4% in 1975 to 18% in 2016 (17). Among European children aged 2–13, overall overweight and obesity prevalence was reported to be 21% in 2011–2016, but with large between-country variations (20). Compared with mean European estimates, prevalence of overweight and obesity among Norwegian children and adolescents is somewhat lower, with approximately 20% of 9-year-olds and 16% of 13-year-olds categorized with overweight or obesity (21, 22). The prevalence of overweight and obesity among children in Norway has been stable over the past decade (21). A higher prevalence of overweight and obesity exists among children of parents with low education compared with higher education (23). In high-income countries, including Norway, overweight and obesity prevalence tends to be inversely associated with socioeconomic status (SES) (15, 23).

Childhood overweight and obesity are associated with both short-term and long-term consequences (24). Childhood obesity is of particular concern, as it is associated with cardiovascular risk factors in childhood and several psychological comorbidities, such as depression, low self-esteem, and poor (health-related) quality of life (24-26). Moreover, strong indications exist that overweight follows individuals from childhood to adulthood, with increased morbidity and mortality in adulthood (24, 27, 28).

The factors that influence overweight and obesity are complex, yet most cases arise from physical inactivity, surplus caloric intake, and poor diet quality (15, 29, 30). Moreover, tracking of both diet and physical activity from childhood to adulthood indicates the need for intervention in childhood (31). Consequently, dietary intake in childhood and adulthood is important in preventing and reducing both overweight and NCDs.

1.2 Diet

1.2.1 Dietary factors and health outcomes

A suboptimal diet is one of the most important risk factors for overweight, and NCDs (1, 5). Globally, dietary risk factors were responsible for 8 million deaths and 188 million DALYs in 2019 (1). Worldwide, a suboptimal diet currently can be defined as one with low intake of fruit, vegetables, legumes, nuts, and whole grains, and high intake of refined sugars, sugar-sweetened beverages (SSBs), red or processed meat, and processed foods high in sodium, added sugars, and trans fats (1, 32, 33). More than half of diet-related deaths and two-thirds of diet-related DALYs were attributed to high sodium intake and low intake of whole grains and fruit. Furthermore, dietary intake directly contributes to energy balance and body weight regulation, and a suboptimal diet may increase the risk of excessive caloric intake, resulting in overweight and obesity (30, 34, 35). Therefore, improving diet is important to reducing the burden of disease.

Establishing a causal relationship between dietary factors and health outcomes is complex (36). Nonetheless, an optimal diet – incorporating high intake of fruit, vegetables, legumes, plant oils, whole grains, and fish, and limiting refined grains, sugar, processed meats, and highly processed foods high in sodium, added sugars, or trans fats – is associated with optimal metabolic risk factors and reduced risk of

NCDs and deaths from all causes (3, 32, 33, 37). Moreover, high intake of fruit and vegetables, and limited intake of energy from added sugars and saturated fats – often found in unhealthy products such as soda, chocolate, and candy – are viewed as important for an optimal diet (33). Additional dietary factors and overall dietary patterns are essential for health, but this is not the focus of this thesis. From here, the dietary risk factors most relevant to this thesis will be elaborated and emphasized in the following sections, mainly fruit, vegetables, and foods and beverages high in energy density, added sugars, and/or saturated fats. Additional information on other dietary risk factors and health outcomes can be found elsewhere (3, 32, 33, 37, 38).

Fruit and vegetables

According to the global burden of disease project, a diet low in fruit and vegetables is associated with increased deaths from NCDs (3). Fruit and vegetable intake can reduce the risk of hypertension, CVDs, type 2 diabetes, certain types of cancer, and all-cause mortality (39-48). Furthermore, fruit and vegetables are excellent sources of several nutrients, fiber, and bioactive compounds (41). Although most studies that link fruit and vegetable intake to health outcomes are observational, the evidence is viewed as consistent and justifies promoting fruit and vegetable intake from a public health perspective to decrease the disease burden from NCDs (49).

Moreover, fruit and vegetables are low in energy density and might reduce caloric intake if they replace energy-dense foods (41). Studies indicate an inverse association between fruit and vegetable intake, and body weight outcomes (34, 50-52). Randomized controlled trials (RCTs) among adults indicate that intake of whole, fresh fruit promotes weight maintenance or modest weight loss over a period of 3–24 weeks (52). However, observational studies among children and adolescents have found mixed associations between fruit and vegetable intake, and weight outcomes (53-56). Field et al. reported that fruit and vegetable intake did not predict BMI changes over a three-year period among 9- to 14-year-olds in a prospective U.S. cohort study (54). Bayer et al. reported a tendency toward lower BMI gains among children with increased fruit intake compared with children with decreased fruit intake from age 6 to the age of 10 years (53). However, an opposite, tendency was reported for vegetables. Altogether, the significance of consuming fruit and vegetables in relation to weight has been suggested among adults, but the evidence among children is somewhat contradictory. Nonetheless, promotion of fruit and vegetable intake is used as a tool to tackle obesity (57-59).

Unhealthy foods and beverages

In this thesis, *unhealthy foods and beverages* are defined as products high in energy density, added sugars, and/or saturated fats, typically SSBs and candy. Some of the aforementioned nutrients are investigated to a larger extent than food groups; therefore, the following section will include health outcomes associated with both nutrients and food and beverage groups.

Energy-dense foods and foods high in added sugars and/or saturated fats – such as fast foods, snacks, sweets, and desserts – are linked with high caloric intake, tooth decay, and increased risk of obesity and NCDs (3, 14, 32, 60). Refined grains, often part of pastries and other baked goods, are associated positively with weight gain and overweight (34). Extant evidence also suggests that higher, compared with lower, sugar intake negatively influences blood pressure and serum lipids and, thus, may increase the risk of CVDs (33, 61, 62).

Most SSBs contain high amounts of added sugars and, therefore, may increase the likelihood of excess calorie intake (33, 63). Moreover, studies indicate a positive association between SSB consumption and weight gain, as well as greater risk of overweight and obesity, hypertension, CVDs, type 2 diabetes, and tooth decay (34, 42-44, 46, 60, 63-65). Artificially sweetened beverages (ASBs), which mostly contain no sugar and close to zero calories, have emerged as an alternative to SSBs and may be used as a tool in weight reduction and management (66). However, ASBs also are associated with dental erosion and some studies indicate that ASBs may trigger compensatory bodily mechanisms that offset any benefits from calorie reduction through less SSB consumption (66, 67). No global consensus on ASB recommendations exists. Because water is the recommended beverage, a discussion of any possible health effects from intake of SSBs vs. ASBs is not elaborated further in this thesis, and the term *soda* henceforth may refer to both beverages.

1.2.2 Dietary recommendations

Studies that indicate a relationship between dietary factors and different health outcomes have been used widely to inform national and international guidelines for the general population on a healthy diet (3, 33, 68). The prevailing message from various guidelines is to consume adequate amounts of whole grains, fruit, and vegetables, with moderate or low intake of fats, sugars, meats, caloric beverages, and salt (69). For generally healthy populations, the WHO recommends 400 grams (five portions) of fruit and vegetables daily (33, 70). Total fat intake should not exceed 30% of total energy intake, and less than 10% of energy intake should come from saturated fats (33). Furthermore, it is recommended that fat intake shift from saturated and trans fats to unsaturated fats. It also is recommended that intake of free sugars[1] not exceed 10% of total energy intake (71), with a further reduction to less than 5% for additional health benefits (33). Salt intake should not exceed 5 grams per day. Furthermore, energy intake should be in balance with energy expenditure to avoid overweight and obesity. Norway's nutritional recommendations are in line with those of WHO, but deviate somewhat, as they recommend 500 grams of fruit and vegetables per day, that total fat intake contribute 25–40% of total energy intake, and that salt intake should not exceed 6 grams per day (72). Despite efforts to promote dietary recommendations, adherence to an optimal diet generally is low worldwide, representing a substantial health concern (3).

1.2.3 Dietary intake among adults and children in Europe and Norway

Worldwide, large populations report having suboptimal diets with low intake of healthy foods such as fruit and vegetables (3, 33). Across Europe, 14% of individuals over age 15 adhere to the recommendation of consuming five portions of fruit and vegetables per day (73, 74), with large variations between countries (75). A national survey on Norwegian adults in 2020 revealed that 2.3% of adults met the recommended intake of fruit and vegetables, with a mean self-reported intake of two portions per day (18). Moreover, most European children, including Norwegians, do not meet the recommendation for fruit and vegetable intake (76).

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[1] Free sugars are all sugars added to foods or drinks by the manufacturer, cook or consumer, as well as sugars naturally present in honey, syrups, fruit juices, and fruit juice concentrates (71). Added sugar is covered under the *free sugar* definition. Norwegian nutritional recommendations use the term *added sugar* in their recommendations (72).

Among children in ten European countries, 23.5% met the WHO's recommendations in 2009, with a mean fruit and vegetable intake of 220–345 grams per day. Compared with European estimates, intake of fruit and vegetables among Norwegian 9- and 13-year-olds was lower in 2015, with a reported mean intake of approximately 200 grams per day (77). More recent data (2018) indicate that half of Norwegian 11-, 13- and 15-year-olds do not eat the recommended amount of fruit and vegetables (78).

A suboptimal diet also is characterized by surplus caloric intake and excessive intake of saturated fats, added sugars, trans fats, and salt due to increased consumption of highly processed, energy-dense foods and SSBs (3, 33, 79). Most European countries exceed the recommendation on saturated fats (80). Moreover, European adults exceed the WHO recommendation of 5% of total energy from free sugars (81), with children and adolescents often exceeding the 10% recommendation. Similar findings have been reported from Norway, with national surveys among adults indicating that saturated fats contribute 13% of total energy intake and added sugars 7% (82). The main reported sources of added sugars among European and Norwegian adults are sweet products and SSBs (81, 82). In 2020, 13% of Norwegian adults reported drinking SSBs three times or more each week, and approximately 30% reported eating chocolate and candy more than three times a week (18). Among European and Norwegian children, 11–17% of total energy intake is obtained from added sugars, with sweet products and beverages reported as the main sources (77, 81). Furthermore, about 1-in-10 European children report consuming sweet snacks or SSBs daily (83). Mean daily intake of sweets among Norwegian 9- and 13-year-old children has been reported to be 20 and 30 grams respectively, and intake of SSBs 1.5 dl and 2 dl, respectively (77).

Furthermore, unhealthy dietary patterns are more prevalent among individuals with lower SES (75, 84, 85). Those with lower SES often report lower intake of fruit and vegetables and higher intake of SSBs than individuals with higher SES (84, 85). This pattern also has been observed in the Norwegian population (18). Suboptimal dietary patterns in those with lower SES indicate the importance of interventions reaching individuals with lower SES to reduce inequalities. Regardless of socioeconomic inequalities in diet, the mismatch between dietary recommendations and reported intake among a large number of individuals suggests that an optimal diet (and healthy body weight) should be emphasized in public health promotion.

1.3 Promoting health and health-related behaviors

The number of individuals with suboptimal diets and the prevalence of overweight and obesity necessitate action to improve diet and reduce overweight and obesity worldwide (3, 17, 86). To promote a healthy diet and reduce overweight and obesity, efforts should aim to affect influential factors (determinants) of diet and weight. The terms *interventions* and *efforts* are used interchangeably in the coming sections.

1.3.1 Determinants of health and health-related behaviors

Determinants of health are defined as factors that may influence health positively or negatively (87). Many determinants of various health behaviors and several models exist and are used to classify determinants that can be used as tools to examine determinants of health and specific health-related behaviors, such as dietary intake and overweight and obesity (88-90). Most models conceptualize determinants according to societal levels. Such models are useful in explaining health and may be used as a framework in developing efforts aimed at improving health or specific health-related behaviors. In this thesis, a broader model used to classify determinants of health is described in the following section.

One of the most common eco-social models used to classify determinants of health in populations is presented by Dahlgren and Whitehead (89, 91), who conceptualized the main determinants of health with the individual at the center, containing mostly fixed characteristics that influence health, such as age, sex, and constitutional characteristics (87, 91). Surrounding the individual at the center are four levels of modifiable determinants (Figure 1). The level closest to the individual (first level) comprises individual lifestyle factors, such as diet, tobacco use, and physical activity. Other important determinants include social and community networks (second level), and living and working conditions (third level). The fourth level is the major structural environment, comprising general socioeconomic, cultural, and environmental conditions. Determinants can be influenced at all levels and interact with each other.

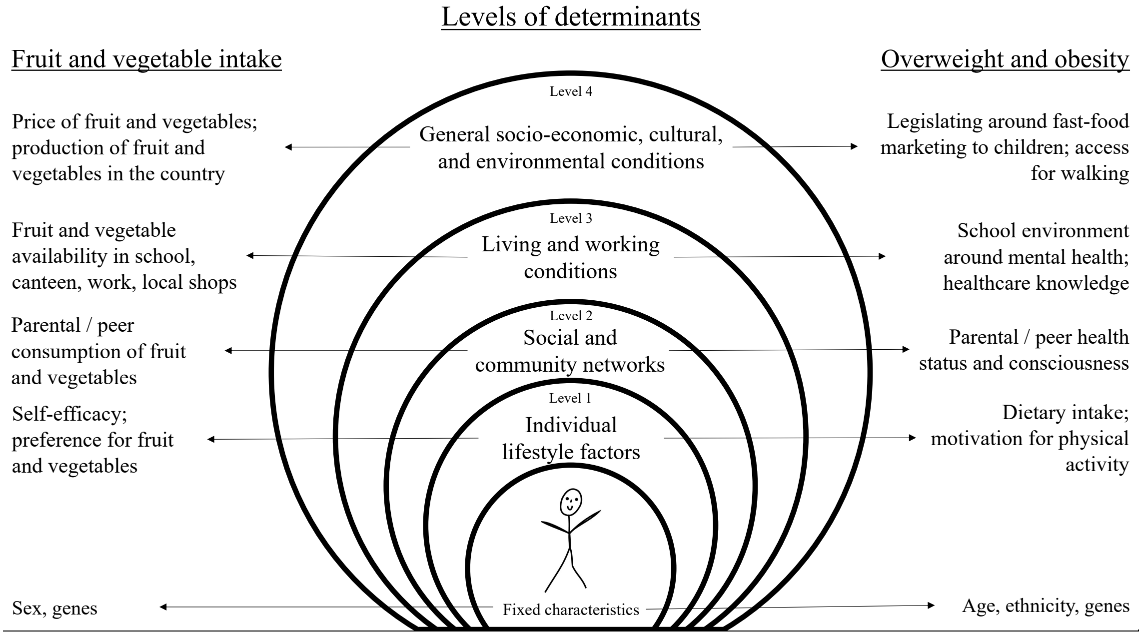

Figure 1. The main determinants of health conceptualized by Dahlgren and Whitehead (middle), including examples of determinants of fruit and vegetable intake (left) and overweight and obesity (right).

Figure adapted from Dahlgren and Whitehead (91). Examples of the determinants at different levels are not exhaustive.

The levels of determinants can serve as levels for interventions to influence health-related behaviors (91). For example, interventions aimed at changing diet and weight can use various techniques directed at one or more determinants of the target behavior (92, 93). To be successful, efforts should affect modifiable determinants and determinants relevant to the outcome. For illustrative purposes, Figure 1 includes examples of important and potentially modifiable determinants of fruit and vegetable intake, and overweight and obesity at each level in accordance with the model by Dahlgren and Whitehead (91).

Determinants of diet and overweight and obesity

Diet is influenced by various determinants depending on the individual, such as nutrition knowledge, preferences, and shopping and food preparation skills (88, 90, 91, 94-96). Other individual determinants of diet include habits, taste, and social-cognitive determinants such as self-regulation, intention, and self-efficacy (97, 98). Furthermore, diet is influenced by environmental conditions (90, 91, 94). Key environmental determinants often targeted to improve diet include availability and accessibility of foods and beverages, exposure to food and beverage marketing, and market prices (91, 94, 95, 99, 100).

Determinants found to be associated positively with fruit and vegetable consumption in childhood and identified as strong predictors of fruit and vegetable consumption in adulthood are taste preferences, knowledge, and awareness (101-105). Furthermore, availability, habits, motivation, goals, and beliefs about capabilities are some of the most consistent determinants of fruit and vegetable consumption (101, 104-107). Moreover, affordability, limited availability of unhealthy foods at home, intake of other foods, higher self-efficacy/perceived control, higher social support, and higher (household) income have been associated with increased fruit and vegetable consumption (102, 104, 106).

Arguably, determinants of diet also can be categorized as indirect determinants of overweight and obesity, which are driven partly by dietary intake (15, 30). Thus, typical individual determinants of overweight and obesity are factors related to lifestyle, such as diet and physical activity level (108). As for diet-related behavior, environmental determinants of overweight and obesity also include taxation, income, and the built environment, such as access to transportation and affordable and healthy foods (15, 108).

1.3.2 Individual-level and structural efforts

As mentioned in Section 1.3.1, levels of determinants can serve as levels for interventions, such as at the individual and structural levels (91). Generally, individual-level interventions can be effective and may yield positive effects, as they can be adapted to a specific individual and target high-risk individuals (109-111). Individual-level interventions that intend to affect dietary intake often aim to change individuals' nutrition knowledge, taste, and self-efficacy through individual or group-based strategies (89, 90, 95, 98). Several studies evaluating individual-level interventions have reported small effects, making it challenging to identify which techniques used in the various interventions are the most effective and which determinants are the most influential with respect to targeted outcomes (89, 112). However, the most successful individual-level interventions that aim to change diet have some components in common, such as an emphasis on improving self-efficacy and increasing self-monitoring (89, 113, 114). The effects reported from individual-level interventions may vary by sociodemographic factors, and some can increase health inequalities (115). Furthermore, individual-level interventions can have limited coverage and may require large resources and high individual agency[2] (109-111, 116, 117).

Structural interventions arguably rely less on individual agency and target environmental determinants that affect diet and weight in physical, social, and economic environments, often without individual enrollment or knowledge of participation, thereby potentially reaching all individuals, e.g., national restrictions of unhealthy foods and beverages or fiscal policies (118). Several examples of structural interventions exist that have improved public health, such as taxation of tobacco products and removal of vending machines in schools (119, 120). Examples of nutrition-specific structural policies that may affect dietary behaviors include economic instruments, such as subsidies on healthy foods; government regulation of food advertising of unhealthy foods and beverages; food labeling; food reformulation; targeted food-relief schemes, such as financial assistance for disadvantaged households (95); and school procurement policies (100). Structural interventions can have a broad reach, may have low costs and greater sustainability, and reduce disparities (115, 121, 122). However, evidence of structural interventions' effectiveness in improving diet and weight is limited, as comprehensive evaluations of such interventions are relatively new (100). Moreover, large contextual variations exist that may influence such interventions' effects. Structural interventions often rely on political will and, therefore, may lack implementation from a research and public health perspective, thereby resulting in insufficient or no evaluations (100, 120, 123).

Structural interventions that affect determinants at the environmental level may affect diet-related behavior and weight without depending on individual agency (97, 124). Arguably, both individual-level and structural efforts are needed. Various individual and structural interventions directed at one or several determinants of dietary intake and weight – such as media and education campaigns, nutrition labeling and information, economic incentives, multicomponent intervention in schools and workplaces, and restrictions on advertising and marketing – have improved diet and population health (100).

[2] *Individual agency* refers to the individual capacity to actively and independently choose and affect change (117).

However, these interventions' effectiveness varies across outcomes, contexts, settings, groups, etc. (32, 100, 115). For example, taxes may make a larger impact among lower-income households (100, 125). Notably, school settings and fiscal measures are two specific areas in which one can influence determinants of dietary intake and overweight and obesity (126). Implementation and evaluation of efforts that aim to promote a healthy diet and reduce overweight and obesity are essential to reducing the health and economic burden of diet-related illness worldwide (100), including in Norway.

1.3.3 Recommended efforts to promote a healthy diet and weight

Interventions to promote healthy diet-related behaviors and weight should reach a large part of the population, and schools represent an optimal setting for such efforts (127, 128). In WHOs European Food and Nutrition Action Plan, school nutrition policies are highlighted as recommended initiatives (129). School-based efforts have the potential to promote healthy diets and address childhood obesity by affecting several determinants (128, 130) and are of particular interest, as they have the potential to reach all children across various socioeconomic groups (131). To improve diet, the WHO recommends implementation of subsidies to increase fruit and vegetable intake (132). Furthermore, the WHO recommends implementing mass media campaigns to promote consumption of fruit and vegetables and reduce intake of total fat, saturated fats, sugars, and salt; and recommend nutrition education and counselling in different settings (such as schools) to increase fruit and vegetable intake. The WHO also recommends taxes on unhealthy foods and beverages to promote a healthy diet, particularly to reduce SSB consumption (132, 133). These interventions have been suggested to combat NCDs and are viewed as cost-effective, feasible, and effective, although not necessarily across all countries, populations, and settings (132).

School-based interventions and policies have been demonstrated to improve diet and overweight and obesity outcomes (123, 134), but some studies have reported mixed results (135, 136). Moreover, higher taxes on targeted foods and beverages are among the most promising dietary policies, resulting in reduced sales and consumption of these products (137-150). Worldwide, taxes on SSBs are the most common and are implemented in several countries and cities globally (133, 151). Although less common, Mexico and Hungary also have implemented taxes on other unhealthy food products, with promising results (152-155). However, for both school-based initiatives and taxes, effects vary according to intervention type, intervention design, target population, context, and outcomes. Thus, evaluations of such initiatives in different countries and across groups of individuals are important for informing policy makers. School settings and fiscal measures are two of the specific recommended areas in which Norway has implemented initiatives that may benefit dietary patterns and weight. From here, these areas will be the focus of this thesis.

1.3.4 Norwegian initiatives

School-based fruit and vegetable efforts

During the first decade of the 21st century in Norway, school-based efforts to increase fruit and vegetable intake among children and adolescents were introduced. In 2001, the research project Fruit and Vegetables Make the Marks (FVMM) was implemented in schools in two Norwegian counties in an effort to increase fruit and vegetable intake among children (156). The project mainly comprised an individual-level intervention within a multicomponent school-based educational program (156, 157). Furthermore, the project provided free fruit and vegetables to some schools. The multicomponent education program yielded no short-term effects on fruit and vegetable intake but it increased awareness of the five-a-day recommendation (156), and the provision of free fruit and vegetables resulted in increased intake of fruit and vegetables when they were provided, as well as up to three years after the intervention ceased (158, 159). Possible long-term effects into adulthood from the multicomponent educational program are unknown.

In 2007, Norway's government implemented a nationwide free fruit and vegetable (FFV) policy in schools (160). All Norwegian schools were obligated to provide pupils in grades 8–10 with a daily piece of free fruit or vegetables during the 2007–2014 period. The FFV policy was statutory, aiming to improve healthy dietary habits among children and adolescents (160, 161). Furthermore, it was argued that the FFV policy could prevent overweight and NCDs, increase concentration, and improve learning outcomes. However, the FFV policy's effects on these outcomes have not been evaluated.

Taxes on unhealthy foods and beverages

For several decades, unhealthy foods and beverages have been taxed in Norway (162). Taxes on (I) chocolate and sugar products[3], and (II) non-alcoholic beverages[4] first were implemented in the 1920s, primarily to increase revenues. However, it also has been debated whether these taxes could carry beneficial health implications. Although the taxes' content and context have been subject to minor changes over the years, they have been relatively stable over the past decade. The tax levels are price-adjusted annually, but in November 2017, national budget negotiations led to an abrupt 80% increase in the tax on chocolate and sugar products (from 20.19 to 36.92 Norwegian kroner [NOK][5] per kg), and a 40% increase on the non-alcoholic beverage tax (from 3.34 to 4.75 NOK[6] per liter), effective January 1, 2018. The tax increases were suggested to elicit positive public health effects, but the taxes' potential implications on diet-related outcomes (including sales) have not been subject to extensive evaluation (163).

Taken together, large-scale initiatives with possible benefits for health and health-related behaviors have been implemented in Norway over the past two decades. These initiatives hold significant relevance for public health and, thus, should be evaluated extensively to provide policy and decision-makers with important information with which to improve health and health-related behaviors in the Norwegian population.

1.4 Rationale for thesis

A suboptimal diet and overweight and obesity are some of the leading risk factors for NCDs, and a need exists for governments to employ a range of efforts to promote a healthy diet and reduce the prevalence of overweight and obesity (164). School-based and fiscal efforts are encouraged by the WHO (126, 165), but short- and long-term effects from real-life large-scale interventions and policies in various settings remain scarce (86, 130). However, a call for implementation of interventions and policies remains (86, 123, 166), and governments recognize the need for action (165). This sometimes results in non-systematic and ad hoc

[3] Mainly chocolate and sugar products such as candy, sweets, chocolate, cookies with chocolate covers, etc.
[4] Mainly prepared and mixtures of non-alcoholic beverages with added sugars and/or artificial sweeteners.
[5] 2.09 to 3.82 euros per kilogram.
[6] 0.35 to 0.49 euros per liter.

implementation of large-scale public health interventions and policies that are not always evaluated or have a high risk of bias (166, 167).

In Norway, comprehensive school-based efforts to increase fruit and vegetable intake have been a priority for decades, but evaluations of their health effects and sustained effects over time are limited. Norway's FVMM project and FFV policy are school-based efforts that provide us with the possibility of evaluating these initiatives on diet-related behaviors and weight outcomes in childhood and their potential effects in adulthood. Long-term evaluations of school-based interventions are warranted (130), and arguably are particularly important, as we know that poor nutrition and an unhealthy weight at an early age may track into adulthood and can affect adult morbidity and mortality (27). Moreover, real-life evaluations of taxes on unhealthy foods and beverages are warranted, considering the WHO's recommendations to implement taxes to improve diet (133), though few nations have implemented and evaluated taxes on unhealthy foods (67, 168). The recent tax increases in Norway provide a unique opportunity to investigate their effects, something that is lacking in Norway.

The Norwegian school-based initiatives were implemented with the aim of improving fruit and vegetable intake, and possibly improving health. The tax increases have been argued as a public health measure; therefore, these efforts' implications should be assessed. Evidence-based knowledge of real-life school-based and fiscal efforts' effectiveness may help policy and decision-makers determine whether such efforts should be prioritized or possibly adapted further. This thesis will contribute by evaluating Norwegian school-based and fiscal efforts on diet-related behaviors and weight, with a particular emphasis on fruit, vegetables, candy, and soda. This thesis could be of importance to public health, policy makers and politicians, particularly those in Norway, and may be generalizable to other high-income countries with similar government systems.

1.5 Overall research aim and specific objectives

The overall aim of this thesis was to evaluate effects of school-based and fiscal efforts on diet-related behaviors and weight, with a particular emphasis on fruit, vegetables, candy, and soda. Sales of products are included in the term *diet-related behaviors*[7] in this thesis.

The three included papers will address the present thesis' overall aim, with the following specific objectives:

Paper I

- The primary objective was to evaluate whether (childhood) exposure to the FVMM multicomponent school-based educational program could yield effects on adult fruit and vegetable intake. A secondary objective was to evaluate whether the multicomponent educational program exerted a synergistic long-term effect in a subgroup that also received free fruit and vegetables in school.

Paper II

- The objective was to investigate whether exposure to the national FFV policy affected weight among children and adolescents in Norway, assessed by sex and SES.

Paper III

- The objective was to evaluate whether the abrupt increases in Norwegian taxes on chocolate and sugar products (candy) and non-alcoholic beverages (soda) reduced these products' sales.

[7] Sales are linked to household expenditures and purchases, which have been demonstrated to be a good indicator of intake (200-202).

2 Materials and methods

This thesis includes data from several different sources: The FVMM project (Paper I); the Norwegian Childhood and Youth Growth Studies, including data from the Medical Birth Registry of Norway and Statistics Norway (Paper II); and retail data from Nielsen Norway (Paper III).

2.1 Fruit and Vegetables Make the Marks project (Paper I)

2.1.1 Study design

The FVMM project was a Norwegian cluster-randomized school-based intervention study initiated in 2001 that aimed to increase fruit and vegetable intake among schoolchildren (169). The intervention comprised a multicomponent educational program implemented from October 2001 through April 2002.

Figure 2 shows the overall study design. Elementary schools with more than ten pupils per grade were selected randomly in each of two Norwegian counties (Hedmark and Telemark) and invited to participate in the FVMM project (48 schools, 24 in each county) (169). Of the 48 schools, 38 agreed to participate (19 in each county). Nine schools from each county (18 schools total) were selected randomly to serve as intervention schools, while the rest served as control schools (20 schools, 10 in each county). For practical reasons, pupils in the intervention schools in Hedmark County were provided with one daily piece of free fruit or vegetables at school during the intervention period. This resulted in breaking the randomized design between counties. However, within counties, the randomization remained valid.

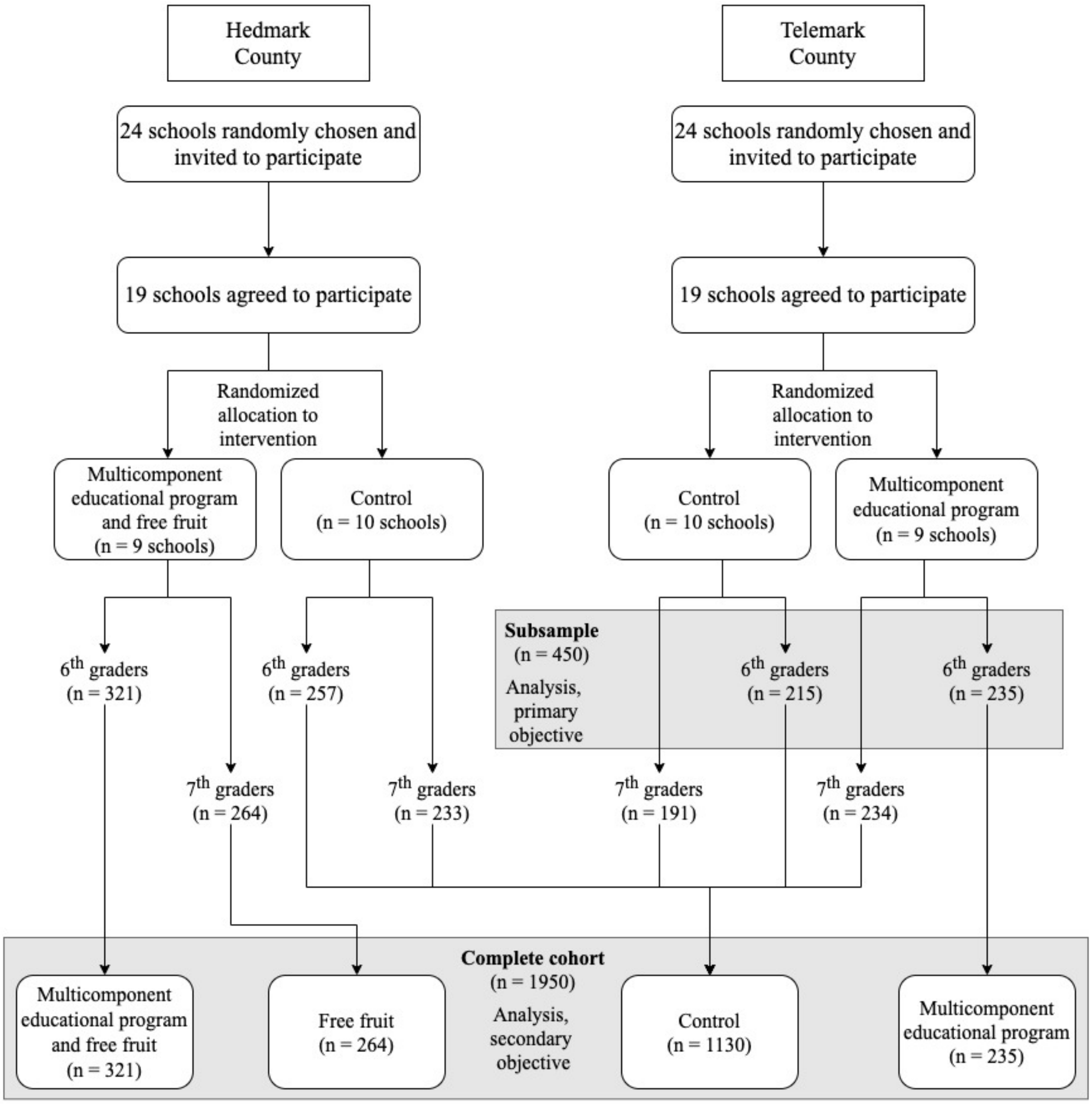

Figure 2. Overall study design of the Fruit and Vegetables Make the Marks project, with gray boxes illustrating the conditions and comparable groups used to evaluate the two objectives in Paper I.

All sixth- and seventh-graders in the included schools were invited to participate in the study (169). Only sixth-graders in the 18 intervention schools received the multicomponent educational program, while seventh-graders were included as controls. All pupils attending the intervention schools in Hedmark County (i.e., both sixth- and seventh-graders) were given one daily piece of free fruit or vegetables at school. This resulted in four conditions, illustrated in Figure 2: 1) Multicomponent educational program and free fruit; 2) Multicomponent educational program only (only sixth-graders); 3) free fruit only (seventh-graders in Hedmark County); and 4) control.

2.1.2 Sample

Altogether, 2,287 sixth- and seventh-graders from the 38 schools were invited to participate in the baseline survey (2001) (169). Of these, 337 refused or were unable to participate in the baseline survey (e.g., did not attend school that day). Thus, the baseline sample contained 1,950 pupils (85% of all eligible pupils), comprising 52.3% sixth-graders and 50.5% boys. The estimated mean age at baseline was 11.8 years. Of the pupils participating at baseline, 85% of their parents (n = 1,647) also provided baseline information.

2.1.3 Intervention components

The intervention components in the FVMM project comprised a multicomponent educational program with classroom and parental components (169). The multicomponent educational program was given to sixth-graders in the intervention schools and lasted from October 2001 through April 2002. Furthermore, a daily piece of free fruit or vegetables was given to sixth- and seventh-graders at the intervention schools in Hedmark County. The intervention's overall aim was to increase fruit and vegetable intake by affecting various determinants through several components.

Multicomponent educational program

Classroom component

The classroom component comprised a behavior-focused curriculum included in sixth-grade home economics classes (169). The curriculum was administered in one session (lasting 3 x 45 minutes) each month over a seven-month period. Three sessions were completed before and four after Christmas. The classroom component was administered by home economics teachers who had attended an all-day seminar, during which they reviewed the behavior-focused curriculum and its implementation.

The behavior-focused curriculum was guided by social cognitive theory to change determinants associated with fruit and vegetable intake (169). Bere described the details on the development of the behavior-focused curriculum (170). The curriculum aimed to influence several individual determinants of fruit and vegetable intake using various techniques. During the initial session, pupils were introduced to the recommendations on how much fruit and vegetables to eat, thereby increasing knowledge and awareness (169). Thereafter, sessions included educational information and food preparation of dishes based on a variety of fruit and vegetables that the home-economics teacher taught. The educational curriculum focused on information on areas of use, qualities, and availability of fruit and vegetables; practical skills; self-efficacy; and taste preferences. Furthermore, the pupils monitored their fruit and vegetable intake for three days, followed by a self-assessment and goal setting for future intake affecting awareness/perceived personal need for increased intake. To increase short- and long-term fruit and vegetable intake ultimately, the classroom component's goals were to focus on fruit and vegetables throughout the year to create awareness; improve preparation of fruit and vegetables; increase practical skills, sense of self-efficacy, knowledge of, and preferences for fruit and vegetables; and create positive attitudes toward fruit and vegetables. Throughout the school year, home economics teachers also were given 50 NOK (equivalent to six euros [EUR]) per pupil to encourage the use of fruit and vegetables in dishes made weekly during regular home economic classes.

Parental component

A parental component was included in the educational program to affect determinants of fruit and vegetable intake in additional settings (169). Parents were introduced to the multicomponent educational program at school meetings, including information about fruit, vegetables, and health. The parental component included six theme-based newsletters distributed to parents during the intervention period. The newsletters included health-related information, recipes, activities for parents and children, and competitions in which the children could win a fruit and vegetable gift certificate. The letters aimed to increase communication about fruit and vegetables between parents and their children to create awareness and stimulate availability and accessibility of fruit and vegetables at home. Additionally, the parental component included presentation of the project during parental meetings. Furthermore, during the intervention period, the pupils held a fruit and vegetable event for either parents or younger pupils in the school. The event included serving several self-made fruit and vegetable dishes, and distributing information about fruit and vegetables.

The nine intervention schools in one of the counties (Hedmark) received free fruit and vegetables, funded by the Norwegian Fruit and Vegetable Marketing Board (169). Local fruit and vegetable distributors provided the fruit and vegetables; therefore, it was practical to distribute the fruit and vegetables to elementary schools in one of the counties. Pupils received one piece of ready-to-eat fresh fruit or vegetables every day, usually in connection with lunch. The fruit or vegetable could be an apple, pear, orange, banana, carrot, kiwi, nectarine, or clementine.

2.1.4 Data collection

Data were collected through questionnaires in September 2001 (baseline), May 2002 (after the intervention period), May 2003 (one-year follow-up), May 2005 (three-year follow-up), September 2009 (seven-year follow-up), and throughout 2016 (14-year follow-up) (169). The mean ages were 11.8 years, 12.5 years, 12.0 years, 15.5 years, 19.8 years, and 26.5 years, respectively.

The questionnaires at baseline and the next three follow-ups (2002–2005) were completed during a school lesson (45 minutes) with a trained project worker present (169). The questionnaire was designed to be understood by sixth-graders and completed in 45 minutes to achieve high participation rates. The project worker helped with dietary assessments. Furthermore, in 2001 and 2002, the pupils brought a separate questionnaire home for one parent to complete. Due to the study's design, the original seventh-graders in 2003 started secondary school and consequently, data from these participants were not collected, as study personnel only returned to the original schools included at baseline. Therefore, the 2003 follow-up was conducted only among the original sixth-graders still in elementary school. The fourth follow-up (2009) was conducted by contacting baseline participants and sending information and questionnaires via regular mail. In the final follow-up (2016), five master's students tried to locate baseline participants through social media (Facebook) or by phone. Participants were verified through name, age, elementary school, geographical location, and friend lists on social media. The master's students contacted the verified individuals by private message or phone and provided information about the follow-up and the option to reply to the questionnaire. The questionnaire was answered through an online link, by e-mail, or by phone.

Questionnaires and variables

In addition to information about sex, the questionnaire comprised a written 24-hour recall section used to assess fruit and vegetable intake in portions per day (169). The reported intake represented a weekday, but in the final two follow-ups, it was not specified on which day the questionnaire was to be completed. The 24-hour recall conducted in 2001–2005 separated intake into five periods throughout the day (before school, at school, after school, at dinner, and after dinner), while at the final two follow-ups, the day was separated into four periods to fit an adult schedule (morning, including breakfast; after breakfast, including lunch; after lunch, including dinner; and after dinner, including supper).

The participants were instructed to provide the information in household measures (e.g., a cup of lettuce), units, or portions (e.g., one apple, a portion of broccoli) (169). No information about portion size was given. Intake in household measures and units was converted into portions, e.g., one apple counted as one portion. The conversion was based on the Measures and Weights of Foods booklet published by the Norwegian National Association for Nutrition and Health (171). The 24-hour recall's validity and reliability among sixth-graders has been evaluated, with the findings revealing that the 24-hour recall 14 days apart produced consistent responses on fruit and vegetable estimates (172). Regarding validity, the sixth-graders recorded vegetable intake, but may have overestimated fruit and juice intake when results were compared with the reference method (a seven-day food diary).

Parental education information was provided by the parent who filled out the parental questionnaire (169). Parental education was dichotomized into lower education (no university/college) or higher education (having attended university/college), and used as an indicator for SES. Questionnaires from baseline and the last follow-up (in Norwegian) are included in Appendices 1 and 2.

2.1.5 Statistical methods

Baseline differences and attrition between the groups were assessed with a chi-square test for categorical variables and a t-test or analysis of variance for continuous variables (169). An additional z-test of proportion was completed with a Bonferroni adjustment if the overall analysis yielded significant differences.

To evaluate the effects from the multicomponent educational program on long-term fruit and vegetable intake (primary objective), sixth-graders receiving the multicomponent educational program and sixth-grade controls were included (see subsample in Figure 2) (169). Linear mixed models were performed to adjust for observations nested within individuals. All available and relevant data from each follow-up were used in the analyses. The model included group (educational program vs. control), time, and group × time interaction term as fixed variables, as well as subject as random intercept and time as random slope. Models were adjusted for sex, parental education level, and baseline observations.

To evaluate the secondary objective, we used the complete cohort with four groups as dummy variables (see Figure 2) (169). The intent was to assess the possible potential synergistic effect between the two groups given free fruit and vegetables in school, with and without the multicomponent educational program. These effects were evaluated with linear mixed models identical to the models presented previously. The follow-up in 2003 was only completed on initial sixth-graders who received the multicomponent educational program, resulting in no participants in the control group who only received free fruit and vegetables, reported as not applicable (NA). All analyses were conducted using two-sided p-values, with the significance level set to 5%.

2.1.6 Ethics

The FVMM project was conducted according to the Helsinki Declaration. Written informed consent from both parents and children was obtained prior to participation in the study. Ethical approval and research clearance were obtained from the National Committees for Research Ethics in Norway (file No. S-01076) and the Norwegian Center for Research Data (file No. 12395).

2.2 The Childhood Growth study and Youth Growth study (Paper II)

2.2.1 Study design

From August 2007 to June 2014, students in all combined elementary and secondary schools (grades 1–10) were offered one piece of fresh fruit or vegetables during the school day (usually at lunch) due to the national FFV policy (referred to as FFV schools). Typical fruit and vegetables offered were apples, pears, bananas, oranges, clementines, kiwis, carrots, and nectarines. Children attending pure elementary schools (first through seventh grades) were not covered under the policy. Due to the FFV policy rollout, a quasi-natural experimental design was used to capture the FFV policy's effects on weight among children and adolescents in Norway, i.e., comparing children who had attended FFV schools with children who had attended pure elementary schools (referred to as no free fruit and vegetable [NFFV] schools). The evaluation was conducted by using cross-sectional and longitudinal anthropometric data from two studies: the Norwegian Child Growth Study (NCGS) – conducted in 2010, 2012, and 2015 – and the Norwegian Youth Growth Study (NYGS), conducted in 2017. From here, the cohorts are referred to by year (e.g., 2010, 2012, 2015, and 2017). Both studies are part of the Norwegian Growth Study conducted by the National Institute of Public Health in collaboration with the School Health Service.

The NCGS is a repeated cross-sectional study of 8-year-olds (third-graders) conducted in elementary schools. The NYGS is a cross-sectional study of 13-year-olds (eighth-graders) conducted in secondary schools in 2017. The shared objective of the NCGS and NYGS was to obtain nationally representative information on height and weight among Norwegian schoolchildren and adolescents. In the NCGS, waist circumference (WC) also was collected. Furthermore, previous routine measurements of height and weight from birth were collected among participants in the 2010, 2015, and 2017 cohorts. An overview of the design is presented in Figure 3.

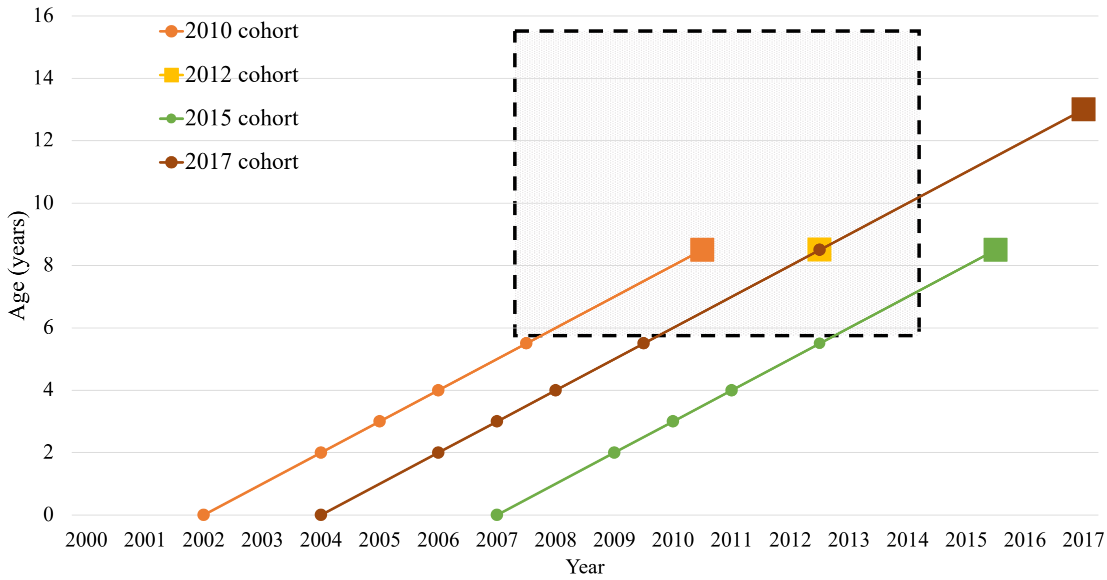

Figure 3. Schematic of the quasi-natural experimental design.

The dashed square indicates the period with the FFV policy; the squares indicate measurements in the NCGS (2010, 2012, and 2015) and NYGS (2017); and the dots indicate approximate (routine) measurements included in the analyses. FFV: Free fruit and vegetables; NCGS; Norwegian Childhood Growth Study; NYGS: Norwegian Youth Growth Study.

Both studies used a two-stage sampling design to ensure a national representative sample. During the first stage, counties were sampled from geographical strata in Norway, and during the second stage, schools were sampled randomly within each county. In the NCGS, the same approximately 130 elementary schools were invited to participate in each cross-sectional survey, in which 123–126 schools accepted the invitation. In the NYGS, 150 out of 159 invited secondary schools agreed to participate in the study. See Table 1 for a sampling overview and additional details.

2.2.2 Sample

Among the schools that agreed to participate in the studies, all third-graders were invited to participate (NCGS), and only one eighth-grade grade class with a maximum number of 30 adolescents participated (in the NYGS). Consent was obtained from a total of 11,935 participants (details by cohort in Table 1).

Table 1. Overview of sampling and participants in the Norwegian Childhood and Youth Growth studies.

	Norwegian Childhood Growth Study			Norwegian Youth Growth Study
Study year (cohort)	2010	2012	2015	2017
First stage sampling	10 out of 19 counties sampled from four geographical strata			10 out of 19 counties sampled from five geographical strata
Second stage sampling	Random sample of schools within each county			Random sample of schools within each county
Schools invited	n = 127	n = 127	n = 127	n = 159
Schools participating	n = 125	n = 126	n = 123	n = 150
Invited pupils	All third-graders at the participating schools			One class of eighth-graders at the participating schools; maximum of 30 eighth-graders
Previous routine measurement	Yes	No	Yes	Yes
Participants with consent	n = 3,182	n = 3,508	n = 3,338	n = 1,907
Exposed to FFV policy	n = 621 (19.9%)	n = 700 (20.6%)	n = 575 (17.9%)	n = 446 (30.2%)
Years exposed to the FFV policy in third grade	2–2.5 years	2–2.5 years	1 year	2–2.5 years (four years in eighth grade)
Participants in longitudinal analysis at age 8.5	n = 3,125	n = 3,405	n = 3,207	n = 1,478

FFV: Free fruit and vegetables.

2.2.3 Data collection and variables

Anthropometrics

The School Health Service maintained contact with the schools, and the school health nurses conducted and reported the third-graders' measurements during the fall of 2010, 2012, and 2015 and among the eighth-graders during the fall of 2017 (Appendices 3 and 4). Measurements conducted in the NCGS were conducted according to the WHO European Childhood Obesity Surveillance Initiative (COSI) protocol (173), whereas measurements of the eighth-graders in 2017 followed National Guidelines (174). The COSI protocol and National Guidelines procedures are similar, and the same equipment with comparable accuracy was used (173, 174). All children and adolescents were asked to remove loose objects, wear light indoor clothing, and remove their shoes while measured. Weight was recorded to the nearest 0.1 kg and height to 0.1 cm. Waist circumference was measured to the nearest 0.1 cm with arms hanging relaxed along the sides of the body (only collected in NCGS).

The Health Centers and School Health Service record routine measurements of height and weight in Norway, with the data kept in individual health records. These measurements are scheduled at birth and at the age of 6 weeks; 3, 6, 9, 12, 15, 18, and 24 months; and 3, 4 and 6 years. The school health nurse forwarded a copy of the previous routine measurements from the participants in the 2010 and 2015 cohorts to the Norwegian Institute of Public Health. Research assistants entered these measurements into an electronic database twice, with any punching errors corrected (23). School health nurses plotted previous routine measurements from the participants in the 2017 cohort into web forms, which had a restriction on numbers to be plotted, preventing extreme or very implausible values. All values later were cleaned using a longitudinal algorithm that checked for logical errors and internally inconsistent values (175).

Other variables

The school health nurses also completed a school questionnaire that was returned to the Norwegian Institute of Public Health (Appendices 5 and 6). School information was available for all schools in the NCGS and for 137 out of the 150 schools in the NYGS. County and region (North; Mid; West; and South-East) indicated the schools' geographical locations. The indicator of each school's location according to population density was categorized into three categories provided by Statistics Norway: urban (municipalities with a population > 50,000); semi-urban (municipalities with a population of 15,000–50,000); and rural (municipalities with a population < 15,000).

Furthermore, participants were linked with data records from the Medical Birth Registry of Norway and Statistics Norway, providing information on sex and parental education. Parental education was used as an indicator of SES and defined by using the highest level of education from either the father or mother before any possible FFV policy exposure (when the children were 4 years old). Parental education was collapsed into two main categories: higher+ (> 0 years of university/college) or <higher (≤ high school).

Free school fruit and vegetable policy exposure

School affiliation in third grade (age 8) was used to categorize exposure to the FFV policy. In the consent form (Appendix 7), parents of the participants in the NYGS were asked to provide information about previously attended elementary schools – information that were used to categorize exposure to the FFV policy. Exposure to the FFV policy was defined as participants having attended at least one year at a school with the FFV policy, while those who were unexposed had never attended a school under the FFV policy. Length of exposure to the FFV policy varied between cohorts, as presented in Table 1 and illustrated in Figure 3.

Outcome

The main outcomes were BMI (kg/m^2) standard deviation scores (BMI_{SDS}) and overweight, including obesity (OW/OB) in third grade (age 8.5 years) and eighth grade (age 13 years). Waist circumference and waist-to-height ratio (WHtR) in third grade were additional outcomes at age 8.5. The BMI_{SDS} were standardized internally by age and sex (176). Overweight (including obesity) status was indicated by age- and sex-specific BMI cut-off in accordance with the International Obesity Task Force (177).

2.2.4 Statistical methods

For the BMI_{SDS} and odds ratio (OR) of OW/OB, in which longitudinal data were available, two models were used to estimate the FFV effect. The first model was similar to a comparative interrupted time-series analysis (178). The pre- and post-intervention slopes in each group were modelled with linear splines and a knot at the pre-exposure time point (age 5.5). The pre-intervention slopes were modeled from two years of age. The counterfactual (trajectory that the FFV group would have taken in the absence of the policy) was estimated by the change in slopes in the control group. Thus, the between-group difference in the pre-post difference in slopes was an estimate of the FFV effect. The second model was adjusted for the pre-intervention BMI_{SDS} (using the closest available measurement before the possible FFV exposure). In the analysis of effects at 13 years (using only the 2017 cohort), the models included an extra knot at age 8.5 years. For equation specifics, see Paper II. For the WC and WHtR outcomes, in which only a single measure of the outcome was available, the FFV estimator was a simple post-intervention, between-group comparison.

Analyses included pooled cohort estimates, but also stratified by cohort and sex due to differences in exposure duration and the potential for different effects between sexes. Multilevel models (MLMs) were used to employ all available outcome data and account for the hierarchical data structure. A logit MLM with maximum likelihood with adaptive Gauss-Hermite quadrature estimation was used for the OW/OB outcome.

For the longitudinal cohorts, three analytical sets were conducted: First, an unadjusted (crude); second, adjusting for region, population density, and parental education (adjusted); and third, an analysis that also adjusts for pre-policy BMI. For the cross-sectional WC and WHtR outcomes, only crude and adjusted analyses could be conducted. Adjustments for region and population density were conducted, as combined schools (FFV schools) are more likely to be in rural areas of Norway than pure elementary schools (NFFV schools), violating the assumption of random allocation to exposure (additional details in Paper II). To assess potential effect modification by SES, similar models were estimated, but stratified by parental education (higher+, <higher) with Wald tests of interaction terms. In

this thesis, effects from pooled cohort estimates are presented for outcomes at age 8.5 years, but for outcomes at age 13, only the 2017 cohort could be presented. In addition to supplemental and sensitivity analyses, results by cohort and parental education are described and presented in Paper II.

2.2.5 Ethics

The NCGS and NYGS were in accordance with the Helsinki Declaration. Ethical approval and research clearance were obtained from the Regional Committee for Medical Research Ethics (2017/431 and 2010/938) and approved by the Norwegian Data Inspectorate. Detailed information about the studies (NCGS and NYGS) were sent to parents or guardians prior to each survey, and the School Health Service obtained written informed consent from parents or other legal guardians on behalf of the Norwegian Institute of Public Health (Appendices 3 and 7).

2.3 Retail data from Nielsen Company (Paper III)

2.3.1 Study design

Evaluations of how the abrupt tax increases in 2018 affected sales were conducted with a quasi-experimental design using longitudinal retail data from the Nielsen Company (179). Due to strong seasonal variations in sales, two models were used to evaluate potential changes in volume sales of taxed products after the increases in the tax on chocolate and sugar products and the tax on non-alcoholic beverages. The models compared sales from the season after the taxes were increased (intervention season) with sales from the previous year (control season). The intervention season included the periods before and after the tax hikes, effective as of January 1, 2018 (weeks 30–52 in 2017 and 1–23 in 2018), and the control season comprised the same period the previous year (weeks 30–52 in 2016 and 1–23 in 2017). Due to high variability in sales around Christmas, four weeks on each side of the cutoff (Week 1) during each season were excluded, for a total of eight weeks.

2.3.2 Data and variables

The retail data that grocery stores provided comprised sales as registered at checkout scanners between June 2016 and June 2018 from the four largest chains in Norway, collected by Nielsen Company Norway (179). Data comprised sales in value (NOK) and volume, aggregated by product category, store, and week.

Furthermore, the data included municipal and county-level data. Compared with official retail sales from Statistics Norway (180), the total data set included about 98% of annual sales in Norwegian grocery stores (181). Because definitions of *grocery store* may differ, this is an estimate of the proportion of sales.

Both taxes are payable on products independent of sugar or sweetener content (179). Two groups of taxed products served as primary outcomes corresponding with the two taxes: 1) candy (chocolate and sugar products) and 2) soda (non-alcoholic beverages). The following subcategories were excluded due to seasonal sales trends or products deviating from “typical candy”: energy tablets; marzipan; seasonal marzipan; cough pastilles; seasonal chocolate; seasonal sugar products; and regular gum. Furthermore, bulk-weight candy was excluded, as this was not provided in volume sales. The following subcategories of products were included in the analyses as candy: pastilles; other sugary products; bubblegum; sweets; caramels; chocolate (bars, figures, boxes, etc.); and licorice. The soda product category comprised subcategories of prepared soda with sugar and/or artificial sweeteners. For each grocery store, the weekly volume sales within each of the two product groups were added up – candy in kg and soda in liters. The natural log of these sums was used in the analyses.

2.3.3 Statistical methods

Stata version 15.1 software (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC) was used to complete analyses and create figures (179). Two different models for each of the product groups were developed and performed as per the pre-registered analysis file (Appendix 8) (182). Model 1 used a difference-in-discontinuity design, in which average sales over time were modeled flexibly with splines before and after January 1 (excluding the window of eight weeks), permitting different slopes during the control and intervention seasons, thereby accounting for trends within seasons and capturing local changes around the cutoff (179). Model 1 was an ordinary least squares regression with sales in log-volume as the outcome, which estimated the tax effect and captured the difference between the discontinuity in the intervention and control season, comparing the jump from late November to early February (a local effect). Specific details about the regression equation can be found in Paper III. Notably, the model included controlling for store, Halloween, Easter, and the value of sales of non-edible products (an exogenous proxy for total sales). Shared time trends were modeled by restricted cubic splines using the *mkspline* function in Stata, with a total of three knots: one before the cutoff (Week No. 30); one at the cutoff (Week No. 5); and one after the cutoff (Week No. 23).

Model 2 used a difference-in-difference design, generating the difference between the intervention and control seasons in their average changes from before to after the cutoff (179). The effect estimate presents the difference between seasons in changes of average sales from the period before to after January 1. In Model 2, time was modeled by fixed effects of week number across the two seasons, replacing the joint and separate trend modeling used in Model 1. Because Halloween fell on the same week number during both seasons, it was not included, as Model 2 includes fixed effects of week number. However, the model controlled for Easter and total sales, as in Model 1. Specific details about the regression equation to Model 2 can be viewed in Paper III.

The user-written function *reghdfe* was used to estimate robust standard errors with two-way clustering on time and at the level of municipalities to account for dependencies (e.g., autocorrelation) within geography and time (179, 183). One-sided 95% confidence intervals (CIs) are presented, as the hypothesis was one-sided, expecting a decrease in sales of the taxed products.

Price changes were described by calculating the price per volume for each subcategory within the two product groups (179). This was reported as the mean (± standard deviation [SD]) weekly volume price (in NOK) of the subcategories of taxed candy and soda, pre- and post-cutoff (January 1), during each season.

Supplementary analyses

Several additional supplementary analyses were conducted to investigate robustness, sensitivity, and possible effects from cross-border shopping (179). Details about these analyses can be found in the preregistration (Appendix 8) and Paper III (182).

2.3.4 Ethics

No ethical approval was needed according to national legislation, as included data did not contain information qualifying as human participant research or medical research (179).

3 Results

3.1 Effects from a multicomponent school-based educational program on long-term fruit and vegetable intake (Paper I)

Effects from the multicomponent school-based educational program

In the subsample (n = 450) used to evaluate the effects from the FVMM multicomponent school-based educational program (without provision of free school fruit and vegetables), 237 (53%) completed the 14-year follow-up (169). The analysis found that 14 years after the intervention, mean daily fruit intake among young adults who had received the FVMM multicomponent educational program was no different from daily fruit intake among controls (respectively, 1.2 vs. 1.2 portions per day, p-value = 0.976; see Table 2). Similarly, no significant difference between the groups was observed regarding daily vegetable intake either (1.5 vs. 1.7 portions per day, respectively; p-value = 0.492).

Table 2. Adjusted means (95% CI) of fruit and vegetable intake at each follow-up by group in the subsample (n = 450) (169).

	Baseline* (2001)	2002**	2003**	2005**	2009**	2016**
Fruit, portions per day						
Multicomponent educational program	1.7 (1.5, 1.9)	1.4 (1.2, 1.7)	1.2 (1.0, 1.5)	1.4 (1.2, 1.6)	0.9 (0.4, 1.4)	1.2 (1.0, 1.5)
Control	1.7 (1.5, 2.0)	1.3 (1.1, 1.5)	1.4 (1.2, 1.6)	1.3 (1.1, 1.6)	0.8 (0.2, 1.3)	1.2 (0.9, 1.5)
p-value	0.840	0.409	0.377	0.578	0.689	0.976
Vegetables, portions per day						
Multicomponent educational program	1.0 (0.8, 1.2)	0.7 (0.5, 0.9)	0.7 (0.5, 0.9)	1.0 (0.8, 1.2)	1.1 (0.6, 1.5)	1.5 (1.3, 1.8)
Control	0.9 (0.7, 1.1)	0.8 (0.6, 1.0)	0.8 (0.6, 1.0)	1.0 (0.8, 1.2)	1.0 (0.5, 1.6)	1.7 (1.4, 2.0)
p-value	0.443	0.405	0.428	0.893	0.984	0.492

*Adjusted for sex and parental education level. **Adjusted for baseline data, sex, and parental education level. CI: confidence interval.

Synergistic effect from the multicomponent school-based educational program and free school fruit

Of the 1,950 individuals who completed the baseline questionnaire, 982 (50%) answered the follow-up 14 years later (169). The findings indicated no synergistic effects on daily fruit intake among young adults who had received both free fruit and the multicomponent educational program compared with the controls, who only received free fruit and vegetables (1.2 vs. 1.3 portions per day, respectively; p-value = 0.481; see Table 3). No difference between groups was observed regarding vegetable intake either (1.6 vs. 1.7 portions per day, respectively; p-value = 0.360).

Table 3. Adjusted means (95% CI) of fruit and vegetable intake at each follow-up by group in the complete cohort (n = 1,950) (169).

	Free fruit	Baseline (2001)*	2002**	2003**	2005**	2009**	2016**
Fruit, portions per day							
Multicomp. educational program	Yes	1.5 (1.2, 1.5)	1.8 (1.7, 2.0)	1.5 (1.3, 1.7)	1.3 (1.1, 1.5)	1.4 (1.1, 1.7)	1.2 (1.0, 1.4)
	No	1.7 (1.5, 1.9)	1.4 (1.2, 1.6)	1.2 (1.0, 1.4)	1.4 (1.2, 1.6)	0.9 (0.4, 1.3)	1.2 (1.1, 1.6)
Control	Yes	1.4 (1.2, 1.6)	1.8 (1.6, 2.9)	NA	1.3 (1.1, 1.5)	1.1 (0.7, 1.5)	1.3 (1.1, 1.6)
	No	1.6 (1.5, 1.7)	1.2 (1.1, 1.3)	1.2 (1.0, 1.3)	1.2 (1.1, 1.3)	1.0 (0.7, 1.2)	1.3 (1.2, 1.5)
p-value***		0.925	0.915	NA	0.985	0.380	0.481
Vegetables, portions per day							
Multicomp. educational program	Yes	0.9 (0.8, 1.1)	0.7 (0.6, 0.8)	0.7 (0.6, 0.8)	1.1 (0.9, 1.2)	1.1 (0.8, 1.4)	1.6 (1.3, 1.8)
	No	1.0 (0.8, 1.2)	0.7 (0.5, 0.8)	0.7 (0.5, 0.8)	1.0 (0.8, 1.2)	1.0 (0.6, 1.4)	1.5 (1.3, 1.8)
Control	Yes	0.8 (0.7, 1.0)	0.6 (0.5, 0.8)	NA	1.0 (0.9, 1.2)	1.0 (0.7, 1.3)	1.7 (1.5, 1.9)
	No	0.9 (0.9, 1.0)	0.7 (0.6, 0.8)	0.7 (0.6, 0.8)	0.9 (0.8, 1.0)	1.0 (0.8, 1.2)	1.6 (1.4, 1.7)
p-value***		0.406	0.663	NA	0.869	0.812	0.360

*Adjusted for sex and parental education level. **Adjusted for baseline data, sex, and parental education level. *** p-values from comparing the two groups who received free fruit. CI: confidence interval. Multicomp. = multicomponent; NA = Not applicable.

3.2 Effects from a free school fruit and vegetable policy on weight (Paper II)

Sample description

Altogether, 7,810 children were included in the pooled longitudinal analyses of BMI_{SDS} and OW/OB outcomes at 8.5 years, and 6,619 in models adjusted for pre-intervention BMI. For the WC outcomes, there were 9,716 children. For the outcome at 13 years, 1,533 adolescents were included in the adjusted longitudinal analyses of BMI_{SDS} and OW/OB outcomes, and 1,355 in the pre-intervention BMI adjusted analyses. Children were similar in terms of sex and age at outcome assessment. Approximately 20% of the children were exposed to the FFV policy at age 8.5 and 30% among the 13-year-olds (shown in Table 1).

Policy effect at age 8.5

There was little evidence of a policy effect on BMI_{SDS}, OW/OB, WC, or WHtR in the pooled analyses for either sex at age 8.5. All estimates were close to null (see Table 4). There was a suggestion of an interaction between the FFV policy and parental education. In the analysis including pre-policy BMI adjustment, boys from parents without higher education, on average, had a 0.12 higher BMI_{SDS} (p-value for interaction = 0.04) and increased odds of OW/OB (OR: 1.66, p-value for interaction = 0.02) if they attended an FFV school (see Table 4). This interaction was not evident for WC and WHtR, and the interaction and effect sizes were similar or weaker in sensitivity analyses (details in Paper II). Overall, policy effect estimates were inconsistent when triangulated against other group comparisons or with further adjustment for pre-policy BMI, as estimates were in both directions at 8.5 years across cohorts, sex, and parental education (details in Paper II).

Table 4. Pooled cohort estimates of the effects from the FFV policy on BMI_{SDS}, OW/OB, WC, and WtHR at age 8.5 (third grade).

	BMI_{SDS} difference	OR of OW/OB	WC (cm) difference	WtHR
Boys				
Crude	-0.01 (-0.08, 0.06)	1.23 (0.84, 1.81)	0.5 (-0.1, 1.0)	0.004 (-0.001, 0.008)
Adjusted*	-0.02 (-0.09, 0.05)	1.23 (0.84, 1.81)	0.3 (-0.3, 0.8)	0.002 (-0.002, 0.006)
Adjusted+	0.05 (-0.04, 0.14)	1.20 (0.86, 1.66)	NA	NA
Girls				
Crude	0.04 (-0.03, 0.11)	0.95 (0.64, 1.40)	0.1 (-0.5, 0.7)	0.001 (-0.003, 0.005)
Adjusted	0.02 (-0.05, 0.09)	0.95 (0.64, 1.40)	0.0 (-0.6, 0.6)	-0.000 (-0.004, 0.004)
Adjusted+	0.04 (-0.04, 0.13)	1.03 (0.75, 1.39)	NA	NA
Boys, stratified by parental education†				
Adjusted*	p = 0.00	p = 0.06	p = 0.05	p = 0.58
<Higher	0.10 (-0.01, 0.20)	1.66 (0.95, 2.89)	0.7 (0.0, 1.4)	0.003 (-0.002, 0.008)
Higher+	-0.12 (-0.22, -0.02)	0.79 (0.46, 1.36)	-0.1 (-0.7, 0.6)	0.001 (-0.003, 0.006)
Adjusted+	p = 0.04	p = 0.02	NA	NA
<Higher	0.12 (0.01, 0.23)	1.66 (1.09, 2.54)	NA	NA
Higher+	-0.01 (-0.12, 0.09)	0.87 (0.56, 1.35)	NA	NA
Girls, stratified by parental education†				
Adjusted*	p = 0.47	p = 0.52	p = 0.41	p = 0.14
<Higher	-0.01 (-0.11, 0.09)	0.79 (0.45, 1.39)	0.3 (-0.5, 1.1)	0.002 (-0.003, 0.008)
Higher+	0.04 (-0.05, 0.13)	1.02 (0.59, 1.75)	-0.1 (-0.8, 0.7)	-0.002 (-0.007, 0.003)
Adjusted+	p = 0.32	p = 0.88	NA	NA
<Higher	0.01 (-0.10, 0.12)	1.02 (0.68, 1.51)	NA	NA
Higher+	0.07 (-0.03, 0.18)	1.06 (0.70, 1.59)	NA	NA

Expressed as the difference in outcome or odds ratio vs. the counterfactual as estimated using the individuals attending NFFV schools with a 95% confidence interval. Adjusted*: adjusted for region; population density; highest parental education; cohort. Adjusted+: also adjusted for pre-policy BMI_{SDS}. †P-values show p-values for interaction between parental education and FFV policy. BMI_{SDS}: Body mass index standard deviation scores; cm: centimeter; FFV: free fruit and vegetables; NA; not applicable; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity; WC: waist circumference; WtHR: Waist-to-height ratio.

Policy effect at age 13

There was no strong evidence of a policy effect on BMI_{SDS} or OW/OB among adolescents (age 13) for either sex exposed to the FFV policy for up to four years (estimates in Table 5). It was suggested that girls from parents without higher education had a lower BMI_{SDS} (-0.20, 95% CI: -0.41, 0.01) and lower odds of OW/OB (OR: 0.55, 95% CI: 0.27, 1.12) if they attended an FFV school (p-value for both interactions = 0.05) (Table 5).

Table 5. Estimates of effects from the FFV policy on BMI_{SDS} and OW/OB at age 13 (eighth grade) using the 2017 cohort.

		BMI_{SDS} difference	OR of OW/OB
Boys			
	Crude	-0.05 (-0.20, 0.10)	1.10 (0.57, 2.13)
	Adjusted*	-0.03 (-0.18, 0.12)	1.11 (0.57, 2.14)
	Adjusted+	-0.02 (-0.17, 0.12)	1.04 (0.65, 1.66)
Girls			
	Crude	-0.05 (-0.19, 0.09)	0.83 (0.41, 1.66)
	Adjusted	-0.07 (-0.21, 0.07)	0.82 (0.41, 1.66)
	Adjusted+	-0.05 (-0.19, 0.09)	0.92 (0.57, 1.47)
Boys, stratified by parental education†			
	Adjusted*	p = 0.24	p = 0.49
	<Higher	0.08 (-0.17, 0.33)	1.34 (0.50, 3.55)
	Higher+	-0.11 (-0.30, 0.09)	0.83 (0.33, 2.08)
	Adjusted+	p = 0.48	p = 0.19
	<Higher	0.04 (-0.20, 0.27)	1.42 (0.73, 2.76)
	Higher+	-0.07 (-0.25, 0.11)	0.76 (0.38, 1.50)
Girls, stratified by parental education†			
	Adjusted*	p = 0.09	p = 0.21
	<Higher	-0.21 (-0.43, 0.00)	0.49 (0.16, 1.53)
	Higher+	0.03 (-0.15, 0.22)	1.23 (0.50, 3.03)
	Adjusted+	p = 0.05	p = 0.05
	<Higher	-0.20 (-0.41, 0.01)	0.55 (0.27, 1.12)
	Higher+	0.07 (-0.12, 0.25)	1.39 (0.75, 2.58)

Expressed as the difference in outcome or odds ratio vs. the counterfactual as estimated using the individuals attending NFFV schools with a 95% confidence interval. Adjusted*: adjusted for region, population density, highest parental education. Adjusted+: also adjusted for pre-policy BMI_{SDS}. †P-values show p-values for interaction between parental education and FFV policy. BMI_{SDS}: Body mass index standard deviation scores; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity.

3.3 Effects from tax increases on sales of soda and candy (Paper III)

Sales data from 3,884 grocery stores were used in the main analyses (179). Results from the models did not consistently detect reductions that coincided with the tax increases. Model 1 (estimating the local jump around the cutoff) revealed an increase in volume sales of 6.1% (one-sided 95% CI: 23.4, p-value = 0.26) for candy and a -3.9% (95% CI: 4.9, p-value = 0.23) reduction in soda sales. Figure 4 shows sales of taxed candy and soda in accordance with Model 1. Unlike Model 1's results, estimates from the difference in changes between average sales before and after the cutoff (Model 2) revealed a relative decrease of -4.9% (95% CI: 1.0, p-value = 0.08) in average sales of candy and an increase of 1.5% (95% CI: 5.0, p-value = 0.24) in soda sales.

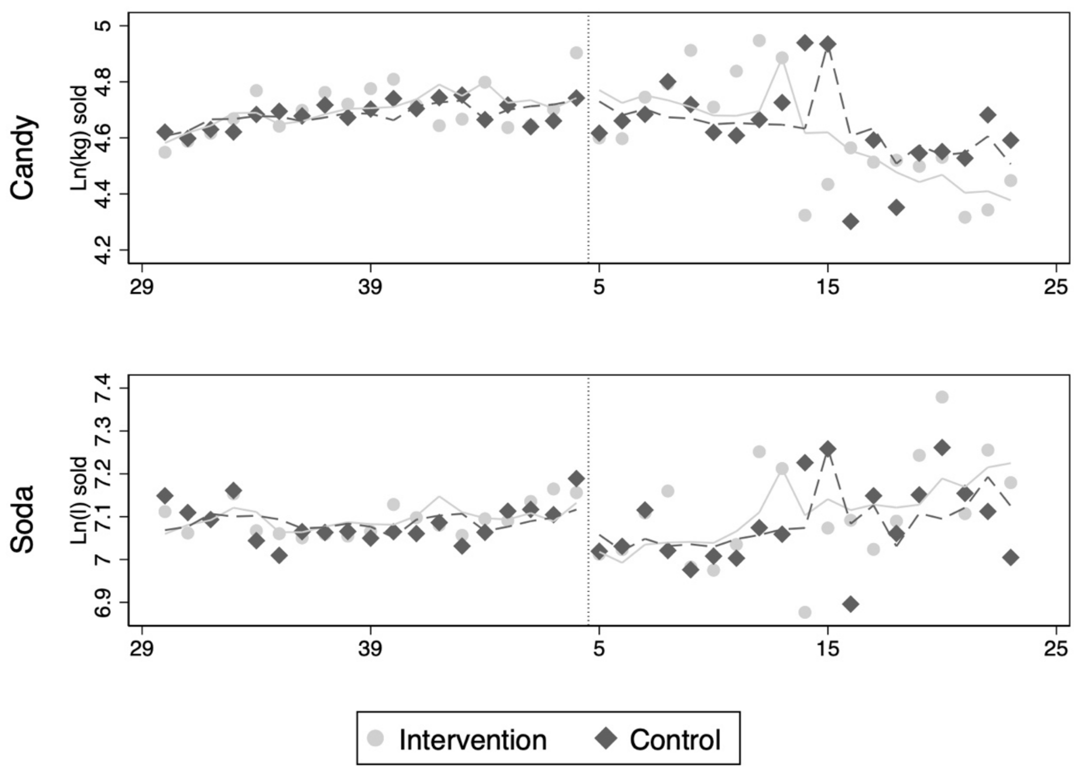

Figure 4. Sales of taxed candy (top) and taxed soda (bottom) (179). Figures show the intervention season (light gray line = predicted values) and control season (dashed dark line = predicted values) from Model 1. Dots and squares represent weekly mean log-volume (kg or liters) sales. The x-axis shows the week number of the year with a dotted vertical line indicating the cut-off.

Change in price per volume of candy during the intervention season increased 5.8 percentage points beyond the changes during the control season, whereas it increased 8.0 percentage points for soda (179).

Supplementary analyses

Detailed findings from the supplemental analyses are provided in Paper III (179). The supplementary analysis of taxed candy with additional control seasons (back to 2012) indicated a reduction in sales of 3.9% (p-value = 0.05). Furthermore, Model 2 only accounted for clustering on municipalities (not time), indicating a reduction in uncertainty (e.g., Model 2 for candy resulted in a coefficient representing the tax effect of 0.951 (one-sided 95% CI: 0.959, p-value < 0.001).

4 Discussion

Preface

The overall aim of this thesis was to evaluate the effects from school-based and fiscal efforts on diet-related behaviors and weight, with a particular emphasis on fruit, vegetables, candy, and soda. Overall, the included studies yielded no detectable or consistent results from the evaluated efforts (169, 179). Specifically, the findings indicated no long-term effects from the multicomponent school-based educational program on fruit and vegetable intake, no consistent beneficial or unintended effects from the FFV policy on weight outcomes among children and adolescents, nor any detectable reductions in candy and soda sales that coincided with tax increases.

Section 4.1 discusses methodological considerations that may have affected the results presented in this thesis. The results are discussed in Section 4.2, including general considerations of efforts to affect diet and weight. Implications for future research and policy formulation are briefly mentioned in Section 4.3.

4.1 Methodological considerations

4.1.1 Randomized controlled trials and quasi-experiments

Randomized controlled trials are viewed as the gold standard for establishing causal relationships between exposure and outcome in the field of nutritional research (184, 185). In RCTs participants are randomized to either intervention or control groups, which are expected to result in even distributions of (background) variables that potentially might affect study outcomes (184, 186). By including a control group, RCTs also provide counterfactual information (i.e., what would have been without the intervention/exposure) (186, 187). Quasi-experiments (QEs) can resemble RCTs, but may lack control elements and randomization to exposure (188). In public health research, QEs are valuable, as they enable evaluations of real-world interventions or policies that are difficult or impossible to manipulate experimentally (188, 189). Quasi-experiments are applied to a wide variety of studies and come in several forms, such as before-and-after comparisons, cross-sectional comparisons of exposed and unexposed (to the experimental intervention) groups, and a combination of before-and-after and group-to-group comparisons (188).

The Norwegian FFV policy (Paper II) and the abrupt increases in the taxes on chocolate and sugar products and nonalcoholic beverages (Paper III) were implemented due to political decisions, not as part of a planned research project. Thus, quasi-experimental methods were used to evaluate these efforts in Papers II and III. The study in Paper II was defined as a quasi-natural experiment because allocation to the FFV policy could not be considered "as-if random,"[8] which is consistent with a natural experiment (189). Different conceptualizations of natural and quasi-experiments exist that lie beyond the scope of this thesis (see de Vocht et al. for more information) (189).

4.1.2 Internal validity associated with study design

Allocation to groups, clustering, and baseline differences

Random allocation to groups can increase internal validity if done properly because random assignment generally ensures that baseline differences in group characteristics are the result of chance, rather than some systematic bias (184, 186, 190). The FVMM project was a cluster RCT. In cluster RCTs, intact groups of individuals are randomized to the intervention or control groups, which may result in uneven distribution of characteristics affecting outcomes between groups (184, 190, 191). In Paper I, the unit of randomization to the multicomponent education program was schools, conducted within each county. Free school fruit and vegetables were provided to the intervention schools in Hedmark County only, thereby breaking the randomization between counties. To adhere to the randomized design, which was intact within counties, participants in Hedmark County were excluded when evaluating the effect from the multicomponent educational program on adult fruit and vegetable intake (primary objective). Baseline characteristics from individuals included in the primary analysis indicated that measured characteristics (i.e., sex and parental education) were distributed evenly between groups. Differences in unmeasured characteristics could be present and introduce bias, such as ethnicity, personality traits, etc. The secondary analysis in Paper I included participants from both counties, in which the randomized design was invalid, possibly introducing bias in the results and weakening causal inferences due to the (partly) non-randomized design. Analyses using the complete sample revealed baseline differences in parental education and

[8] The concept of "as-if randomization" depends on knowledge about exposure allocation and if the process provides a strong argument that allocation is essentially random (189).

baseline fruit consumption. For this reason, and because SES is correlated with fruit and vegetable consumption, the analyses were adjusted for these variables (77, 85, 107). In cluster RCTs, there may be within- and between-cluster similarities and/or differences in characteristics that we were unable to detect and account for, such as ethnicity, teacher effects, pupils' interests, etc. (190, 191). Observations within a cluster tend to be correlated (190). The within-cluster correlation for schools was evaluated, but explained little of the total variance in the outcome between clusters. Linear mixed models used in Paper I account for correlations within individuals.

The study design in Papers II and III did not allow for randomization, which may have resulted in possible differences between intervention and comparison groups/seasons (186, 189). Allocation of the FFV policy among schools could not be considered "as-if randomized" (Paper II) (189). Considering that a higher proportion of FFV schools were located in less-populated areas, such as in the Northern and Mid regions of Norway, analyses were adjusted for region and population density when estimating the FFV policy effect. However, age and sex distributions were similar between the exposed and unexposed in the FFV policy evaluation. Furthermore, pre-exposure trajectories of BMI_{SDS} were similar between groups; however, girls attending an FFV school in the 2015 cohort had a more negative trajectory and lower BMI_{SDS} before exposure than NFFV girls. Therefore, additional analysis included adjustment for pre-exposure BMI_{SDS}. Factors that influence selection bias will be discussed further in Section 4.1.4.

Control group or comparison season

Use of a control group strengthens internal validity because it may indicate the counterfactual (187, 188). In the tax evaluation (Paper III), the previous season was the comparison season, introducing uncertainty regarding extraneous variables (uninvestigated variables that could affect the study's outcome) (186, 188). Although a comparable season strengthens causal inference, it cannot account for factors that influence sales of the taxed products specific to the intervention season, such as weather, marketing, offers on similar or substitutional products, etc. These examples qualify as uncontrolled extraneous variables threatening internal validity.

Papers I and II included a contemporaneous control group, adding strength, as it can exclude alternative extraneous causes expected to affect both groups, such as concurrent events/interventions threatening internal validity in time series design (184, 186-188). For example, the focus on fruit and vegetable consumption and healthy eating in society, which could affect outcomes in Papers I and II, is unlikely to change outcomes, considering that all participants likely were exposed to this. Nonetheless, there may have been concurrent events in schools (the level of the intervention/exposure) altering outcomes assessed in Papers I and II. For example, in Paper I, schools in both counties could have offered a parental paid school fruit subscription program, which was encouraged in the Telemark County intervention schools. Nine schools in both counties offered the parental paid school fruit and vegetable subscription program during the intervention year: six control schools and one intervention school in Telemark, and two control schools in Hedmark. Furthermore, this fruit and vegetable subscription program may have been offered in some schools the following years, as it was implemented nationally in 2004. The schools chose whether to offer the subscription program, and parents could decide whether to subscribe and pay for their children. Parents with higher education were more likely to subscribe than less-educated parents (192). The parental paid subscription program could have diluted the educational program's potential effects, as most schools offering the subscription program were control schools. However, no differences in all-day fruit and vegetable intake between children attending schools offering the parental paid subscription program vs. children attending schools with no fruit and vegetable provision have been indicated (158). Despite this, the possible effects on long-term intake remain unknown. In Paper II, supplementary analyses excluded NFFV schools offering the parental paid subscription program because these schools could dilute possible FFV policy effects.

Pre- and post-exposure outcome measurements

All studies in this thesis include pre- and post-exposure measurements, which minimize threats to internal validity (178, 187). The QE designs used in Papers II and III included longitudinal data collected pre- and post-exposure (178). Including pre-exposure trends from the outcome is important to capture changes in post-exposure trends accurately, so to a larger extent, one can attribute the change to the exposure (178, 185, 193). For example, accounting for an existing trend toward a lower BMI before the FFV exposure (as observed among girls in the 2015 cohort attending FFV schools) could increase certainty that the possible additional downward trend is attributed to the exposure. In Papers II and III, pre-exposure trends from the outcome variable were investigated because these are important assumptions for the conducted models. Regarding the WC and WHtR outcomes in Paper II, data only included a single post-exposure estimate, making it impossible to adjust for pre-exposure trends.

4.1.3 Confounding and information bias

The studies included in this thesis lacked data from potential extraneous and confounding variables, which are additional threats to internal validity. Therefore, we could not exclude the possibility of unmeasured known and unknown factors introducing confounding (186, 188). For example, although previous research has identified a positive correlation between a sedentary lifestyle and obesity (15), sedentary behavior was not measured in the study in Paper II and, thus, may represent a possible bias, thereby limiting validity of these findings. Results from other studies also indicate that sedentary lifestyle and dietary intake are correlated with SES (18, 77, 194). Moreover, maternal education (used as a proxy for SES) has been associated with overweight and obesity among Norwegian children (23). As SES could affect the results from Papers I and II, the analyses were adjusted for parental education. In Paper II, we also stratified analyses by parental education, as this could modify the policy effect because it may affect whether or not the fruit and vegetables provided in school were eaten. Uncontrolled extraneous variables that possibly introduced bias in Paper III are mentioned in Section 4.1.2 in the "Control group or comparison season" sub-section.

Questionnaires can contain inaccuracies (e.g., limited food list), typos, and recall bias, which can lead to errors in data collection and introduce bias. In Paper II, questionnaires were used to provide pupil and school information. A written dietary 24-hour recall was used in Paper I to estimate fruit and vegetable intake. People's ability to remember accurately depends on several factors, such as cognitive abilities, age, and assessed factors (foods or beverages) (195, 196). Self-reported dietary assessment methods, such as 24-hour recalls, may be subject to conscious or unconscious over- and underreporting of actual intake (196, 197). Another limitation of the 24-hour recall method, which relies on memory, is quantification of portion sizes (197). Assessment of children's diet is challenging due to estimation of portion sizes, literacy level, and memory (196). Reproducibility of the 24-hour recall method used in the FVMM project was reported to be good and vegetable intake accurate, but fruit intake may have been overestimated (172). The questionnaire has not been tested on an adult population (participants at last follow-up). Moreover, follow-up surveys may have been completed at different times of the week and during a different season than the original survey, which could have introduced bias. Furthermore, only single-day assessments were conducted, yet it is well-known that day-to-day intake varies and that ideally, multiple-day intake should have been assessed. However, when evaluating group means, a single-day assessment could suffice (197).

Exposure misclassification could have been a source of bias in Paper II, as exposure was classified according to school affiliation at one time point (third grade) (186, 195). Participants could have been assigned to the exposure or control group incorrectly if they changed schools in second grade. This, and the dichotomization of exposure (never attending an FFV school or attending an FFV school for at least one year), could have diluted possible effects from the FFV policy. In Paper III, classification of taxed products also could have been subject to misclassification, considering that categorization was done on a product group level. This could have led to the inclusion of a few untaxed products in the taxed-product group. However, this probably applied to just a few product groups sold in small amounts and likely did not impact findings. Due to uncertainty over the volumes of bulk weight candy sold, this product group was excluded from Paper III because of the strong possibility of information bias. However, excluding such an important product group covered by the tax change might have reduced the possibility of detecting sales reductions.

4.1.4 Selection bias and external validity

External validity pertains to the degree that the observed findings can be generalized to a broader setting or population and is linked to selection bias, as it refers to the sample's representativeness (186). The sample in Paper II was designed to be representative of Norwegian children and adolescents, while the sample in Paper I comprised schoolchildren from two Norwegian counties, which could differ from the general population (schoolchildren in Norway). National nutrition surveys investigating dietary differences between counties in Norway are scarce (18, 77). Nevertheless, indications of differences in dietary patterns between counties exist. Among adults, 19% reported consuming at least three portions of fruit and vegetables daily in the northern parts of Norway, and 9% reported consuming SSBs more than three times a week in Oslo (the nation's capital), compared with the Norwegian average of 13% and 23%, respectively (18). Moreover, children in Hedmark County have been found to have a somewhat higher energy intake from sugar than children in Oslo, but lower than children in the northern parts of Norway (77). Regardless of these differences, the two counties comprising the sample in Paper I included many schools that were selected randomly and believed to be representative of Norwegian schoolchildren (170). Approximately 50% were lost to follow-up for the final survey in Paper I. Attrition analysis found a higher response rate among individuals who had a parent with a higher education compared with those who had a lower education. Furthermore, girls in the complete sample were more likely to respond, which could have made the sample less representative of the adult population, as individuals' willingness to participate in research studies might reflect differences from the general population. This is known as volunteer bias (198). Volunteers are known to be more educated, more intelligent, more approval-motivated, more sociable, and have lower rates of morbidity and mortality. Nevertheless, volunteer bias probably strengthens the null findings in Paper I because girls and individuals with higher SES generally eat more fruit and vegetables (77, 107).

In Paper III, nearly all grocery stores were included, which is where most soda is sold (199). These taxed products also are sold in kiosks, gas stations, and in a few department stores, but possible implications from the tax increases in other outlets are unknown. As stated in Section 1.5, sales of products were included in the term diet-related behaviors for purposes of this thesis. Sales are linked to household expenditures and purchases, which have been demonstrated to be a good indicator of intake (200-202). This is why sales were included in the term diet-related behaviors. Moreover, sales and purchase data are used to evaluate public health interventions and have the advantage of providing large sample sizes and indicating changes (203). However, the use of store sales data, not individual intake data, limits generalizability to individuals. Therefore, the generalizability of Paper III's findings should be limited to sales in grocery stores.

Health-related behaviors are complex, with interactions and synergies that can be difficult to study in large samples and RCTs. Dietary intake, evaluated in Paper I, is complex, difficult to measure accurately, and a strict RCT may not reflect a realistic setting (184, 204). The study in Paper I was conducted in schools, reflecting a real-life context that could be generalized outside the study sample, while considering its limitations. The studies from Papers II and III provide high external validity, evaluating real-life implemented policies and changes deemed important when examining policies, as they could inform future public policies. However, external validity may be limited in Paper III because the tax hikes were evaluated on a national level without individual data. Price increases might affect individuals differently, and individual economic considerations and other preferences can influence how an individual responds to tax changes (94, 205). All studies were conducted in a Norwegian context, with certain aspects differing from other countries. Extrapolation of findings in this thesis needs to be done with caution, keeping in mind the possible limitations and biases discussed above.

4.1.5 Ethical considerations

Studies with human participants adhered to the Declaration of Helsinki. The FVMM project from Paper I and studies from Paper II (NCGS and NYGS) were approved by the Regional Ethical Committee and cleared by the Norwegian Center for Research Data. Although the ethical committee approved the studies used in Paper II, body weight measurements, particularly among children and adolescents, have been debated in Norway (206, 207). Arguably, measuring body weight may increase stigma, emphasize and trigger negative emotions, and require time and resources that could be better spent elsewhere. Furthermore, concerns over a lack of resources to provide aid and support to high-risk children captured from the measurements have been raised. However, the measurements could identify individuals who need assistance and lack support at home (208). Furthermore, the Norwegian Directorate of Health recommend routine height and weight measurements of children and adolescents (209). These measurements are important in determining health, well-being, and nutritional status, and possibly even detecting disease.

Paper III did not qualify as human or medical research, so it did not require ethical approval under national law. However, to preclude any accusations that the models were tweaked to obtain more exciting results or results in line with political, governmental, or business interests, they were pre-registered (182). Furthermore, an ethical discussion of how taxes may be regressive and possibly limit individuals' freedom lies beyond the scope of this thesis; see Véliz et al. (210) and Steele et al. (211) for further details.

4.2 Discussion of results

4.2.1 Why were there no effects from a multicomponent school-based intervention on fruit and vegetable intake in adulthood?

The FVMM project comprised a multicomponent school-based educational program based on techniques consistently associated with higher intake of fruit and vegetables, such as improving practical skills, self-efficacy, preferences, awareness, and knowledge (101, 107, 212). Furthermore, provision of fruit and vegetables to some schools increased availability of fruit and vegetables for some participants, which is an important determinant for fruit and vegetable intake (107). Bere et al. revealed that the multicomponent educational program had no effect on fruit and vegetable intake among children immediately after the intervention or up to one year after the intervention (156). However, the provision of free fruit and vegetables in schools has been found to yield both short- and long-term effects (159, 213). In Paper I, no long-term effects from the multicomponent educational program were found, including among participants who also received free school fruit and vegetables (169).

School-based efforts promoting fruit and vegetable intake

A range of interventions can increase fruit and vegetable intake among children (134, 214, 215). Multicomponent school-based interventions combining nutritional knowledge and availability of fruit and vegetables have increased intake among children (101, 216). Moreover, an umbrella review reported that school-based provision of free (or reduced-cost) fruit and vegetables and increased in-school availability were responsible for the largest increase in fruit and vegetable intake (214). However, school-based interventions that focus on nutrition awareness, knowledge, and skills have shown mixed results (214). Furthermore, evidence of programs with only nutrition education, such as programs that teachers deliver using practical activities – such as taste testing, cooking classes, etc. – is limited (216). Evans et al. reviewed school-based interventions aimed at improving fruit and vegetable intake among children and reported a mean increase in daily fruit and vegetable intake of 0.25 portions (95% CI: 0.06, 0.43) in the intervention group compared with the controls (215). Most interventions that were included contained several components, which comprised home and school elements. Moreover, the multicomponent interventions included in Evans et al.'s review were diverse and included elements ranging from curriculum, communication, and food provision, to multimedia games, changes to the school environment, home-based projects, social marketing, etc. These elements aimed to affect various determinants of fruit and vegetable intake, such as availability, skills, goals, taste, and knowledge. The interventions in the review imply that several methods affecting various determinants may improve fruit and vegetable intake among children. Moreover, the review found that multicomponent programs tended to yield larger improvements in fruit and vegetable intake than single-component interventions. A review by Pineda et al. that evaluated the effects from the school food environment in preventing childhood obesity, including improvements in dietary intake, found that single-component intervention effectively can increase fruit intake (134). Most interventions included in Pineda et al.'s review involved direct provision of food (breakfast, lunch, snack, or fruit and vegetables) (134), coinciding with the knowledge that availability of and accessibility to fruit and vegetables are important for intake (101, 107). Even with success from school-based interventions on fruit and vegetable intake, possible sustained effects into adulthood were not evaluated in the reviews (134, 215). To ensure that individuals meet recommended intake levels of fruit and vegetables to promote health, school-based interventions emphasize creating sustained effects, which are assessed less often (130, 134, 215).

Barriers to adult fruit and vegetable consumption

The multicomponent educational program evaluated in Paper I was comprehensive and affected factors associated with increased fruit and vegetable intake among children and adults (169). Nevertheless, there may be several barriers that affect adult fruit and vegetable intake, limiting possible long-term effects from the intervention. A cross-sectional study from Australia reported lack of time, perception of unachievable guidelines, availability of other foods, and the high cost and limited availability of fresh fruit and vegetables as barriers to fruit and vegetable consumption (217). Furthermore, in certain subgroups, some barriers are more prevalent. For example, lack of time was reported as the most important barrier among 18- to 50-year-olds impacting fruit and vegetable consumption. These barriers could have influenced fruit and vegetable intake in the sample included in Paper I. Furthermore, availability has been reported as a barrier to consumption (106, 217), yet fruit and vegetable supply and availability are assumed to be acceptable in Norwegian stores. Availability of fruit and vegetables is linked closely with affordability, which also has been reported as an additional barrier to fruit and vegetable consumption among Norwegians, who generally have high purchasing power (106, 217, 218). That fruit and vegetable intake seems to increase more consistently from availability indicates the importance of freely available fruit and vegetables in settings such as schools and workplaces (214).

Methods to increase and sustain fruit and vegetable intake

The initial evaluation of the multicomponent educational program in the FVMM project indicated increased awareness of the five-a-day recommendation among exposed children (156). Therefore, increased fruit and vegetable awareness in childhood might affect fruit and vegetable intake in adulthood. However, no effect from the intervention was observed on adult fruit and vegetable intake (169). Lack of awareness of fruit and vegetable intake in adulthood could explain the null findings in Paper I, as it is unknown whether the awareness and knowledge acquired in childhood were sustained into adulthood in the sample. It was not possible to evaluate awareness in adulthood because questions about this were not included in the last survey. Reviews of interventions focusing on increasing knowledge or skills suggested that such strategies are effective immediately following the intervention, but that long-term effects are unclear (214, 219, 220).

During the follow-up period, national campaigns that health authorities conducted have focused on increasing knowledge and understanding of health benefits associated with daily intake of fruit and vegetables, as well as awareness of the five-a-day recommendation (221-223). This may have increased awareness of fruit and vegetable intake in the complete FVMM sample, reducing differences in awareness between the intervention and control groups reported from the initial evaluation of the program (156). Although it is unknown whether these national campaigns were successful, mass media campaigns have been reported to improve consumption (100, 214). Furthermore, wholesale consumption of Norwegian fruit increased from 69.3 to 88.6 kg per person per year, while vegetable consumption increased from 59.3 to 81.0 kg per person per year from 2000 to 2016 (224).

Awareness and knowledge are important determinants of fruit and vegetable consumption, but it is unknown how influential these determinants are for fruit and vegetable consumption relative to other determinants in adulthood (101). The determinants of nutrition and eating (DONE) framework indicates that nutrition knowledge and awareness may be modifiable and provide effects, but that environmental factors such as availability, accessibility, and price might yield higher population-level effects (225).

Sustained effects from interventions may depend on maintaining habits, motivation, knowledge, and taste, which are some of the most consistent predictors of fruit and vegetable consumption, thereby suggesting that these determinants should be affected in interventions (105). This was attempted in Paper I, but with little success (169). To create habits and sustained effects, an extended intervention period could be essential. Interventions with longer durations (> 24 weeks) are reported to be more likely to achieve maintenance than shorter interventions (226). However, once policies are canceled, improvements seem difficult to sustain (227).

From the FVMM project, it seems apparent that the only component increasing and partly sustaining fruit and vegetable intake was provision of free fruit and vegetables to children (159, 213). Increasing availability by providing free fruit and vegetables in schools was sustained three years after the provision ended (159). Furthermore, a mean higher daily fruit intake of 0.38 portion was reported among women given one year of free fruit and vegetables during childhood compared with the controls (213). Although sample size might have limited these findings, they might indicate that free availability of fruit and vegetables in school can yield a small, long-term effect on fruit intake. A possible explanation as to why one year of providing free fruit and vegetables in schools might yield sustained effects could be that it affected other important determinants of fruit and vegetable intake, such as habits and preferences (105, 107). Nevertheless, based on Paper I, adding the multicomponent education program exerted no synergistic effect on individuals given free fruit and vegetables in school (169), indicating that availability and accessibility of fruit and vegetables are essential determinants of intake (104, 107, 214).

The FVMM multicomponent education program was designed primarily to increase fruit and vegetable intake in childhood, with no success (156). Thus, expecting the intervention to yield an effect on adult fruit and vegetable intake when other determinants and/or barriers of fruit and vegetable consumption may exert a larger impact might have been unrealistic, in hindsight. Nevertheless, studies have found that school-based interventions can increase fruit and vegetable intake among children (134, 215, 227, 228). However, as Thomson and Ravia argued, achieving and sustaining recommended intake of fruit and vegetables across the population cannot be achieved through behavior-based interventions alone, making it necessary to include additional, structural efforts to ensure that recommendations are met and sustained (229).

4.2.2 A free school fruit and vegetable policy as an effort to address childhood and adolescent overweight and obesity

Possible relationship between fruit and vegetable intake and weight

Although increased availability of fruit and vegetables in schools has been demonstrated to increase fruit and vegetable intake (157, 158, 230, 231), the study in Paper II found no strong evidence that exposure to a national FFV policy exerted any beneficial effect or unintended consequences on weight outcomes among children and adolescents. One suggested mechanism for the relationship between fruit and vegetable intake and improvements in weight outcomes is that fruit and vegetables might replace higher, more energy-dense foods, such as unhealthy snacks, thereby decreasing overall energy intake (52, 53). Bayer et al. did not substantiate an association from high fruit and vegetable intake replacing unhealthy snacking while watching TV on BMI gain (53). Øverby et al. reported a decrease in frequency of unhealthy snack intake among schoolchildren in Norway from 2001 to 2008, with lower intake among children attending FFV schools than children in schools with no fruit provision in 2008 (232). The latter study suggested that the additional decrease in unhealthy snack intake could be attributed to increased fruit intake due to the provision of free fruit and vegetables in school. However, another study found no significant differences in consumption of typical unhealthy, energy-dense snacks among adolescents attending FFV schools compared with controls from the first year of the FFV policy, while still observing greater odds of daily fruit intake (OR 1.75, 95% CI: 1.25, 2.43) among the exposed (233).

Multifaceted drivers of obesity

Childhood obesity is driven by several factors beyond fruit and vegetable intake (15, 234), such as availability of unhealthy foods and beverages (234, 235). Factors linked to increased risk of childhood obesity include lack of breastfeeding (236, 237), low physical activity level (234, 238), excessive sedentary behavior (238), sleep behaviors, and high energy intake (237), particularly from frequent snacking (56) and SSB intake (15, 237). Furthermore, environmental and genetic factors also influence the risk of overweight and obesity (29, 234, 239). No consensus exists on one primary cause of childhood obesity (240, 241). Because drivers of obesity are complex and multifaceted (15, 29), measures probably need a comprehensive approach in which fruit and vegetable availability might be one included component. However, based on Paper II's results, a FFV policy is likely insufficient to tackle the childhood obesity issue by itself. Arguably, additional and more influential determinants of overweight need to be affected in school-based childhood obesity prevention efforts.

Effects from different efforts in obesity prevention

Findings from Paper II indicate that a national FFV policy in schools may be ineffective as an obesity prevention measure, partly in line with previous research evaluating different obesity prevention programs (135, 242-244). A meta-analysis evaluating diet-related policies reported small, non-significant reductions in BMI_{SDS} (-0.02: 95% CI: -0.07, 0.02) (135). The evaluated policies varied from removing low-nutrient, energy-dense foods, to ensuring fruit and vegetable availability in cafeterias. Numerous school-based interventions, programs, and policies have been implemented to improve childhood obesity (123, 134, 245, 246). A systematic review and meta-analysis evaluating the school food environment for prevention of childhood obesity reported an effect from the included studies on BMI z-score (-0.12, 95% CI: -0.15, -0.10) (134). The studies included in the latter meta-analysis affected one or several different determinants of dietary intake in the school food environment, such as availability by increasing visibility of healthy food options, addition of salad bars, and healthy foods in vending machines, canteens and/or kiosks. The most effective interventions included use of clear and precise dietary guidelines and school meal standards in terms of type, amount, and presentation of foods. Bramante et al. conducted a systematic review evaluating the effects of population-level policies from natural experiments on childhood obesity prevention (123). They demonstrated consistently larger improvements in childhood obesity from school-based polices focusing on both food/beverage and physical activity environments vs. targeting only one environment. Therefore, targeting several determinants of obesity, such as diet and physical activity, is important. This is also supported by a meta-analysis evaluating school-based RCTs, reporting larger effects in school obesity prevention programs that include both diet and physical activity components (245).

On the other hand, a Cochrane review of RCTs for preventing obesity among children aged 6–18 indicated that physical activity interventions alone can reduce the risk of obesity, while there was no evidence of effectiveness from interventions focusing on diet (247). The dietary interventions included in the Cochrane review were mainly educational programs focusing on healthy eating and/or reduction of SSB consumption in schools or community settings. Still, the Cochrane review presents some evidence that diet combined with physical activity interventions may be effective (247), which is also supported by others concluding that school-based interventions with combined diet and physical activity components and a home element were most effective in obesity prevention (123, 245, 248).

Findings from the aforementioned studies indicate that various interventions and policies can yield improvements in childhood overweight and obesity outcomes. The evidence implies that including physical activity components in childhood obesity prevention is important (123, 245, 247). Dietary interventions and policies aimed at childhood obesity also can yield beneficial effects (123, 134, 245, 246). Based on the aforementioned findings, school-based interventions and policies targeting obesity through diet probably should focus more on environmental determinants – such as availability of healthy foods and beverages, by increasing visibility of healthy food options, adding salad bars, and selling healthier foods in vending machines – than on, for example, knowledge and awareness through educational programs (123, 134). Nevertheless, school-based health education programs can provide small improvements in BMI z-scores (-0.06, 95% CI: -0.10, -0.03) (249), but the most effective interventions seem to include parental involvement and modifications to the school environment (123, 134).

Most studies evaluate effects within a year of the intervention (247), which might not be enough time to detect effects on childhood and adolescent BMI (250). Long-term interventions (lasting one to four years) have been found to be more effective than short-term interventions, indicating the importance of intervention duration (245). Furthermore, nutritional training to reduce intake of unhealthy foods, promoting physical activity, and limiting sedentary activities are important elements in obesity prevention. The latter is supported by a recent review examining school-based efforts to promote healthy eating and physical activity, or to prevent obesity (251). The review reported that strategies enhancing the nutritional quality of foods served at schools and implementing nutrition policies were effective. Altogether, extant research indicates that various school-based interventions and policies can yield improvements in childhood obesity (123, 134, 245, 246, 249, 251); thus, promoting school-based interventions should be encouraged (244). A complex approach that includes additional components beyond the availability of fruit and vegetables, and that targets several environmental determinants of overweight, is probably needed to generate significant results.

4.2.3 Fiscal efforts that affect sales and possibly diet

Findings compared with tax evaluations worldwide

The evaluation of the increases in taxes on candy and soda implemented January 1, 2018, in Norway (Paper III) detected no consistent reductions in sales of these products (179). The findings contradict other evaluations of real-world implemented SSB taxes in other nations, which consistently demonstrate that SSB taxes reduced sales, purchases, and consumption of the taxed products (137-144, 146-150). However, the effects vary considerably, from a 4% reported reduction in sales in Barbados (139) to a 38% reduction in Philadelphia (138). Large differences exist in sales and/or purchases depending on store, beverage size, and beverage type (e.g., SSBs, ASBs, energy drinks) (140, 146, 148, 252, 253). The Norwegian tax on non-alcoholic beverages did not differentiate between beverages sweetened with sugar or artificial sweeteners, so we analyzed all sodas as one category. Considering that some studies have indicated a difference in sales by beverage type (140, 146, 252, 253), a sub-analysis within the Norwegian soda evaluation could have been conducted. However, as the tax level was equal across sodas, possible differences in sales could not have been attributed to the tax increases with certainty.

Similar to findings in Paper III, inconsistent impact, no impact, or modest overall impact from beverage taxes on purchases (254-256) and consumption (257, 258) have been reported. Some potential explanations are that effects vary depending on the season, with a more limited effect during the holidays (254), as well as differences in sample characteristics (254, 258), measurement errors (254), low tax rate (255), differences in implementation areas (258), and already-existing downward trends (256). Moreover, variations in reported sales, purchases, and consumption might be due to the different taxes, contexts, study designs, substitution effects, and tax level pass-through.

Evaluations of taxes on unhealthy foods are limited because such taxes are less common. However, both Mexico and Hungary have reported reductions (between 3.4–6.0%) in purchases of energy-dense, nutrient-poor foods after implementing taxes on these products (152-155). The tax on saturated fats in Denmark was implemented for a short period (about one year), resulting in a 4% reduction in saturated fat purchases (259). These evaluations indicate reductions in sales, contradicting findings from Paper III. Taxes on foods and/or nutrient components are heterogenous, and additional research is required to gain knowledge and draw certain conclusions.

Price as a determinant for diet

One pathway for taxes to yield effects is through price increases on the taxed products (260), as price and affordability are key determinants of food and beverage choices (94, 261, 262). Effects on consumption from increased prices vary significantly between product groups, and reductions are lower for typical staple foods (e.g., eggs, cereals, fats, and oils) (205). Thus, effects from prices on sales relate to specific foods/products. Increasing food prices can result in reductions in food purchases and consumption across countries, with larger reductions in poor households. Price and affordability of foods and beverages have been found to be important determinants of food choices for those with lower SES (94, 263), indicating that some groups are more price-sensitive than others (125). Sex and age also affect how price influences purchases (264). Due to the nature of the data used in Paper III, we could not evaluate effects from the Norwegian tax increases on subgroups.

Theoretically, for taxes to yield effects, prices need to increase (260). Variations exist in the pass-through of the implemented taxes on prices for consumers (146, 150, 258, 265, 266), which also are tied to time of implementation (267), store (265, 266), and beverage size and type (146, 265). Descriptive estimates of price per volume on candy and soda in Paper III were 5.8 and 8.0 percentage points higher during the intervention season, respectively, compared with the control season (179). The relative price increase of products varies substantially. Teng et al. reported that a 10% SSB tax was associated with an average decline in purchases and dietary intake of 10%, but also specified that context and tax design might influence impacts (268). It has been proposed that the price increase needs to be 20% or more to yield effects (133, 269), indicating that the Norwegian taxes need to be higher to reduce sales consistently, and that future studies should investigate the price level required to affect sales in Norway.

Possible additional tax effects

Although the Norwegian tax increases did not consistently affect sales, it may have resulted in additional unevaluated effects. Taxes have been shown to affect additional determinants of dietary intake, such as availability of products in stores, by decreasing availability of taxed products and increasing untaxed products (168, 265). Availability is an important determinant of food choice and consumption (94, 99). Furthermore, taxes could affect attitudes and awareness (140, 270, 271). The increase in the Norwegian taxes introduced a public debate, creating awareness about the tax, which we mistakenly expected would result in immediate effects on sales. Taxes on SSBs have been reported to create awareness of beverage consumption (253, 270). Fiscal measures could be an important tool in strategies that aim to promote healthy eating patterns across populations (272), as they may affect additional determinants of dietary intake (140, 168, 265, 270, 271).

A trend toward lower soda sales

Norwegian sales of SSBs has experienced a downward trend since 2000 (273), and similar tendencies have been reported in the United Kingdom (256), Spain, and other regions (149, 271, 274). During the past five years, Norwegian soda sales have remained quite stable, but a shift has occurred in sales, from SSBs toward ASBs (273). Still, Norwegian soda sales averaged 93 liters per person per year in 2019 (53% of sales were ASBs). Reasons for these downward trends are unknown, but they probably were a consequence of several contributing factors, such as improved health consciousness, limited availability in schools, marketing restrictions toward children, greater focus on healthy eating in kindergartens and schools, and health campaigns by authorities. Although indications of downward trends in soda sales have been reported in some countries, the continued focus on limiting SSBs in particular is needed because they are linked to tooth decay, overweight, obesity, and diabetes (60, 64, 275).

Taxes and health

Although Paper III did not evaluate the relationship between taxes and health outcomes, it is important to recognize that taxes on SSBs (and some on unhealthy foods) mostly indicate to result in reduction in sales, purchases, and consumption, thereby promoting a healthy diet that improves health due to lower intake of free/added sugars and/or high energy foods (260, 272). Even without sales reductions, a two-tiered tax[9] has been demonstrated to reduce sugar consumption in the United Kingdom from reformulation of products (252, 256). Health implications from implemented taxes on foods and beverages might take years to emerge, and evidence is limited, with low certainty (276). Even so, models estimating health effects from taxes have simulated a reduced incidence of obesity in children, adolescents, and adults (277), as well as other favorable health outcomes in addition to cost reductions (259, 278, 279).

Meaningful effects from taxes on health outcomes also depend on other factors, such as substitution effects. Taxes on unhealthy foods and beverages can influence demand for substitutes or complementary products (259, 269, 280-282). Evaluations of substitution effects due to taxes are limited, but both positive and negative substitution effects have been reported (259, 281, 282). Estimating substitution effects following a tax is challenging, but important, as they can mitigate the effect from the tax on diet quality and health.

Moreover, taxes can increase sales and/or purchases of the taxed products outside the geographical area of the tax jurisdiction area (137, 138, 142, 148), leading to

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[9] A tax that differentiates by sugar content: With a higher rate charged on drinks with more sugar (≥ 8 grams sugar per 100 milliliters), a lower rate for drinks with ≥ 5 to 8 grams sugar per 100 milliliter, and no tax for drinks with < 5 grams sugar per 100 milliliter (256).

so-called cross-border shopping. This can limit potential improvements in diet quality and health. Notably, taxes intended to reduce sales and/or accomplish product reformulation are likely to benefit health, but health effects also depend on substitutions and cross-border shopping, which need to be investigated further, as they are important in the evaluation of desired health effects.

4.2.4 General considerations

The need for a complex approach

Awareness, availability, and price are valid targeted determinants in efforts to improve diet and weight (94). Nevertheless, the evaluated efforts presented in this thesis did not yield any detectable or consistent effects, which could be explained by various factors already discussed. Overall, available data used in the evaluations may not have been able to yield observable effects and/or efforts may not have affected the most influential determinants of diet and weight. This does not necessarily imply that school-based and fiscal efforts should be discouraged. Instead, findings in this thesis indicate the need for adapted and/or additional efforts to achieve improvements in diet-related behaviors and weight in Norway. For example, to affect childhood obesity in schools, efforts should probably aim to affect diet and physical activity (248), not solely fruit and vegetable availability. Furthermore, to ensure lower sales of taxed products in Norway, taxes on unhealthy products may need to be higher.

To improve diet and reduce overweight and obesity, efforts probably should affect modifiable and influential determinants at the individual and structural levels. Individual determinants of diet may be easier to modify, such as attitudes (96), self-efficacy (98), and nutrition knowledge (94), indicating the importance of individual-level efforts. Structural interventions – which affect determinants such as availability, accessibility, and affordability – are arguably more difficult to modify, but might be more influential and, thus, provide larger population-level effects (94, 225).

Several individual and structural determinants seem to be generalizable across sex and SES, but effects from interventions may differ between sociodemographic groups (94, 283). To yield effects within different groups, efforts that affect various determinants across different settings may be important. Schools are an optimal arena for interventions to reach a large part of the population (127), but efforts could be implemented in additional settings (95, 108, 124). For example, interventions aimed at increasing fruit and vegetable intake can be delivered in a wide variety of settings in addition to schools, e.g., workplaces, grocery stores, community or religious centers, primary care settings, homes, and online (284).

Researchers, organizations, and governments frequently state that complex approaches are needed to address complex challenges using multiple techniques to affect several influential determinants within various groups of individuals and different settings (15, 108, 132, 285-287), as well as increase range and possibly effects (100, 214, 285). The Norwegian efforts evaluated in this thesis might be insufficient to promote a healthy diet and weight as sole efforts, but can be modified and included as part of a complex approach that targets additional individual and structural determinants.

Social inequalities in diet and health

Effects from school-based and fiscal efforts to reduce social inequalities in diet and health are important, but have not been the focus in this thesis. Social inequalities in diet and weight will be mentioned only briefly below.

Because those with lower SES generally have poorer diet quality and a higher prevalence of overweight and obesity, efforts aimed at improving these outcomes in particular should target individuals with lower SES to reduce health inequalities (15, 18, 23, 84). Drivers of inequalities in diet and health are complex and multifaceted, and a wide array of approaches that affect various determinants can be implemented to reduce inequalities (87, 91, 288). Affordability, availability, and accessibility of foods and beverages are important diet determinants and may be more relevant for those with lower SES, suggesting the need for structural interventions to reduce social inequalities in diet and overweight (94, 95). For example, taxes have been demonstrated to be more effective among those with lower SES (100, 125, 205). Free fruit and vegetables provided at school can reduce inequalities in health-related behaviors by increasing fruit and vegetable intake (192). However, a paid parental subsidized school fruit and vegetable subscription program can increase differences in fruit and vegetable intake among children, as children of parents with higher education levels are more likely to subscribe.

Furthermore, subsidizing healthy foods can increase intake among individuals who already eat healthy foods, but not among individuals with the lowest intake, resulting in inequalities (289). Different effects from interventions between socioeconomic groups indicate the importance of evaluating efforts by SES to reduce inequalities (283).

Common efforts to improve diet and prevent obesity rely on individual agency and assume that education and information can lead individuals to change their behaviors, which may increase health inequalities (95, 108, 116). Low agency interventions, such as structural interventions, are likely to be more effective (116). A mismatch seems to exist between the distribution of individual-level vs. structural interventions, with more interventions targeting individual determinants instead of determinants in the wider society (13, 108, 116). Individual-level interventions may yield improvements and are important. Nevertheless, efforts that focus on environmental determinants depend less on individual agency and, therefore, arguably are important in reducing social inequalities in health (95, 108, 283).

Lessons from other health promotion areas

For adherence to healthy dietary patterns and reductions in overweight and obesity, successful health promotion lessons from other areas could be considered. In Finland, prevalence of cardiovascular disease has decreased due to a comprehensive national effort that began with the North Karelia project (290). By using broad actions to change national diets and target metabolic risk factors, Finland reduced annual cardiovascular disease mortality in the working-age population by 80% between 1970 and 2005. The North Karelia project aimed to change general risk-related lifestyles through community-based action that included preventive services, information, and community organization. The project changed the social, physical, and policy environment, and included a wide range of components, such as health education, which was promoted in various forms (posters, leaflets, and meetings) and several settings (health care and schools), collaborations with local food manufacturers to promote and produce healthier products, and actions in the health, agriculture, and commerce sectors. Additional information about the project can be found on its website (291). Although the North Karelia project had some problems and constraints (292), it illustrated the importance of efforts that affect several individual and structural determinants in multiple settings, and that many small contributions yield large population effects over time (290). A complex approach, as illustrated in the North Karelia project, might be required to tackle overweight and obesity challenges.

Progress has been made worldwide to target tobacco use, with tobacco-related morbidity and mortality expected to decrease in the future (293). Declines in tobacco use indicate the importance of individual and structural efforts aimed at several (modifiable and influential) determinants, such as efforts that affect prices, advertising, and promotion; restrictions in smoking areas; education campaigns; and smoking-cessation therapies (293, 294). In Norway, more than 700,000 residents have ceased smoking over the past 50 years, and the prevalence of smokers is now below 10%, with smoking somewhat stigmatized (295-297). These improvements are likely the result of several measures, such as marketing restrictions, health warnings, obligations to mark products, age limits, plain packaging, tobacco legislation, school-based prevention programs, product regulations, tax increases, and information campaigns (295, 296, 298). The different measures aimed at smoking reduction are likely to elicit synergistic effects, and the consensus is that a comprehensive approach is the most effective. Methods used to reduce smoking in Norway could be used to increase fruit and vegetable intake, as well as reduce intake of unhealthy foods and beverages, if adapted accordingly. A comprehensive approach that affects availability, affordability, acceptability, and awareness of dietary determinants may yield large improvements, as experienced with tobacco control. Although it may take time and political will, the examples suggest that alignment of several efforts in affecting modifiable and influential determinants (of the targeted behavior) in various settings can generate effects.

Favorable trends

Trends in dietary consumption and the prevalence of overweight and obesity in Norway are encouraging (21, 273). From 1999 to 2019, Norwegian wholesale consumption of fruit increased from 69 to 85 kg per person per year, and consumption of vegetables increased from 61 to 80 kg per person per year (273). Furthermore, wholesale consumption of sugar has been almost halved (decreasing from 43 to 24 kg per person per year) from 2000 to 2019. Furthermore, national cross-sectional surveys indicate a stabilization of childhood overweight and obesity (21). Altogether, these trends imply improvements and may reflect that slowly, the population's diet is developing in accordance with national guidelines, possibly leading to stagnation of the increase in overweight prevalence. These favorable developments could be the result of years of (small) societal changes and public health efforts (221-223), ultimately affecting Norwegian residents and their diets. However, to continue these favorable trends, action is still needed.

4.3 Implications

The studies presented in this thesis did not provide detectable and consistent improvements from Norwegian school-based and fiscal efforts on diet-related behaviors and weight, with an emphasis on fruit, vegetables, candy, and soda. The presented findings and discussion aimed to provide valuable information that may be used to adapt and improve nutritional and diet-related interventions and policies. Moreover, the findings highlight the need for adapted and/or additional efforts to address these complex issues in a Norwegian setting.

Future research

The research results presented in this thesis suggest the need to investigate further how to increase fruit and vegetable intake among adults. Although the FFV policy did not seem to affect childhood or adolescent overweight and obesity, a potential subject for future research is how this might impact future dietary patterns and adult overweight and obesity prevalence. Furthermore, it would be important to investigate the tax level required in Norway to yield consistent and substantial reductions in sales of unhealthy products. However, considering that the tax on chocolate and sugar products and the tax on nonalcoholic beverages have been repealed (as of January and July 2021, respectively), future research should evaluate the possible implications from these tax repeals on sales and consumption, including subgroup analyses.

Health promotion practitioners and policy and decision makers

The findings in this thesis provide knowledge from implemented, real-world measures that can inform health promotion practitioners and policy and decision makers. The absence of consistent and beneficial effects indicates the need for adapted and/or additional measures to improve diet and reduce overweight and obesity. Nevertheless, no unintended consequences from the FFV policy on weight suggest that this policy could be used to increase fruit and vegetable intake. Changing a population's dietary patterns and the obesogenic environment is complex, yet efforts are needed to reflect the challenges in society and should target the modifiable and most influential determinants. To increase the possibility of yielding substantial effects faster, a larger need may exist for implementation of effective population-wide measures, which may require resources and probably depend on political will.

5 Conclusion

The school-based and fiscal efforts evaluated in this thesis did not yield detectable and consistent improvements in diet-related behaviors and weight when focusing on fruit, vegetables, candy, and soda. This thesis has contributed important evaluations of real-life, implemented efforts and policies that affect diet-related behaviors and weight in Norway, providing knowledge to policy and decision makers. The findings indicate the need for adapted and/or additional measures to improve diet and reduce overweight and obesity in Norway, probably requiring substantial political will.

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Appendices

Paper I: Øvrebø B, Stea TH, Te Velde SJ, Bjelland M, Klepp KI, Bere E. A comprehensive multicomponent school-based educational intervention did not affect fruit and vegetable intake at the 14-year follow-up. Prev Med. 2019 Apr;121:79-85.

Paper II: Øvrebø B, Stea TH, Bergh IH, Bere E, Surén P, Magnus PM, Juliusson PB, Wills AK. No strong evidence of benefits or unintended consequences on BMI or overweight from a nationwide school fruit and vegetable policy: a quasi-natural experimental study. PLoS Med. 2021 Sep (under revision).

Paper III: Øvrebø B, Halkjelsvik TB, Meisfjord JR, Bere E, Hart RK. The effects of an abrupt increase in taxes on candy and soda in Norway: an observational study of retail sales. Int J Behav Nutr Phys Act. 2020 Sep 14;17(1):115.

Appendix 1: Questionnaire from Fruit and Vegetables Make the Marks, baseline 2001

Appendix 2: Questionnaire from Fruit and Vegetables Make the Marks, follow-up 2016

Appendix 3: Pupil form including consent from the Norwegian Childhood Growth Study

Appendix 4: Pupil web form from the Norwegian Youth Growth Study

Appendix 5: School form from the Norwegian Childhood Growth Study

Appendix 6: School web form from the Norwegian Youth Growth Study

Appendix 7: Norwegian Youth Growth Study 2017 consent form

Appendix 8: Pre-registered analysis of Paper III

Paper I

Øvrebø B, Stea TH, Te Velde SJ, Bjelland M, Klepp KI, Bere E. A comprehensive multicomponent school-based educational intervention did not affect fruit and vegetable intake at the 14-year follow-up. Prev Med. 2019 Apr;121:79-85.

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A comprehensive multicomponent school-based educational intervention did not affect fruit and vegetable intake at the 14-year follow-up

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ABSTRACT

The intake of fruit and vegetables is associated with beneficial health outcomes, and studies aimed at increasing fruit and vegetable intake lack long-term follow-up. The primary objective of this study was to evaluate the long-term (14-year) effects of a multicomponent school-based educational intervention targeted to increase fruit and vegetable intake in children. The secondary objective was to evaluate the potential synergistic effect between free school fruit and the educational program. A cluster randomized school-based intervention was initiated in 2001 in Norway, known as the Fruit and Vegetable Make the Marks study. In total, 38 schools were randomized; for the intervention (n = 18) and as control schools (n = 20). A subsample of the intervention schools (n = 9) were additionally given free school fruit, resulting in two intervention groups - one with and one without free fruit. Participants completed questionnaires in September 2001 (baseline, mean age 11.8), May 2002 (at the end of the intervention), May 2003, May 2005, September 2009 and throughout 2016 (mean age 26.5). Of 1950 participants, 982 (50.4%) completed the 14-year follow-up and were considered as the current study sample. Analysis yielded no 14-year effects of the educational program on fruit and vegetable intake. A synergistic effect between the educational program and free fruit was not observed either. Future studies might benefit from increased focus on more extensive parental involvement, increased home availability, and a longer intervention period. However, more long-term studies are needed to evaluate the effects of school-based interventions into adulthood.

Trial registration number: Ethical approval and research clearance was obtained from The National Committees for Research Ethics in Norway (file number S-01076) and The Norwegian Centre for Research Data (file number 12395).

1. Introduction

European children, including Norwegian children, do not meet the recommended intake of fruit and vegetables (FV) (Lynch et al., 2014). To improve overall public health and prevent non-communicable diseases (NCDs), The World Health Organization recommends an intake of 400 g of FV per day (WHO, 2018). In Norway, health authorities recommend a daily intake of at least five portions (500 g) of FV, of which about half should be vegetables and the other half fruit and berries (Helsedirektoratet, 2011). A study among children across Europe reported a mean intake of FV between 2 and 3.5 portions per day and Norwegian children reported a daily intake of approximately 2.5 portions of fruit and 1 portion of vegetables (Lynch et al., 2014). Therefore, an important step in the prevention of NCDs is to increase FV in accordance with the recommendations (WHO, 2018).

Because schools are attended by children with a wide range of socioeconomic backgrounds, they are optimal for implementing public health interventions, which may result in healthy eating patterns (Glasuer and Sherman, 2005). Various school-based intervention studies have increased FV intake in children, and the pooled estimate from a meta-analysis by Evans et al. (2012) indicates that different school-based interventions have increased the daily mean FV intake (without

Abbreviations: CI, confidence interval; FV, fruit and vegetables; FVMM, Fruit and Vegetables Make the Marks; NA, not applicable; NCDs, non-communicable diseases; SCT, social cognitive theory; SD, standard deviation

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fruit juice) with 0.25 portions (Evans et al., 2012).

Evans et al. (2012) have argued that multicomponent interventions are more effective in increasing FV intake than single component interventions as their meta-analysis suggested that multicomponent interventions tended to yield larger improvements in FV intake (Evans et al., 2012). Additionally, preferences, taste, parental intake, home availability and methods of preparation have been reported by other authors as modifiable determinants of FV intake in children (Krolner et al., 2011; Rasmussen et al., 2006), and therefore these determinants should be targeted in interventions to increase FV intake.

Poor long-term adherence to healthy behavior has been reported as a common challenge in intervention studies (Middleton et al., 2013). FV intake should be at the recommended levels and sustained throughout life to have an impact on health (WHO, 2018; Helsedirektoratet, 2011; Slavin and Lloyd, 2012). The few studies that have evaluated interventions aimed at increasing FV intake in children have included follow-up surveys after the interventions had ended (Evans et al., 2012). When including the time of the intervention, the longest follow-up in the meta-analysis by Evans et al. (2012) was approximately 2.5 years. To our knowledge, no study with a school-based educational program aimed at increasing FV intake in childhood has evaluated the potential effects in adulthood. From a public health perspective, evaluating interventions from childhood and possible effects in adulthood is important.

The Fruit and Vegetable Make the Marks (FVMM) project included an educational program based on a framework from social cognitive theory (SCT) (Bere et al., 2006a). Social cognitive theory proposes that behavior, environmental and personal factors interact and all contribute to action (Bandura, 2001), and these factors have been used to develop the FVMM educational program (Bere et al., 2006a). This program consisted of a classroom component and parental involvement (see further details under Methods) and both had significant focus on changing different determinants of FV intake in accordance with SCT (e.g. frequency of FV intake, accessibility, awareness, preferences) (Krolner et al., 2011; Rasmussen et al., 2006; Bere and Klepp, 2004). The program targeted both school and home environments by providing a range of activities aimed at increasing FV intake. Although no effect on FV intake was reported after eight and 32 months, respectively, the educational program yielded an effect on awareness of the five-a-day recommendation (Bere et al., 2006a) which may affect FV intake in adulthood when the participants themselves are responsible for their own nutritional intake. Further, a substantial part of the intervention was to influence determinants of FV intake (Krolner et al., 2011; Rasmussen et al., 2006), which might have led to behavior changes later in life (Larson et al., 2012).

A subgroup of the participants in the FVMM was given free school fruit. This resulted in an increased FV intake while it was given (Bere et al., 2005). Furthermore, in the seven-year follow-up analysis of free school fruit, sensitivity analysis revealed the highest effect size in the group receiving both free fruit and the educational program (Bere et al., 2015). This might indicate a possible synergistic effect of the educational program when combined with free fruit.

Based on this, our primary objective was to evaluate the effect of the FVMM multicomponent school-based educational program 14 years after the intervention ended, when the participants were adults. The secondary objective was to evaluate a possible synergistic long-term effect between the educational program and free fruit.

2. Methods

2.1. Design and setting

The design of the FVMM project has previously been reported by Bere et al. (2006a), Bere et al. (2005), and Bere et al., 2006b); nevertheless, a short overview follows. A cluster of randomized school-based interventions was initiated in 2001 with the aim of increasing FV intake in school children. A total of 48 elementary schools in two Norwegian counties, Hedmark and Telemark, were randomly selected and invited to participate. Of these, 38 schools agreed to participate (19 schools in each county). Nine schools in each county were randomized to the intervention and the remaining were included as control schools. The participants consisted of pupils in the 6th and 7th grades during the school year of 2001–2002, where 6th graders in the intervention schools were given a multicomponent educational program to increase FV intake. Due to practical reasons, all pupils (i.e. both 6th and 7th graders) in the intervention schools in Hedmark County were also given free school fruit during the intervention period. This resulted in breaking the randomized design between counties. However, within counties, the randomization was still valid. Regarding the multicomponent educational program, it resulted in two intervention groups and two control groups, both with and without free school fruit. The study design of the current study is shown in Fig. 1.

2.2. Sample

From the 38 schools, a total of 2287 pupils were invited to participate. 337 pupils did not want to participate or did not complete the baseline survey for other reasons (e.g. did not attend school the day of the survey). The baseline sample consisted of 1950 (85%) pupils in 6th and 7th grades. For 1028 6th graders (10–11-year-olds) and 922 7th graders (11–12-year-olds), we also obtained data from parents. Of the 1950 pupils, 984 were boys and 966 were girls. All parents gave informed consent prior to the first survey.

2.3. Interventions

2.3.1. Multicomponent educational program

The multicomponent educational program consisted of an educational program with a classroom and a parental component as described in Bere et al. (2006a). A brief overview of these components follows.

2.3.2. Classroom component

The classroom curriculum was based on SCT and given once a month in Home Economics classes by Home Economic teachers over a 7-month period (October 2001 to April 2002). Three sessions were completed before Christmas and four were completed after. Each session lasted 3 h and included preparation of dishes and snacks with a focus on FV, group activity and information. The pupils monitored their own FV intake for 3 days followed by self-assessment and goal setting for future intake (awareness/perceived personal need to increase consumption). The goals were to focus on FV throughout the year, preparation of FV (to increase practical skills, sense of self-efficacy, and preferences), increase knowledge about FV, create positive attitudes toward FV and increase short and long-term intake of FV.

2.3.3. Parental involvement

Parents were introduced to the intervention at school meetings, including information on FV and health. During the intervention, parents received six newsletters (each with a theme) aiming to increase communication between parent and child regarding FV and how to increase their access to FV at home. In addition, an FV event was held where the children served self-made FV dishes.

2.3.4. Free school fruit

During the intervention period, pupils in the intervention schools in Hedmark (n = 9) received one piece of free fruit or carrot at lunch, as previously described (Bere et al., 2005). The most frequent fruits given were: apples, pears, bananas, oranges, clementines, kiwis, carrots, and nectarines.

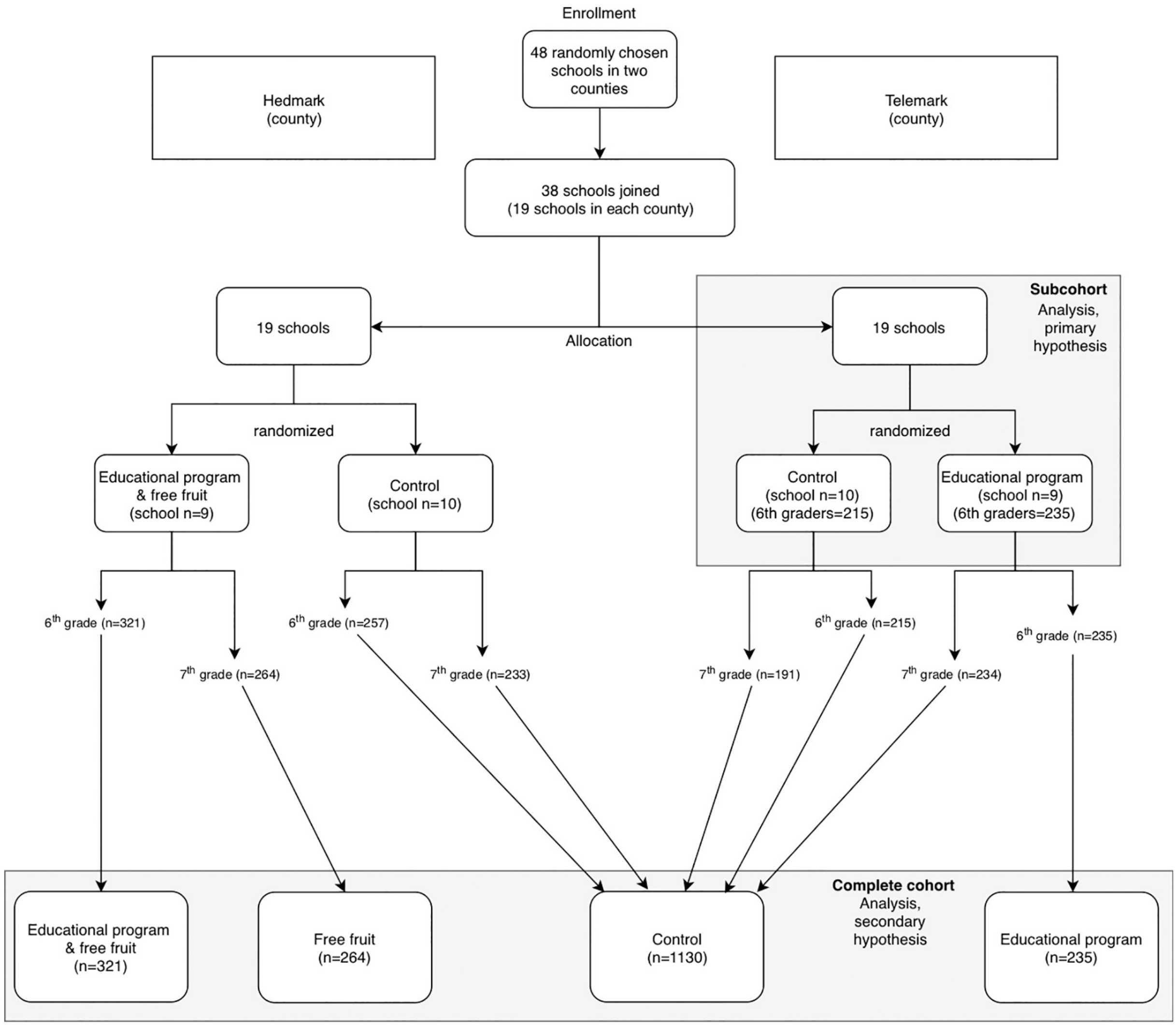

Fig. 1. Study design of the Fruit and Vegetable Make the Marks project, showing the intervention conditions and the comparable groups in the current study in the grey boxes, initiated in Norway in 2001.

2.4. Measurements

Baseline questionnaires were completed in September 2001 and follow-up questionnaires were administered in May 2002 (after the intervention period), May 2003 (1-year follow-up), May 2005 (3-year follow-up), September 2009 (7-year follow-up) and throughout 2016 (14-year follow-up). At baseline and the first three follow-ups questionnaires were completed by the pupils at school with a trained project worker present. The project worker helped with the dietary assessment. The 7-year follow-up was completed by a questionnaire sent by mail, while the 14-year follow-up was a web-survey.

A written 24-hour recall was used to assess FV intake in portions per day. Intake recorded at school (years 2001–2005) represented a weekday, while the two former follow-ups (in 2009 and 2016) did not specify which day the questionnaire was to be completed. In follow-ups between 2002 and 2005 the 24-hour recall separated intake in five periods through the day (before school, at school, after school, at dinner and after dinner). At the last two follow-ups the participants had finished school, so the day was separated into four periods fitting an adult schedule (morning including breakfast, after breakfast including lunch, after lunch including dinner, and after dinner including supper). The sample recorded gender and age at baseline. Socio-economic status was based on parental education level at baseline (lower: no college or university education versus higher: having attended college or university).

The study was conducted according to the Helsinki Declaration. Ethical approval and research clearance were obtained from The National Committee for Research Ethics in Norway (for the first three surveys (file number S-01076)) and all surveys were cleared by The Norwegian Centre for Research Data (file number 12395).

2.5. Statistical analysis

To assess baseline differences and attrition between the groups, we used x^2-test with categorical variables, and *t*-test or ANOVA with continuous variables. Additional z-test of proportion was completed with Bonferroni adjustment where necessary.

Analysis to evaluate our primary objective was conducted with 6th graders in Telemark county only (referred to as the subcohort, see Fig. 1), to exclude the potential effect of also receiving additional free fruit. The 7th graders were excluded from this analysis to have similar age in the groups, and to stick to the pure randomized design. To adjust for observations nested within subjects, the linear mixed model was used to determine the effect of the educational program on FV intake by using all the relevant, available data from each follow-up. The model included group (educational program versus control), time and

Table 1
Baseline (year 2001) characteristic of the study sample.

	Free fruit	Boys n (%)	Low parental education n (%)	Baseline fruit intake mean (SD)*	Baseline vegetable intake mean (SD)*
Subcohort (n = 450)					
Educational program	No (n = 235)	114 (49)	121 (60)	1.7 (1.9)	1.0 (1.3)
Control	No (n = 215)	90 (42)	112 (66)	1.6 (2.1)	0.9 (1.3)
p-Value		0.145	0.206	0.717	0.596
Complete cohort (n = 1950)					
Educational program	Yes (n = 321)	174 (54)	155 (54)[a, b]	1.3 (1.5)[a]	0.9 (1.2)
	No (n = 235)	116 (49)	121 (60)	1.7 (1.9)[a]	1.0 (1.3)
Control	Yes (n = 264)	127 (48)	113 (49)[a, c]	1.4 (1.5)	0.8 (1.2)
	No (n = 1130)	567 (50)	555 (61)[b, c]	1.6 (1.9)	0.9 (1.3)
p-Value		0.442	0.003	0.039	0.549

* Intake in portions per day. Similar subscripts within column indicates significant differences between the groups. SD: Standard deviation.

group*time interaction as fixed variables, subject as random intercept and time as random slope. We adjusted for gender, parental education level and baseline observations. The residuals were examined, and the model assumptions were considered met.

Analysis to evaluate the secondary objective was completed with the use of the complete cohort with four groups (intervention and control group, with and without free school fruit) as dummy variables. Our main focus assessing the potential synergistic effect was the differences between the two groups with free fruit, with and without the educational program, and these results are therefore reported. The linear mixed model, with the same settings as above, was completed to evaluate this effect. The follow-up in 2003 was only completed on initial 6th graders who received the educational program, which resulted in no participants in the control group who only received free fruit, reported as Not Applicable (NA).

Analysis were completed in Stata version 15.1 software (StataCorp. 2017. *Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC), with two-sided p-values and significance level set to 5%.

3. Results

3.1. Baseline characteristics

Baseline characteristics are presented in Table 1. Mean age at baseline was 11.8 years, while mean age at follow-up in 2016 was 26.5 years. There were no significant differences in gender, parental education or FV intake between the intervention and control group at baseline in the subcohort. In the complete cohort, there was a significant overall difference between the groups at baseline regarding fruit intake (p = 0.039) and parental education (p = 0.003), but no differences in gender or vegetable intake were observed.

3.2. Effect of the educational program

Of the 450 6th graders in the subcohort who completed the baseline questionnaire, 237 (53%) completed the 14-year follow-up. There were no significant differences in attrition at the 14-year follow-up regarding baseline fruit intake, baseline vegetable intake, gender or group. Attrition was significantly higher among participants who had parents with low education versus high education (77% versus 23%, $p < 0.001$).

Predicted means of FV intake for each group are presented in Table 2. The linear mixed model analysis yielded no overall significant effect of group, time or group ∗ time interaction on fruit intake (all p-values > 0.05). The analysis yielded a significant increase in vegetable intake over time ($p < 0.001$, data not shown), but no significant overall effect of group (p = 0.405) or differences between the groups over time (group ∗ time interaction, p = 0.975) with regards to vegetable intake.

3.3. Synergistic effect of the educational program and free school fruit

Of the 1950 6th and 7th graders who completed the baseline questionnaire, 982 (50%) completed the 14-year follow-up. There were no significant differences in attrition at the 14-year follow-up regarding baseline fruit intake, baseline vegetable intake, or group. Analysis showed a significantly higher 14-year attrition rate among men compared to women (55% versus 45%, $p < 0.001$). Additionally, attrition was significantly higher among participants who had parents with low

Table 2
Adjusted means (95% CI) of fruit and vegetable intake at each follow-up by group in the subcohort.

Variable	Group	Baseline[a] (2001)	2002[b]	2003[b]	2005[b]	2009[b]	2016[b]
Fruit, portions per day	Educational program	1.7 (1.5, 1.9)	1.4 (1.2, 1.7)	1.2 (1.0, 1.5)	1.4 (1.2, 1.6)	0.9 (0.4, 1.4)	1.2 (1.0, 1.5)
	Control	1.7 (1.5, 2.0)	1.3 (1.1, 1.5)	1.4 (1.2, 1.6)	1.3 (1.1, 1.6)	0.8 (0.2, 1.3)	1.2 (0.9, 1.5)
	p-Value	0.840	0.409	0.377	0.578	0.689	0.976
Vegetables, portions per day	Educational program	1.0 (0.8, 1.2)	0.7 (0.5, 0.9)	0.7 (0.5, 0.9)	1.0 (0.8, 1.2)	1.1 (0.6, 1.5)	1.5 (1.3, 1.8)
	Control	0.9 (0.7, 1.1)	0.8 (0.6, 1.0)	0.8 (0.6, 1.0)	1.0 (0.8, 1.2)	1.0 (0.5, 1.6)	1.7 (1.4, 2.0)
	p-Value	0.443	0.405	0.428	0.893	0.984	0.492

CI: Confidence interval.
[a] Adjusted for gender and parental education level.
[b] Adjusted for baseline data, gender and parental education level.

Table 3
Adjusted mean fruit intake in portions per day by group in the complete cohort.

	Free fruit	Baseline (2001)[a]	2002[b]	2003[b]	2005[b]	2009[b]	2016[b]
Educational program	Yes	1.5 (1.2, 1.5)	1.8 (1.7, 2.0)	1.5 (1.3, 1.7)	1.3 (1.1, 1.5)	1.4 (1.1, 1.7)	1.2 (1.0, 1.4)
	No	1.7 (1.5, 1.9)	1.4 (1.2, 1.6)	1.2 (1.0, 1.4)	1.4 (1.2, 1.6)	0.9 (0.4, 1.3)	1.2 (1.1, 1.6)
Control	Yes	1.4 (1.2, 1.6)	1.8 (1.6, 2.9)	NA	1.3 (1.1, 1.5)	1.1 (0.7, 1.5)	1.3 (1.1, 1.6)
	No	1.6 (1.5, 1.7)	1.2 (1.1, 1.3)	1.2 (1.0, 1.3)	1.2 (1.1, 1.3)	1.0 (0.7, 1.2)	1.3 (1.2, 1.5)
p-Value[c]		0.925	0.915	NA	0.985	0.380	0.481

CI: Confidence interval. NA = not applicable.
[a] Adjusted for gender and parental education level.
[b] Adjusted for baseline data, gender and parental education level.
[c] P-values from comparing the two groups who received free fruit.

Table 4
Adjusted mean vegetable intake in portions per day by group in the complete cohort.

	Free fruit	Baseline (2001)[a]	2002[b]	2003[b]	2005[b]	2009[b]	2016[b]
Educational program	Yes	0.9 (0.8, 1.1)	0.7 (0.6, 0.8)	0.7 (0.6, 0.8)	1.1 (0.9, 1.2)	1.1 (0.8, 1.4)	1.6 (1.3, 1.8)
	No	1.0 (0.8, 1.2)	0.7 (0.5, 0.8)	0.7 (0.5, 0.8)	1.0 (0.8, 1.2)	1.0 (0.6, 1.4)	1.5 (1.3, 1.8)
Control	Yes	0.8 (0.7, 1.0)	0.6 (0.5, 0.8)	NA	1.0 (0.9, 1.2)	1.0 (0.7, 1.3)	1.7 (1.5, 1.9)
	No	0.9 (0.9, 1.0)	0.7 (0.6, 0.8)	0.7 (0.6, 0.8)	0.9 (0.8, 1.0)	1.0 (0.8, 1.2)	1.6 (1.4, 1.7)
p-Value[c]		0.406	0.663	NA	0.869	0.812	0.360

CI: Confidence interval. NA = not applicable.
[a] Adjusted for gender and parental education level.
[b] Adjusted for baseline data, gender and parental education level.
[c] *p*-Values from comparing the two groups who received free fruit.

education versus high education (67% versus 33%, $p < 0.001$).

Analysis revealed no significant difference in fruit intake at neither follow-up between the two groups who received free fruit, with and without the educational program (Table 3). There were no significant differences in vegetable intake between the groups who received free fruit, with and without the educational program, at any time (Table 4).

4. Discussion

Results from the present study showed no effect of a multi-component school-based educational program on FV intake 14 years after the intervention period. Furthermore, analysis revealed no synergistic effect of the educational program and free school fruit.

Several multicomponent intervention studies have increased FV intake in children (Evans et al., 2012; Van Cauwenberghe et al., 2010). However, the effects of multicomponent interventions reveal inconsistent results (Evans et al., 2012; Van Cauwenberghe et al., 2010; Delgado-Noguera et al., 2011). Although these interventions are argued better than single component interventions, this might rely more on the actual components, as well as the total comprehensiveness, than the number of components. Also, single component interventions might be effective, e.g. it has been shown that giving free fruit in schools increases intake (Evans et al., 2012; Bere et al., 2015; Delgado-Noguera et al., 2011). In the present study, we reported no synergistic effect between the educational program and free fruit, which indicate free fruit as an important single component in FV intake in children.

We hypothesized that children's awareness of the five-a-day recommendation would result in an increased FV intake in adulthood when the participants themselves were responsible for their own nutritional intake. The health authorities have over the last decade increased focus on healthy eating, which might have increased awareness of five-a-day in the whole Norwegian population and their intake. Although awareness has been found to explain variations in FV intake (Van Duyn et al., 2001), our study might indicate that other factors have a higher impact on long-term FV intake.

Our intervention had a parental component, but this component might not have involved parents at a sufficient level (Jorgensen et al., 2016). Parental involvement has previously been identified as an important factor affecting the result of interventions targeting adolescents (Jorgensen et al., 2016; Golan, 2006). A study by Jorgensen et al. (2016) classified high parental involvement as one parent taking part in three out of four parental activities and getting a score of at least four out of six points (Jorgensen et al., 2016). This high involvement was significantly associated with a higher daily FV intake. In comparison, our study had fewer parental activities and we could not achieve the equivalent of what was classified as high parental involvement. This indicates the importance of a higher focus on parental involvement and the home environment when trying to increase FV intake in children/adolescents.

Furthermore, home availability has been identified as one of the most important predictors of FV intake (Larson et al., 2012), which remained unchanged by our intervention (Bandura, 2001). This suggests that newsletters have a low impact. Therefore, an intervention changing FV intake in children should address the availability of FV in the home environment but probably with other strategies. Several studies have attempted to increase home availability of FV, but with no significant effects (Ganann et al., 2014). Increasing availability of FV both in the home environment and at school is important (Krolner et al., 2011; Rasmussen et al., 2006), however the implementation of comprehensive programs focusing on increased availability in different arenas may be financially challenging.

The educational program was based on SCT, which assumes that initiation and long-term maintenance of behavioral change involves health knowledge, self-efficacy, outcome expectancies, self-regulatory skills and barriers to change (Middleton et al., 2013). Models that for a large part rely on individual decision-making processes, such as the SCT, may not be appropriate to target behavior change in young children (Golan, 2006). Nevertheless behavior change strategies based on the SCT toward young children have significantly increased physical activity and healthy eating, especially where there is high parental involvement (Nixon et al., 2012).

To our knowledge, no other studies have evaluated a multi-component school-based educational intervention promoting an increased intake of FV with a 14-year follow-up period. Long-term adherence to health behavior is generally difficult (Middleton et al., 2013), and our SCT-based, multicomponent intervention did not yield lasting results which one might argue is a waste of resources if continued (Velde et al., 2011). On the other hand, our intervention might have been too short to expect a long-term effect as the intervention lasted only 10 months. In addition, different psychosocial and structural factors might contribute to the intake of FV in adulthood than in childhood (Shaikh et al., 2008; Brug et al., 2006). Family factors such as composition, marital status, presence of children, convenience, time, family and cultural background all impact FV intake (Rekhy and McConchie, 2014). Thus, expecting our intervention to affect adult FV intake might be unreasonable.

Free school fruit is documented to increase short-term FV intake (Bere et al., 2006b), and has also been reported to impact long-term (7 year) FV intake (Bere et al., 2015). Few studies focus and manage to increase long-term vegetable intake in children, however studies suggest that gardening increases short-term vegetable intake (Evans et al., 2012; Langellotto and Gupta, 2012). Interventions like ours do not seem to be enough to increase FV intake to the recommended levels, thus interventions combining several elements like social marketing, economic approaches and technology-based interventions might be tested to ensure that recommendations are met and sustained (Thomson and Ravia, 2011). Future interventions should focus on high parental involvement, vegetable intake, increased home availability, have a longer or sustained intervention, evaluate cost-effectiveness and the potential impact on future health outcomes.

4.1. Study limitations and strengths

A number of methodological considerations should be considered. First, the multicomponent educational program lasted approximately ten months, and it could have been longer and had higher parental involvement, which might have created lasting habits. However, such a comprehensive approach is probably not feasible. Additionally, in the subcohort only one school implemented all sessions as planned which might have affected the impact of the intervention, however six out of eight intervention schools did complete more than five sessions (Bere et al., 2006a). Furthermore, during the intervention, all schools in Norway could choose to administrate a fruit subscription program (Bere et al., 2005) that we could not control. Additionally, lacking information on important confounders, such as e.g. psychosocial factors and economy, may have affected our results. Moreover, a dropout rate of 50% does affect the generalizability. Although with limitations, this study is to our knowledge the only long-term study evaluating a multicomponent educational program aimed to increase FV intake, and thus contributes to the limited knowledge on improving long-term intake of FV. The randomized controlled design in the subcohort and the well-developed educational program adds to show the difficulty of increasing long-term FV intake in children.

5. Conclusion

We show that a well-developed multicomponent, school-based educational program had no effect on FV intake, neither in synergy with free school fruit. This shows the difficulty in affecting long-term FV intake. Future studies may benefit from a higher parental involvement, increased home availability and a longer intervention period. More studies are needed to evaluate the effects of school-based intervention in adulthood.

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Conflicts of interest

None.

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Paper II and supplemental material

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No strong evidence of benefits or unintended consequences on BMI or overweight from a nationwide school fruit and vegetable policy: a quasi-natural experimental study

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Abstract

Background

Free school fruit and vegetable (FFV) policies are used to promote healthy dietary habits and tackle obesity, however, our understanding of their effects on weight outcomes is limited. We assess the effect of a nationwide FFV policy on childhood and adolescent weight status and explore heterogeneity by sex and socioeconomic position.

Methods and Findings

This study used a quasi-natural experiment design. Between 2007 and 2014, Norwegian combined schools (grades 1-10) were obligated to provide FFV while elementary schools (grades 1-7) were not (NFFV). We used four nationwide studies (n = 11215 children) from the Norwegian Growth Cohort with longitudinal or cross-sectional anthropometric data up to age 8- and 13-years to capture variation in FFV exposure. Outcomes were body mass index standard deviation scores (BMI_{SDS}), overweight and obesity (OW/OB), waist circumference, (WC) and weight to height ratio (WtHR) at age 8.5y, and BMI_{SDS} and OW/OB at age 13y. Analyses included longitudinal models of the pre- and post-exposure trajectories to estimate the policy effect. The participation rate in each cohort was >80%, and in most analyses <4% were excluded due to missing data. In pooled pre-exposure adjusted models, there was little evidence of any benefit or unintended consequence from 1-2.5y of exposure to the FSF policy on BMI_{SDS}, OW/OB, WC, or WtHR in either sex. For example, the predicted shift in median BMI and WC from the policy based on the 95% CIs from these models was -0.07 to +0.33 kg/m^2 and -0.5 to +0.7 cm respectively. There was evidence of heterogeneity in the policy effect-estimates at 8.5y across cohorts and socioeconomic position, however these results were inconsistent when triangulated with other comparisons. Analysis at age 13y, after four years of policy exposure, also showed little evidence of an effect on BMI_{SDS} or OW/OB. Residual confounding and exposure misclassification are the main threats to the validity of our estimates but are unlikely to be of sufficient magnitude to affect our conclusions.

Conclusion

We found no strong evidence that the Norwegian nationwide FFV policy had any beneficial effect or unintended consequence on weight status among Norwegian children and adolescents.

Keywords
Children; adolescents; overweight; obesity; fruit; vegetables; policy; waist circumference; waist to heigh ratio

Introduction

Schools are an optimal setting for health promotion due to the potential to reach all children regardless of socio-demographics [1]. The World Health Organization has highlighted the importance of school nutrition policies to promote a healthy diet, and the European Union has implemented a school fruit and vegetable (FV) policy to enhance adherence to nutritional recommendations and prevent overweight and obesity [2-4]. In 2020/21, 26 of 44 European countries distributed FV to schoolchildren [5]. Similar programs have been implemented elsewhere [6-8].

National school FV programs have been shown to increase FV consumption among children [6, 7, 9] but our understanding of their effect on childhood obesity outcomes is limited [8, 10]. Meta-analyses and systematic reviews of randomized controlled trials (RCTs) indicate that increased FV consumption may promote weight loss and prevent weight gain [11, 12], as consuming FV may substitute higher energy dense foods [13, 14]. However, school food provision, such as school lunch programs, could increase weight [15]. Given the public health challenge of childhood overweight and obesity [16-18], information about the possible benefits or unintended consequences of school dietary interventions is clearly important. Despite this, there are very few evaluations of free school FV provision. A 7- and 14-year follow-up comparing self-reported weight status of Norwegians who had received one elementary school year of free FV compared to controls found little evidence for an effect on overweight although the sample size in both studies was small [10, 19]. One other study investigated the effect of a free FV program in low-income public schools in Arkansas, US [8]. This study, set in a population with a high prevalence of childhood obesity, showed a reduction in body mass index (BMI) and obesity. Larger more population-wide evaluations of free school FV provision on overweight and obesity are clearly needed [10, 19].

From 2007 to 2014, the Norwegian government implemented a nationwide free school FV provision policy for lower secondary schools (13-15 years). Since approximately one-third of elementary schools are combined with lower secondary schools, elementary age children (6-12 years) attending a combined school also received free fruit and vegetables (FFV) while those attending a pure elementary school did not receive FV for free (no free fruit or vegetables, NFFV), providing a nationwide quasi-natural experimental setting for policy evaluation [20]. Our objective was to assess whether exposure to the nationwide FFV policy for up to four years from starting school resulted in any benefits or unintended consequences with respect to childhood and early adolescent BMI and weight status. We also assessed if the response differed by sex and socioeconomic position.

Methods

Data are from the Norwegian Growth Cohort. This consists of the Norwegian Childhood Growth Study (NCGS) and Norwegian Youth Growth Study (NYGS), both conducted by the National Institute of Public Health in collaboration with the School Health Service and in accordance with the Helsinki Declaration. Ethical approval and research clearance were obtained from the Regional Committee of Medical and Health Research Ethics (2017/431 and 2010/938) and approved by the Norwegian Data Inspectorate.

The free fruit and vegetable policy and analytical design

From August 2007 to June 2014, all combined schools (grades 1-10) in Norway were obligated by the FFV policy to provide pupils with a daily portion of FV while all pure elementary schools (grades 1-7) were not (referred to as NFFV schools). The portion typically consisted of either an apple, pear, banana, orange, clementine, kiwi, carrot, or nectarine and was usually provided during lunch.

Four nationwide cohorts that are part of the NCGS and NYGS were used to capture variation in the FFV policy exposure. The NCGS is a repeated cross-sectional survey of height, weight, and waist circumference (WC) of 8-year-old children (3rd graders) conducted in schools in 2010, 2012, and 2015. The NYGS is similar but conducted in 2017 on 13-year-olds (8th graders) and only of height and weight. We refer to these as the 2010, 2012, 2015, and 2017 cohorts. We also obtained repeated height and weight measurements recorded during the routine national health examinations scheduled from birth to six years of age for the 2010 and 2015 cohorts and from birth to eight years of age for the 2017 cohort (S1 Fig shows a schematic of the design). These cohorts allow several comparisons to triangulate the evidence and strengthen causal inference. First, within each cohort there is variation in whether a child attended a FFV school or a NFFV school. Second, there is variation in the duration of exposure between some cohorts. Third, two of the cohorts were exposed for the same duration (2010 and 2012 cohorts), providing replication. Fourth, longitudinal information from three of the cohorts allow comparisons of the outcome trajectories before the intervention.

Participants

Both the NCGS and NYGS used a two-stage sampling scheme to obtain a nationally representative sample. In the first stage, ten out of 19 counties were sampled from the geographical regions in Norway. In the second stage, schools were randomly sampled within each county. In the NCGS, the same 130 schools were invited to participate and between 123 to 126 schools agreed; in the NYGS, 150 out of 159 secondary schools participated. All third graders were sampled in the NCGS cohorts, while one eight grade class per school was sampled in the NYGS. The individual-level participation rate was > 80% in the NCGS cohorts; 2010 (n = 3182), 2012 (n = 3508) and 2015 (n = 3338) cohorts. The individual participation rate in the NYGS 2017 is unknown (n = 1907). Additional information about the NCGS and NYGS can be found elsewhere [21, 22].

Data collection

Anthropometry

Height (to the nearest 0.1 cm), weight (to the nearest 0.1 kg), and WC (to the nearest 0.1 cm) were measured by school nurses during the fall for all cohorts using similar protocols (WC was not assessed in the 2017 cohort). The routine anthropometrics from health records were measured by nurses in the Health Centers and the School Health Service. In Norway these are scheduled at birth and 6 weeks; 3, 6, 9, 12, 15, 18 and 24 months; and 3, 4, 6, 8 (grade 3) and 13 years (grade 8). There is fluctuation around these target ages and some appointments are missed (see S2 Fig in supporting information). All height and weight values were cleaned using a longitudinal algorithm that checked for logical errors and internally inconsistent values [23]. Full details of these quality assurance processes are described elsewhere [21, 22].

School information

School names, extracted from questionnaires completed by school nurses, were linked with the national school registry to determine whether it was a combined (FFV) or pure elementary

(NFFV) school. This was received from all schools in the NCGS, and 137/150 schools in the NYGS. Information on elementary school(s) affiliation for the grade eight participants in the NYGS was obtained by parents as part of the consent form.

Other

National personal identification numbers were used to link children with records from the Medical Birth Registry of Norway and Statistics Norway. Parental education was used as an indicator for socioeconomic position. We used the highest parental education (from either mother or father) prior to the policy exposure when the children were four years old. Education was collapsed into two levels: Higher+ (education in university/college) or <higher (≤ high school). Information on county and health region (North; Mid; West; and South-East) were used as markers of geographical location. A three-category population density marker of school placement was obtained: urban (municipalities with a population > 50000); semi-urban (municipalities with a population between 15000-50000); and rural (municipalities with a population < 15000).

Outcomes

Outcomes were BMI and overweight including obesity (OW/OB) in the third (~8.5 years) and eighth grade (~13 years), and WC and waist to height ratio (WHtR) in the third grade. To meet the linearity assumption of the main analytical models, internally standardized age and sex adjusted BMI standard deviation scores (BMI_{SDS}) were created [24]; modelling on the raw (kg/m^2) or externally standardized scale did not meet this assumption (see S1 Text and S2 Table, supporting information for more details). Age and sex-specific OW/OB was classified using the International Obesity Task Force cut-offs for BMI [25].

Exposure classification

For the 2010, 2012, and 2015 cohorts, children attending a combined school at recruitment (third grade) were classified as exposed to the FFV policy. For the 2017 cohort (recruited in grade eight), children were classified as exposed if the child attended a combined school during primary years. This classification does not account for children who were exposed to both school types due to moving schools, however based on information in the 2017 cohort we estimate that this occurs in less than 4% of children (see S2 Text). For the outcome in third grade, this corresponds to 2-2.5 school years of exposure in the 2010, 2012, and 2017 cohorts and one year of exposure in the 2015 cohort. For the outcomes in eight grade in the 2017 cohort, this corresponds to four school years of exposure. As the first day of school for Norwegian 1st graders starts in August the year children turn six, the earliest age at which any child would have received FFV is 5 years and 7 months.

Estimating the free fruit and vegetable policy effect

For BMI_{SDS} and OW/OB where longitudinal data were available, two approaches were used to estimate the FFV policy effect. The first, illustrated in S3 Fig, is similar to a comparative interrupted time-series analysis [26]. The pre- and post-intervention slopes in each group were modelled with linear splines and a knot at the pre-exposure age (5.5 years). The counterfactual is the trajectory that the FFV group would have taken in absence of the intervention and is estimated by the change in slopes in the NFFV group. The between-group difference in the pre-post difference in slopes is thus an estimate of the FFV policy effect. This can be parameterized as:

$$E(Y) = \beta_0 + \beta_1 S_1 + \beta_2 S_2 + \gamma_0 I + \gamma_1 I * S_1 + \gamma_2 I * S_2 \qquad (1)$$

where I is a binary variable indicating FFV exposure, and S_1 and S_2 are linear splines of age centered at the pre-intervention knot (additional details in S3 Text). β_0, β_1 and β_2 describe the outcome ($E(Y)$) at 5.5 years and the pre- and post-intervention slopes respectively in the control group. γ_0, γ_1 and γ_2 are the mean difference in intercept at 5.5 years and mean difference in pre- and post-intervention slopes between groups. Where pre-intervention slopes are similar, γ_1 was removed and γ_2 is the estimate of the policy effect. If the pre-intervention slopes are different (as estimated by γ_1), then $\gamma_2 - \gamma_1$ is the effect estimate, but in this situation, where pre-slopes are not parallel, the counterfactual that slopes would have changed in the same way as the controls is less credible. Similar reasoning applies when there is a large difference in the pre-intervention intercept (γ_0). Hence a second approach that adjusts for the pre-intervention value of the outcome was also estimated:

$$E(Y) = \beta_0 + \beta_1 Y_{PRE} + \delta_1 I \qquad (2)$$

here, Y_{PRE} is the closest available measurement before the introduction of the FFV exposure (5.5 years) and δ_1 an estimate of the FFV effect (difference in Y between groups after accounting for baseline differences). To estimate the effect at 13 years in 2017, equations (1) and (2) were extended in a separate model to include an extra knot at age 8.5 years (algebra in supporting information, S3 Text). For the WC and WHtR outcomes, where only a single measure of the outcome was available the FFV policy effect estimator simplifies to a post-intervention between-group comparison (i.e. equation (2) without β_1). Other potential confounders were added to these models (explained below).

Analytical dataset

The pre-intervention slopes were modelled from age two years. To remove measurement clumping and minimize selection bias, if an individual had more than one measure at a target age, the value closest to the median age at each target assessment was selected. To ensure the pre and post exposure slopes were demarcated by unexposed and exposed data points and avoid bias in estimating the two slopes, measures from age 5.7 years to 7 years were not included (see S3 Text for more details). More than 69% of individuals included in the analysis contributed at least three repeated measures.

Free fruit and vegetable policy allocation and estimating a causal effect

Allocation of the FFV policy could not be considered 'as if' random. Combined (FFV) schools are more likely to be in areas of lower population density compared to pure elementary (NFFV) schools and are thus more common in rural regions of Norway such as the North (see S4 Text and S5 Table). A directed acyclic graph (DAG) was thus used to inform which variables to adjust for to obtain a causal estimate of the policy effect (S5 Text and S4 Fig). Based on the DAG and testing the assumptions it encodes, the following variables were deemed sufficient to adjust for: region, population density, cohort, and parental education. The DAG also suggests parental education and sex may modify the effect of the FFV policy since they may affect whether or not the FV is consumed and/or any induced dietary change. We also consider a separate and additional adjustment for pre-intervention BMI as this is a marker of the obesogenic environment of the child.

Analyses

Free fruit and vegetable allocation and pre-intervention comparisons

Characteristics prior to exposure (sex, parental education, region, and population density) were described by cohort and by FFV allocation. The pre-intervention slopes and intercepts of the BMI_{SDS} and OW/OB outcomes were compared between groups using multilevel models and the marginal unadjusted and adjusted (described below) trajectories were plotted.

Main models

Analyses were stratified by cohort due to differences in exposure duration, and sex (see DAG, S4 Fig), and pooled estimates were also produced. To make use of all available outcome data and account for the hierarchical structure, multilevel models (MLM) were used with random intercepts for each school and child, and random slopes for each child for the BMI_{SDS} outcome. Autocorrelation in the BMI_{SDS} models was handled using a first order autoregressive structure. A logit MLM with maximum likelihood and adaptive Gauss Hermite quadrature estimation was used for the OW/OB outcome.

For the longitudinal cohorts, three sets of models were estimated. First an unadjusted model (crude); second a model adjusting for region, population density, and parental education (adjusted); third a model with additional adjustment for pre-intervention BMI_{SDS} (+pre-intervention adjusted). Potential confounders were allowed to affect intercepts and slopes and pooled models included similar terms for cohort. For the cross-sectional WC and WHtR outcomes, only the crude and adjusted models could be estimated. To assess potential effect modification by socioeconomic position, similar models were estimated but stratified by parental education (higher+, <higher) with Wald tests of the interaction terms.

Effects estimates are reported comparing the difference in outcome at age 8.5 years and age 13 years between FFV exposure and the counterfactual (as estimated using NFFV schools). All results are displayed in forest-style plots to visualize heterogeneity.

Supplemental and sensitivity analysis

The Norwegian Directorate of Health and the Norwegian Fruit and Vegetable Marketing Board also offers a national school FV subscription program which provides schools with the opportunity to offer FV with parental payment. As all pure elementary schools (NFFV schools) were free to decide whether to offer parental paid FV, we conducted sensitivity analysis where we excluded children from the combined (NFFV) schools (151/335 schools; 2022/6168 children) that had offered the paid subscription program during at least one of the first three years of school, as ascertained from the Norwegian Fruit and Vegetable Marketing

Board. If the FFV policy had a causal effect, estimates from this analysis would be expected to be stronger than the main analysis. Other sensitivity analyses were also performed to assess the robustness of findings to the analytical strategy, these are outlined in the supporting information, S9 Table.

Results

Description of sample

In total, 7810 children and 21508 observations were included in the pooled longitudinal analyses of BMI_{SDS} and OW/OB outcomes at 8.5 years, and 6619 in models that adjusted for pre-intervention BMI. For WC there were 9716 children. In the longitudinal analysis of BMI_{SDS} and OW/OB outcomes at 13 years 1533 adolescents were included, and 1355 in models adjusted for pre-intervention BMI. Exclusions due to missing data were small, the largest proportion was in cohort 2017 where 17% were excluded due to insufficient school information to ascertain exposure status (see S5 Fig showing the participant flow charts). Most children attended schools in urban areas from the South-East, reflecting the geographical distribution in the population (Table 1). Approximately 20% of individuals were exposed to the FFV policy. This was higher (30%) in the 2017 cohort reflecting oversampling in these regions. Of the 6168 children in a NFFV schools, 2022 (33%) were attending a school that had signed up to offer the parental paid FV subscription program.

Table 1. Description of individuals included in the analysis of outcomes at age 8.5 (third grade) by attendance at a FFV school in each cohort and pooled across cohorts.

	2010 cohort			2012 cohort			2015 cohort			2017 cohort			Pooled 2010, 2015 and 2017		
	Total	NFFV*	FFV ≥ 1y*	Total	NFFV*	FFV ≥ 1y*	Total	NFFV*	FFV ≥ 1y*	Total	NFFV*	FFV ≥ 1y*	Total	NFFV*	FFV ≥ 1y*
N (%)	3125	2504 (80.1)	621 (19.9)	3405	2705 (79.4)	700 (20.6)	3207	2632 (82.1)	575 (17.9)	1478	1032 (69.8)	446 (30.2)	7810	6168 (79.0)	1642 (21.0)
Paid-sub†, n (%)	2505	830 (33.2)	NA	2705	768 (28.4)	NA	2632	696 (26.4)	NA	1032	496 (48.1)	NA	6168	2022 (32.8)	NA
Age (y), mean (SD)‡	8.3 (0.3)	8.3 (0.3)	8.3 (0.3)	8.3 (0.3)	8.3 (0.3)	8.3 (0.3)	8.3 (0.3)	8.3 (0.3)	8.3 (0.3)	8.5 (0.4)	8.5 (0.4)	8.5 (0.4)	8.3 (0.3)	8.3 (0.3)	8.4 (0.3)
Sex, n (%)															
Boys	1605 (51.4)	1281 (51.2)	324 (52.2)	1755 (51.5)	1380 (51.0)	375 (53.6)	1636 (51.0)	1342 (51.0)	296 (51.1)	732 (49.5)	518 (50.2)	214 (48.0)	3973 (50.9)	3141 (50.9)	832 (50.7)
Girls)	1520 (48.6)	1223 (48.8)	297 (47.8)	1650 (48.5)	1325 (49.0)	325 (46.4)	1571 (49.0)	1290 (49.0)	281 (48.9)	746 (50.5)	514 (49.8)	232 (52.0)	3837 (49.1)	3027 (49.1)	810 (49.3)
Population density, n (%)‡															
Urban	2445 (78.2)	2033 (81.2)	412 (66.3)	2658 (78.1)	2231 (82.5)	427 (61.0)	2486 (77.5)	2134 (81.1)	352 (61.2)	897 (60.7)	669 (64.8)	228 (51.1)	5828 (74.6)	4836 (78.4)	992 (60.4)
Semi-urban	408 (13.1)	301 (12.0)	107 (17.2)	456 (13.4)	312 (11.5)	144 (20.6)	480 (15.0)	350 (13.3)	130 (22.6)	360 (24.4)	242 (23.5)	118 (26.5)	1248 (16.0)	893 (14.5)	355 (21.6)
Rural	272 (8.7)	170 (6.8)	102 (16.4)	291 (8.6)	162 (6.0)	129 (18.4)	241 (7.5)	148 (5.6)	93 (16.2)	221 (15.0)	121 (11.7)	100 (22.4)	734 (9.4)	439 (7.1)	295 (18.0)
Region, n (%)‡															
South-East	1717 (54.9)	1483 (59.2)	234 (37.7)	1868 (54.9)	1627 (60.2)	241 (34.4)	1741 (54.3)	1588 (60.3)	153 (26.6)	387 (26.1)	284 (27.5)	103 (23.1)	3845 (49.2)	3355 (54.4)	490 (29.8)
West	706 (22.6)	563 (22.5)	143 (23.0)	747 (21.9)	570 (21.1)	177 (25.3)	748 (23.3)	571 (21.7)	177 (30.8)	403 (27.3)	311 (30.1)	92 (20.6)	1857 (23.8)	1445 (23.4)	412 (25.1)
Mid	365 (11.7)	267 (10.7)	98 (15.8)	418 (12.3)	298 (11.0)	120 (17.1)	346 (10.8)	248 (9.4)	98 (17.0)	334 (22.6)	220 (21.3)	114 (25.6)	1045 (13.4)	735 (11.9)	310 (18.9)
North	337 (10.8)	191 (7.6)	146 (23.5)	372 (10.9)	210 (7.8)	162 (23.1)	372 (11.6)	225 (8.6)	147 (25.6)	354 (24.0)	217 (21.0)	137 (30.7)	1063 (13.6)	633 (10.3)	430 (26.2)
Parental education, n (%)§															
<Higher	1444 (46.2)	1117 (44.6)	327 (52.7)	1431 (42.0)	1119 (41.4)	312 (44.6)	1229 (38.3)	973 (37.0)	256 (44.5)	586 (39.7)	396 (38.4)	190 (42.6)	3259 (41.7)	2486 (40.3)	773 (47.1)
Higher+	1681 (53.8)	1387 (55.4)	294 (47.3)	1974 (58.0)	1586 (58.6)	388 (55.4)	1978 (61.7)	1659 (63.0)	319 (55.5)	892 (60.4)	636 (61.6)	256 (57.4)	4551 (58.3)	3682 (59.7)	869 (52.9)

*NFFV: Individuals who did not attend a school with free fruit and vegetable provision; FFV ≥ 1y: Individuals attended a school with free fruit and vegetable provision at least one year.
‡In 3rd grade, school
†Of in individuals attending NFFV schools, proportion who attend a school offering the paid fruit and vegetable subscription program.
§Parental education prior to possible exposure (when the child was four years old).
FFV: Free fruit and vegetables; NA: not applicable; NFFV: No free fruit and vegetables; Paid-sub: Individuals attending schools offering the parental paid subscription program; SD: Standard deviation.; y: year.

Internal validity of comparisons

Table 1 also shows the distribution of characteristics by attendance at a FFV school in our sample. Children were broadly similar in terms of sex and age at outcome assessment. Differences between region and population density were as expected with the North and Mid regions and less urban areas having a higher proportion of FFV schools.

Fig 1 and Table 2 compare the pre-intervention BMI_{SDS} trajectories by policy exposure, similar results are shown in the supporting information for the OW/OB outcome (S6 Fig and S7 Table). The trajectories for BMI_{SDS} and prevalence of OW/OB were broadly similar in boys, for example, with cohorts pooled, boys who would attend a FFV school had a pre-intervention BMI_{SDS} 0.05 higher (95% confidence interval (CI): -0.06, 0.16) after adjusting for differences in parental education, region, and population density. In girls, those who would attend a FFV school in the 2015 cohort had a more negative BMI_{SDS} slope and a lower BMI_{SDS} before the intervention compared to those who would attend a NFFV school. The pooled trajectories were more similar, with girls in the FFV group having a -0.08 lower pre-intervention BMI_{SDS} (95% CI: -0.20, 0.034). There was little evidence for differences in the pre-intervention OW/OB trajectory (S6 Fig and S7 Table).

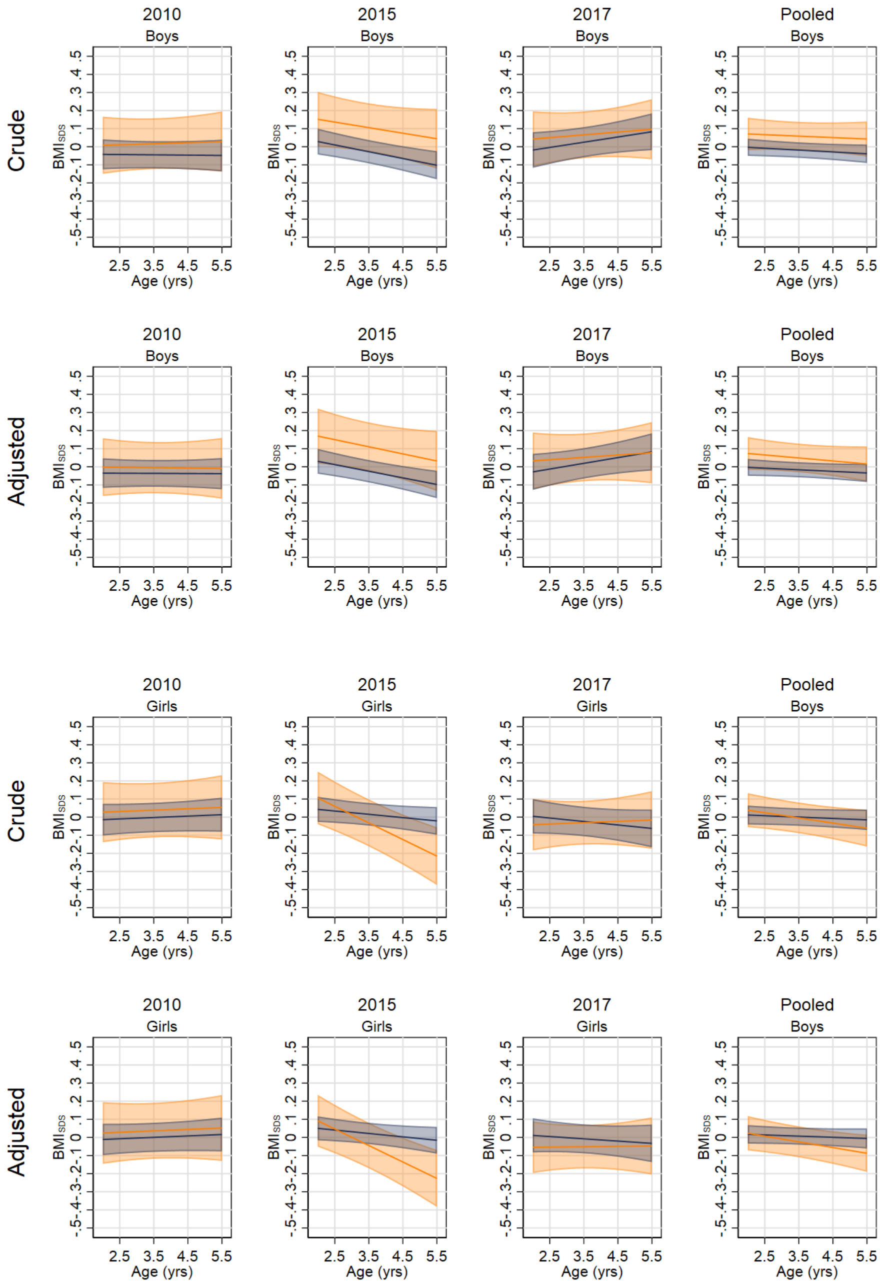

Fig 1. Predicted pre-intervention (2 to 5.5 years) trajectories of BMI_{SDS} in boys and girls who would attend a FFV (orange) or a NFFV school (navy).

The marginal means in each cohort and pooled cohorts and in the crude and adjusted models are presented. BMI_{SDS}: body mass index standard deviation scores; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; yrs: years.

Table 2. Estimated differences in pre-intervention (2 to 5.5 years) trajectories of BMI_{SDS} in boys and girls who would attend a FFV and a NFFV school.

		Crude†				Adjusted‡			
	Cohort	Difference in slope (a) (95% CI)	p	Difference at 5.5y (b) (95% CI)	p	Difference in slope (a) (95% CI)	p	Difference at 5.5y (b) (95% CI)	p
Boys	2010	0.007 (-0.044, 0.059)	0.78	0.08 (-0.11, 0.26)	0.43	-0.001 (-0.05, 0.05)	0.97	0.03 (-0.16, 0.22)	0.76
	2015	0.007 (-0.05, 0.06)	0.8	0.15 (-0.04, 0.33)	0.115	-0.003 (-0.06, 0.05)	0.92	0.13 (-0.05, 0.31)	0.17
	2017	-0.014 (-0.076, 0.049)	0.67	0.014 (-0.18, 0.21)	0.89	-0.02 (-0.08, 0.05)	0.57	-0.004 (-0.20, -0.19)	0.97
	Pooled	0.002 (-0.03, 0.03)	0.89	0.08 (-0.03, 0.19)	0.14	-0.008 (-0.04, 0.024)	0.63	0.05 (-0.06, 0.16)	0.37
Girls	2010	-0.000 (-0.05, 0.05)	0.99	0.04 (-0.161, 0.241)	0.69	0.00 (-0.05, 0.05)	0.99	0.04 (-0.17, 0.24)	0.73
	2015	-0.074 (-0.124, -0.023)	0.004	-0.195 (-0.37, -0.02)	0.03	-0.07 (-0.12, -0.02)	0.006	-0.21 (-0.39, -0.035)	0.019
	2017	0.026 (-0.034, 0.087)	0.39	0.05 (-0.14, 0.24)	0.63	0.015 (-0.05, 0.08)	0.64	-0.014 (-0.20, 0.18)	0.88
	Pooled	-0.021 (-0.052, 0.010)	0.188	-0.05 (-0.161, 0.068)	0.43	-0.03 (-0.06, 0.007)	0.12	-0.08 (-0.20, 0.034)	0.17

Differences in slope from 2 to 5.5 years and in BMI_{SDS} at 5.5 years in each cohort and pooled cohorts and in the crude and adjusted models are presented.

†Crude pooled model includes adjustment for cohort (intercept and slope). All models include a random intercept for school and random coefficients for child.

‡Adjusted model includes region, population density, highest parental education (intercept and slope); pooled adjusted model also includes terms for cohort (intercept and slope). All models include random intercepts for school and random coefficients for child.

(a)Difference in slope (BMI_{SDS} per year): FFV minus NFFV

(b)Difference in BMI_{SDS} at 5.5y: FFV minus NFFV

BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; y: years.

Main analysis

Pooled

There was little evidence of a policy-effect on BMI_{SDS}, OW/OB, WC, or WHtR (Fig 2) with cohorts pooled in either boys or girls at age 8.5 years and all estimates were close to the null. Removing NFFV schools that offered paid FV subscription program for most outcomes shifted effect estimates unremarkably in the direction of the null (opposite to expected if the policy had a causal effect, S7 Fig).

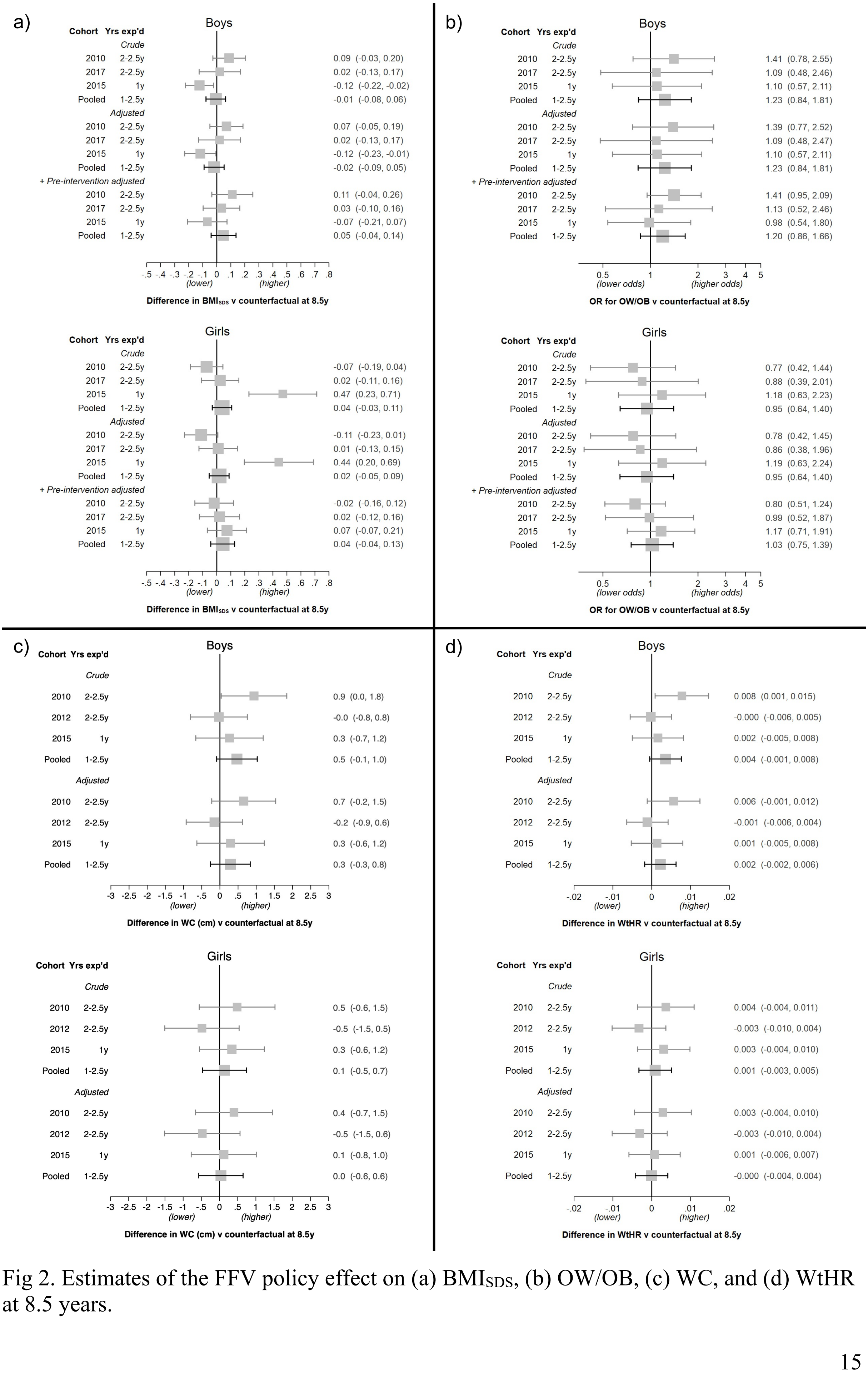

Fig 2. Estimates of the FFV policy effect on (a) BMI_{SDS}, (b) OW/OB, (c) WC, and (d) WtHR at 8.5 years.

Results are presented by sex and cohort (incl. pooled) and for each model. Expressed as the difference in outcome or odds ratio (OR) versus the counterfactual (as estimated using the NFFV schools) with 95% CI.
Analysis of BMI_{SDS} and OW/OB: Pooled models include terms for cohort (intercept and slope). Adjusted model includes region, population density, highest parental education (all intercept and slope). +Pre-intervention adjusted model additionally includes adjustment for BMI_{SDS} prior to the intervention. Note: Pre-intervention slopes were constrained to be the same in each group for all models except for BMI_{SDS} in cohort 2015 girls.
Analysis of WC and WtHR: Outcomes are from grade 3 only. Pooled models include a term for cohort. Adjusted model includes region, population density, highest parental education.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity; WC: waist circumference; WtHR: waist to heigh ratio; y/yrs: year(s).

By cohort

Any evidence of a cohort-specific policy effect was inconsistent. First, among boys in the 2010 FFV schools, there was a suggestion of increases in BMI_{SDS}, OW/OB, WC, and WHtR (Fig 2). However, the estimates for WC and WHtR were substantially attenuated after adjusting for differences in region, population density, and parental education. The estimates for the 2017 (BMI_{SDS}, OW/OB) and 2012 cohort (WC, WHtR), which had the same exposure duration as 2010 but were both born two years later, were also close to the null and so no replication. Removal of schools that signed up to the paid subscription program slightly increased the effect estimates in 2010 boys for BMI_{SDS} and OW/OB but slightly attenuated estimates for WC and WHtR (S7 Fig).

Second, boys in the 2015 FFV schools with only one year of FFV exposure, had a lower rather than higher BMI_{SDS} (-0.12; 95% CI: -0.23, -0.01). However, this was an inconsistent dose-response pattern compared to the 2010 estimate, was attenuated after adjustment for pre-intervention BMI_{SDS} and not evident for any other outcome.

Third, girls from the same 2015 FFV schools had, on average, a higher BMI_{SDS} (+0.44; 95% CI: 0.20; 0.69) but this was completely attenuated after adjusting for the differences (noted above) in pre-intervention BMI_{SDS}.

By parental education

There was a suggestion of an interaction between the FFV policy and parental education. In the pooled and most-adjusted analyses, boys from parents without a higher education had, on average, an elevated BMI_{SDS} (+0.12, p for interaction = 0.04), increased odds ratio (OR) of OW/OB (OR: 1.66, p for interaction = 0.02) and a higher WC (+0.7 cm, p for interaction = 0.05) if they had attended a FFV school (Fig 3). This was not evident in boys from parents with a higher education. The direction of this interaction was consistent across cohorts.

However, the interaction was not evident for WHtR and the interaction and effect sizes were similar or weaker after removing paid subscription schools (S8 Fig). There was also little evidence of an interaction in the girls across any outcome or cohort (Fig 3 and S8 Fig) and the direction of the interaction was in the opposite direction.

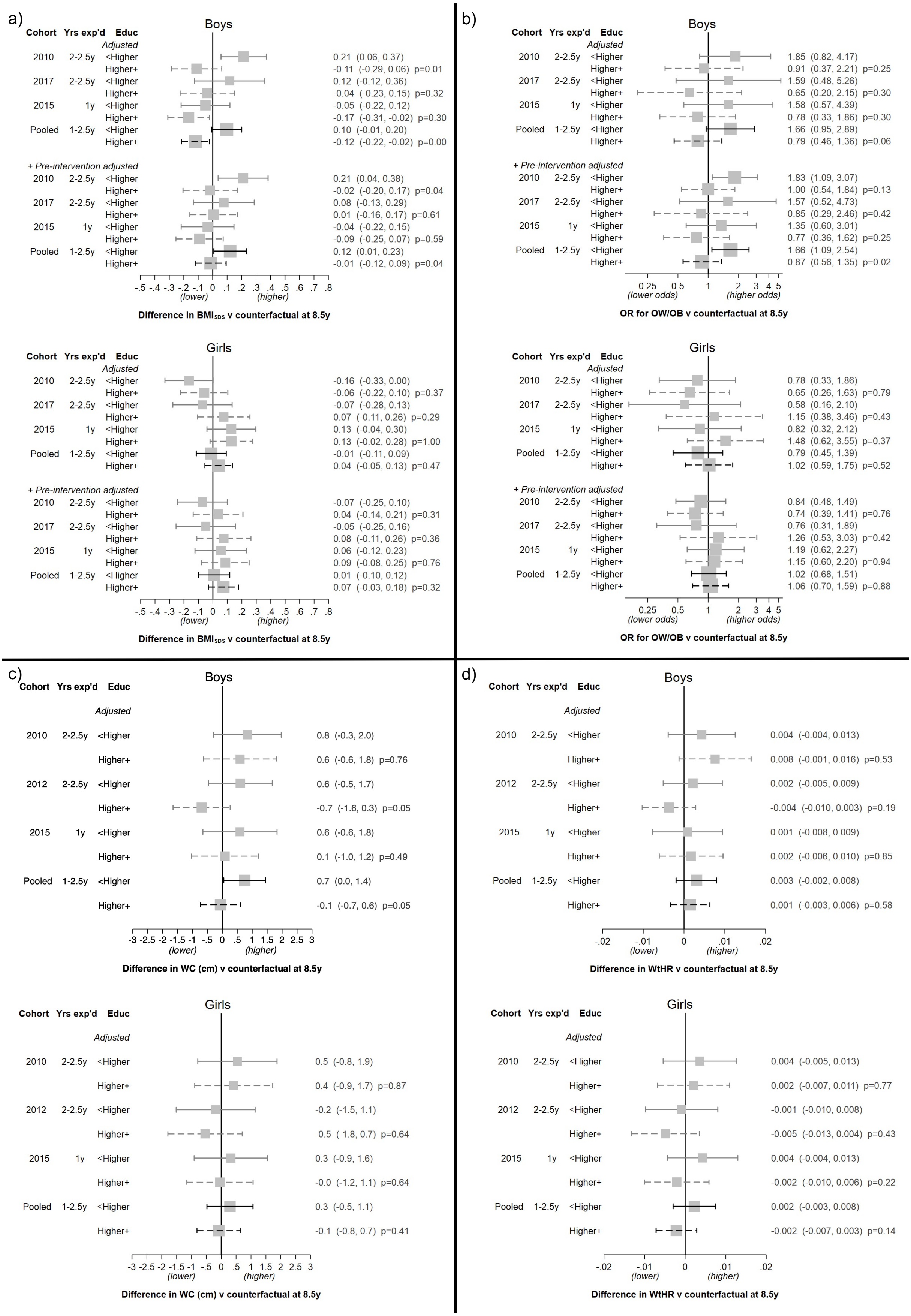

Fig 3. Estimates of the FFV policy effect on (a) BMI_{SDS}, (b) OW/OB, (c) WC, and (d) WtHR at 8.5 years stratified by highest parental education level.

Results are presented by sex, cohort (incl. pooled) and parental education for each model. Expressed as the difference in outcome or odds ratio (OR) versus the counterfactual (as estimated using the NFFV schools) with 95% CI. The p-values are a test of the interaction between parental education and FFV.
Analysis of BMI_{SDS} and OW/OB: Pooled models include terms for cohort (intercept and slope). Adjusted model includes region, population density (all intercept and slope). +Pre-intervention adjusted model additionally includes adjustment for BMI_{SDS} prior to the intervention.
Analysis of WC and WtHR: Outcomes are from grade 3 only. Pooled models include a term for cohort. Adjusted model includes region and population density.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity; WC: waist circumference; WtHR: waist to heigh ratio; y/yrs: year(s).

To triangulate whether the interaction in boys was caused by the FFV exposure or confounded by differences between the school environment or children who go to these schools, in a post-hoc analysis we examined whether the same direction of interaction was evident within elementary-only schools, comparing schools that offered the paid FV subscription program versus schools that did not (see S9 Fig in supporting information). There was no evidence of an interaction in these analyses, neither were interactions qualitatively in the same direction.

Outcomes at age 13 years

There was little evidence for a policy-effect on BMI_{SDS} or OW/OB among adolescents (13 years) of either sex that had been exposed to the FFV policy for up to four years (Fig 4). However, there was a suggestion that girls from parents without a higher education had a lower BMI_{SDS} (-0.20, 95% CI: -0.41, 0.01) and a lower odds of OW/OB (OR: 0.55, 95% CI: 0.27, 1.12) if they had attended a FFV school (p for both interactions = 0.05; see Fig 5) (the direction of this interaction was the same at 8.5 years but weaker). Results from the secondary analysis excluding NFFV schools which offered the paid FV subscription program (S10 Fig) at age 13 outcomes and the latter stratified by parental education (S11 Fig) were broadly similar (see supporting information).

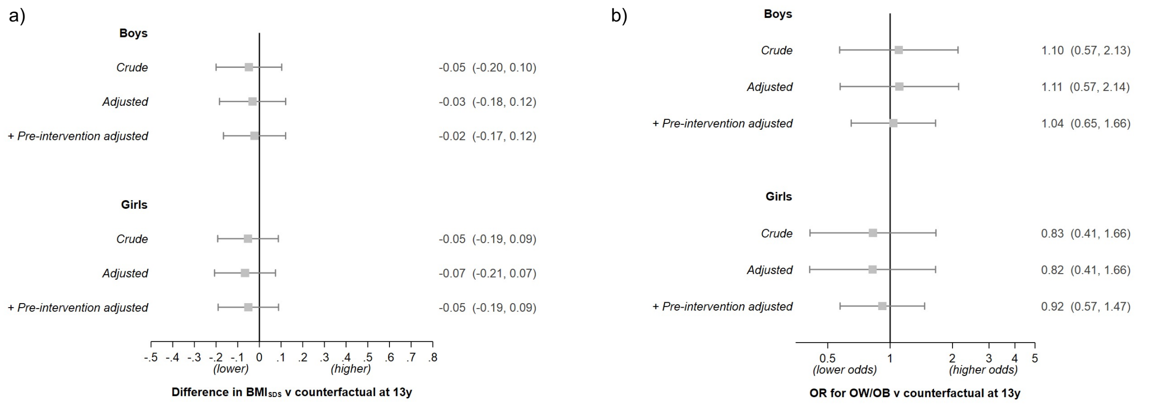

Fig 4. Estimates of the FFV policy effect on (a) BMI_{SDS} and (b) OW/OB at age 13 years.
Results are presented by sex for each model and expressed as the difference in outcome or odds ratio (OR) versus the counterfactual at 13 years (as estimated using the NFFV schools) with 95% CI. Note data are from the 2017 cohort only. Crude model: no adjustment. Adjusted model: includes region, population density, highest parental education (intercept and slopes); +Pre-intervention adjusted model: includes additional adjustment for BMI_{SDS} prior to the intervention.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity; y: years.

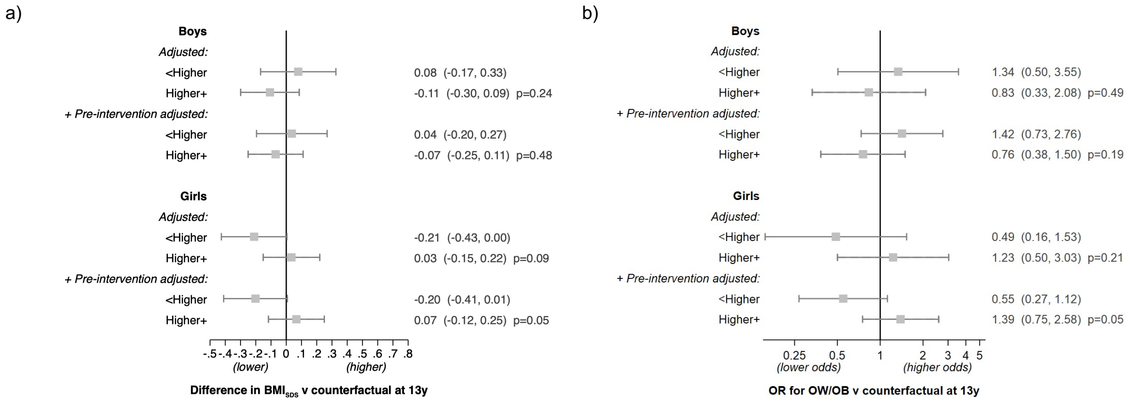

Fig 5. Estimates of the FFV policy effect on (a) BMI_{SDS} and (b) OW/OB at age 13 years stratified by highest parental education level.
Results are presented by sex and parental education for each model. Expressed as the difference in outcome or odds ratio (OR) versus the counterfactual (as estimated using the NFFV schools) with 95% CI. The p-values are a test of the interaction between parental education and FFV. Note data are from the 2017 cohort only.
Adjusted model includes terms for region and population density (intercept and slopes). +Pre-intervention adjusted model includes additional adjustment for BMI_{SDS} prior to the intervention.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity; y: years.

Population distributions

Fig 6 illustrates how the policy effect-estimates from the pooled and most adjusted analyses reflect onto the population distribution of BMI and WC at 8.5 years. Shifts in the location of the distribution are small contrasted against the population variation. The bounded estimate based on the 95% CI shifted median from a -0.07 kg/m^2 reduction to a +0.33 kg/m^2 increase. For WC this ranged from a reduction of 0.5 cm to an increase of 0.7 cm.

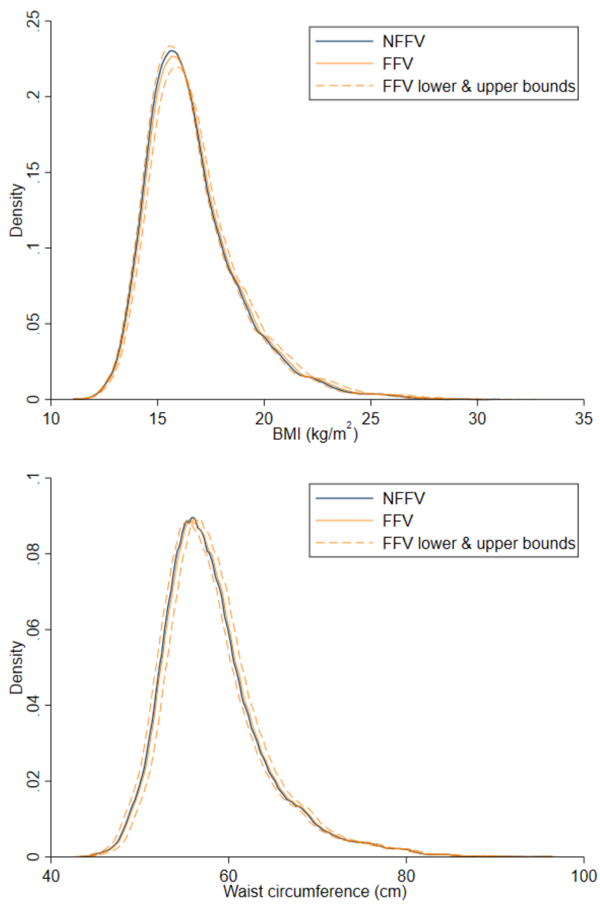

Fig 6. Model based predictions for the FFV policy effect on the distribution of BMI (kg/m^2) and waist circumference (cm) at 8.5 years.

Estimates use the point estimates and 95% confidence intervals to give a bounded prediction for the FFV effect. The estimates are from the +pre-intervention adjusted models in boys and girls. A kernel density smoother was used to illustrate the distribution.

BMI: body mass index; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables.

Discussion

Summary of findings

Overall, we found no strong evidence that 1 to 2.5 years of exposure to a nationwide FFV policy in Norway had an appreciable benefit or unintended consequence among boys or girls with respect to childhood BMI_{SDS}, OW/OB, WC, or WHtR. There was some heterogeneity in the policy effect estimates in both directions at 8.5 years across cohorts, sex, and parental education although the results were inconsistent when triangulated against other group comparisons or with further adjustment for pre-policy BMI. Additionally, we found little evidence for a policy effect at age 13-years in a cohort which had a longer duration of FFV exposure (four years). There was a weak interaction with parental education in girls, suggesting a lower BMI_{SDS} and reduced odds of OW/OB at 13 years among girls from parents without higher education who attended FFV schools. We were unable to further test this finding in another cohort.

Comparison with previous studies

A two-year follow-up evaluation of the FV program in Arkansas US, showed a mean 0.17 z-score reduction in BMI among children exposed to the FFV program compared to strictly matched unexposed children, and also a three percentage point reduction in school-level obesity as a result of the program [8]. We found no evidence to support such a benefit. However, this study was in a predominately low-income setting children, reflecting a substantially different target population compared to our study. The prevalence of childhood OW/OB in Norway is approximately 16% [22] versus almost 40% in Arkansas, US [8], and children from all socioeconomic positions were targeted by the Norwegian policy. The lack of evidence for a benefit that we found is supported by a much smaller Norwegian intervention study evaluating the association of one school year of FFV provision in Norwegian schools on overweight [10, 19].

Findings from a meta-analysis and a systematic review of RCTs indicate beneficial effects of FV consumption on weight outcomes [11, 12], however, the interventions evaluated are heterogenous in regard to complexity, setting and/or target populations e.g., those with chronic conditions [11]. Moreover, studies evaluating various dietary interventions and policies on childhood obesity usually include additional components beyond sole FV provision [15, 27-30]. Two recently published systematic reviews reported improvements in childhood BMI from school food environment interventions focusing on competitive food and beverage policies [29] and using clear and concise dietary guidelines [28], indicating that complex interventions and/or policies may benefit childhood obesity. Altogether, these studies include aspects that are beyond comparison to a nationwide FFV policy and make them sufficiently different to be used as part of the evidence-base to inform a FFV policy implementation compared to our study.

Interpretations

One explanation for the absence of clear beneficial effect of the Norwegian FFV policy may be that exposed children did not substitute higher energy foods, such as unhealthy snacks, with FV, which has previously been proposed as a possible pathway for weight loss [14, 31]. This is supported by findings reported after the first year of the Norwegian FFV policy, indicating no substantial differences in consumption of unhealthy energy-dense snacks, despite an increased odds of daily fruit consumption among adolescents (mean age 14.5 years) attending FFV schools compared to those attending NFFV schools [32]. On the other hand, by solely adding daily FV to the diet without any compensatory behavior changes (e.g., eating less of other foods or increasing physical activity level), one might expect an increase in weight outcomes. However, FV are generally low in energy and providing one portion of fresh FV each school day may not contribute to an excessive energy intake. Substitution and compensatory behavior changes in response to the FFV policy among some children but not others might result in no overall aggregated policy-effect in the population, as suggested by our pooled estimates.

We anticipated confounding to act in the direction of weight gain due to the predominance of FFV schools in less population-dense areas that have slightly higher levels of OW/OB [22]. If results were biased in this direction as, in most part, our results suggest, it is reassuring that there was still no consistent evidence of unintended consequences from the FFV policy. Further, our upper bound prediction of the policy's effect on the population distribution of BMI and WC would suggest that even in the worst-case scenario, a FFV policy is unlikely to cause a population shift of concern. Nonetheless, it should be mentioned that our stratified analysis showed an interaction of the FFV policy and parental education among boys suggesting an increased BMI_{SDS} and odds of OW/OB among boys from parents without higher education exposed to the FFV policy compared to unexposed. This result was driven by the earliest born 2010 cohort, and we speculate that healthier behavior trends and changes to the obesogenic environment over time may explain this (see examples in S8 Table). On the other hand, the lack of triangulation of this finding with our other comparisons and secondary analysis suggest chance or confounding as the most plausible explanation.

In the present study, even with a relatively large study sample of 1533 adolescents in the 2017 cohort who could have been exposed to FFV for a total of four years at age 13, no consistent reductions in weight outcomes were observed. The lack of effect on weight status may partly reflect the repeal of the FFV policy in 2014, meaning that, at the time of the 13-year measurement, three years had passed since the FFV provision in school. However, analysis stratified by parental education among adolescents in the 2017 cohort indicated lower BMI_{SDS} and reduced odds of OW/OB among girls from parents without higher education who attended FFV schools, compared to unexposed girls. Norwegian girls generally report eating more fruit and berries than boys [33]. Additionally, a sufficiently long follow-up period could be of importance to detect possible effects on body weight from a FFV policy [34], which might explain this beneficial finding among girls from parents without higher education. Another Norwegian study reported a significantly higher sustained fruit consumption among less-educated young women who in childhood had received one school year of FFV compared to controls [35]. Nonetheless, this result should be interpreted with caution and requires replication.

Implications and further work

Free FV policies and programs have been shown to increase consumption of FV [6, 36] and may thereby improve nutrient intake and other health outcomes [37]. However, our findings question whether FFV policies and programs can be expected to reduce rates of childhood or adolescent obesity. One or two of the interactions between weight outcomes and parental education require further investigation, and we recommend that future studies designed to evaluate nationwide policies should be population-wide and sufficiently powered to assess heterogeneity across boys and girls from different socioeconomic positions and across other potentially vulnerable subgroups. Including data on FV consumption at the individual level may aid the understanding of potential mechanisms of how the policy acts. Additionally, as provision of FV may contribute to promote healthy eating habits, future work should evaluate if a FFV policy contributes to longer-term healthy eating habits and thereby preventing OW/OB in adulthood [12].

Strengths and limitations

Although our study was nationwide, generalizability might be limited to countries with a similar prevalence of OW/OB [38]. The use of longitudinal data in the current study allowed the assessment of pre-intervention weight trends, and a more plausible counterfactual to estimate the policy effect compared to difference-in-difference or cross-sectional designs used in similar previous evaluations [8, 10]. The high quality objective data, which was standardized and cleaned using a systematic approach [23], and use of models that made use of all available outcome measures and handled the relatively small amount of missingness in a principled way, are also strengths. Further, we were also able to look at WC as an outcome, acknowledging that BMI has limitations as a marker of excess adiposity among children [39]. However, our sample size was insufficient to allow us to assess effects on obesity (BMI ≥ 30 kg/m^2), which has a relatively low prevalence in Norwegian children. We also lacked information on consumption of the FFV which may have enhanced interpretation and translation of our findings.

Using the ROBINS-I tool [40], we assessed the potential overall risk of bias in our study to be moderate (details in S7 Text and S12 Fig). Since we were unable to assume "as if" random allocation of the FFV policy, residual confounding is a key risk of bias, as is misclassification of exposure caused by some children attending both an FFV and NFFV school. However, the slopes of the pre-policy trajectories were in most part quite similar, and the use of multiple cohorts and additional school information allowed us to draw stronger conclusions by triangulating the evidence from several sets of comparisons each with the potential for different biases. The risk of bias due to other co-interventions was also deemed low (see S6 Text and S8 Table) and checks of robustness of results to the choice of analysis strategy suggest these are unlikely to have influenced our key findings (see S9 Table). There is inevitable bias compared to a well-controlled RCT, however we do not predict these to be sufficient to alter our main conclusions.

Conclusion

Our study found no strong evidence that exposure to a nationwide FFV policy had any beneficial effect or unintended consequence on weight status among Norwegian children and adolescents. While a nationwide FFV policy may not be justified as a useful public health tool for tackling childhood obesity, given the benefits linked to enhanced nutrition as documented in other studies, the policy may have benefits to other aspects of health and dietary behavior without the unintended consequences that are a risk of such population-wide interventions.

Abbreviations

BMI: body mass index; BMI_{SDS}: body mass index standard deviation scores; CI. Confidence interval; DAG: directed acyclic graph; FFV: free fruit and vegetables; FV: fruit and vegetables; MLM: multilevel models; NCGS: Norwegian Childhood Growth study; NFFV: no free fruit and vegetables; NYGS: Norweigan Youth Growth study; OR: odds ratio; OW/OB: overweight and obesity; RCTs: randomized controlled trials; SD: standard deviation; WC: waist circumference; WHtR: waist to heigh ratio.

Declarations

Authors' contributions

Conceptualization: Per, Elling, Andrew, Tonje
Methodology: Andrew, Elling, Per
Preparation of data and analysis: Andrew, Bente
Writing: Bente, Andrew, Tonje, Ingunn
All authors have read and agreed to the published version of the manuscript.

Data availability

Data cannot be shared publicly because of General Data Protection Regulation (GDPR) as it contains personal data which is potentially identifying participant data. The Personal Data Regulations and Health Research Act (§ 7) in Norway and GDPR in the EU restrict sharing of these data. The Norwegian Institute of Public Health administer the main data used in this study. External researchers can apply for access to indirectly identifiable data based on appropriate legal bases for processing the data in accordance with GDPR Article 6(1) and 9(2). To apply for access to the data for non-Norwegians: https://www.fhi.no/en/more/access-to-data/applying-for-access-to-data/. For more information about access to the data used in this study or questions regarding data requests: https://www.fhi.no/div/helseundersokelser/vekstkohorten/tilgang-til-data-fra-vekstkohorten/#soek-om-datatilgang (website in Norwegian) or contact vekstkohorten@fhi.no.

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Conflicts of Interest

None

Ethics approval

The studies were conducted in accordance with the Helsinki Declaration. Ethical approval and research clearance were obtained from the Regional Committee for Medical Research Ethics (2017/431 and 2010/938) and approved by the Norwegian Data Inspectorate.

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Supporting information

S1 Fig. Schematic of the quasi-natural experimental design.
The dashed square indicates the period with the FFV policy; the squares indicate measurements in the NCGS (2010, 2012, and 2015) and NYGS (2017); and the dots indicate approximate (routine) measurements included in analysis. FFV: Free fruit and vegetables; NCGS; Norwegian Childhood Growth Study; NYGS: Norwegian Youth Growth Study; yrs: years.

S1 Table. Frequencies of schools, children and observations by county illustrating the hierarchical data structure of the three longitudinal cohorts (pooled) based on the analysis sample.
†Region and county at recruitment.
FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls); Obs: observations.

S2 Fig. Plot of individual values used in the analysis samples of BMI in each cohort (2010: orange; 2015: green; 2017: brown).
BMI: body mass index; yrs: years.

S1 Text. Standardizing the BMI outcome (BMI standard deviation scores).

S2 Table. Wald tests (p-values) of a non-linear term (quadratic) added to the functional form to model the shape of BMI from 2 to 5.5 years using three different scales, in each of the longitudinal cohorts and with cohorts pooled.
BMI: Body mass index; BMI_{SDS}: body mass index standard deviation scores; WHO: World Health Organization.

S2 Text. Exposure to FFV policy classification

S3 Table. Frequency of children by number of elementary schools reported attended from the 2017 cohort.

S4 Table. History of attendance (exposure) at FFV and NFFV schools in children that attended more than one school (n = 164) from the 2017 cohort.
FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls).

S3 Text. Longitudinal estimation of the FFV policy effect

S3 Fig. Illustration of the estimation of the free fruit and vegetable policy effect in the longitudinal analysis.
The counterfactual is that the slope in the intervention group would have changed the same way post-intervention as observed in the control group. This is shown by the dashed line and indicated by the red arrows. The effect is thus estimated by the difference between what was observed in the intervention group versus the counterfactual, as represented by the black arrow. The figure on the left shows a credible comparison for such a policy effect estimator where the pre-intervention slopes are similar. The situation on the right is less credible - the pre-intervention slopes and intercepts are quite different between groups, in this setting the counterfactual is less believable.

S4 Text. Regional patterning of combined elementary and secondary (FFV) and elementary-only schools (NFFV)

S5 Table. Mean national distribution of combined (FFV) and pure elementary (NFFV) schools from 2010, 2012, and 2015, by region and total.
Source: The Norwegian Directorate of Education.
FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls).

S5 Text. Directed Acyclic Graph

S4 Fig. Directed Acyclic Graph encoding the hypothesized causal relations between FFV allocation and weight status outcomes.
Dashed indicated unmeasured variables. FFV: free fruit and vegetables; FV: fruit and vegetables.

S6 Table. Association between FFV and education conditional (stratified) on region and population density (pooled across all cohorts).
[†]: Chi-squared test of association in each region-population density stratum.
FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls).

S5 Fig. Participant flow charts by cohort.
[*]: lost individuals are missing outcome.
[†:] Pre-intervention BMI adjusted model.
Adj: adjusted; BMI: body mass index; Educ: parental education; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls); pop-den: population density; WC: waist circumference; y: years.

S6 Fig. Predicted pre-intervention (2 to 5.5 years) trajectories of overweight (including obesity) in boys and girls who would attend a FFV (orange) and a NFFV school (navy).
The marginal proportions in each cohort and pooled cohorts and in the crude and adjusted models are presented.
FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls); yrs: years.

S7 Table. Odds ratios comparing pre-intervention (age 2 to 5.5 years) trajectories of overweight including obesity in boys and girls who would attend a FFV and a NFFV school.
The ORs compare the slopes of the log odds of OW/OB from age 2 to 5.5 years and the odds of OW/OB at age 5.5 years (pre-intervention age).
† Crude pooled model includes adjustment for cohort (intercept and slope). All models include a random intercept for school and child.
‡ Adjusted model includes region, population density, highest parental education (intercept and slope); pooled adjusted model also includes terms for cohort (intercept and slope). All models include random intercepts for school and child.
[(a)] OR comparing slopes of log odds (log odds per year) of overweight: FFV/NFFV
[(b)] OR comparing log odds of overweight at 5.5y (pre-intervention): FFV/NFFV
CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; y: years.

S7 Fig. Secondary analysis showing estimates of the FFV policy effect without NFFV schools that took part in the parental paid subscription program on (a) BMI_{SDS}, (b) OW/OB, (c) WC, and (d) WtHR at 8.5 years.
Results are presented by sex and cohort (incl. pooled) and for each model. Expressed as the difference in outcome or odds ratio (OR) versus the counterfactual (as estimated using the NFFV schools) with 95% CI.
Analysis of BMI_{SDS} and OW/OB: Pooled models include terms for cohort (intercept and slope). Adjusted model includes region, population density, highest parental education (all intercept and slope). +Pre-intervention adjusted model additionally includes adjustment for BMI_{SDS} prior to the intervention. Note: Pre-intervention slopes were constrained to be the same in each group for all models except for BMI_{SDS} in cohort 2015 girls.
Analysis of WC and WtHR: Outcomes are from grade 3 only. Pooled models include a term for cohort. Adjusted model includes region, population density, highest parental education.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity; WC: waist circumference; WtHR: waist to height ratio; y/yrs: year(s).

S8 Fig. Secondary analysis showing estimates of the FFV policy effect without NFFV schools that took part in the parental paid subscription program on (a) BMI_{SDS}, (b) OW/OB, (c) WC, and (d) WtHR at 8.5 years stratified by highest parental education level.
Results are presented by sex, cohort (incl. pooled) and parental education for each model. Expressed as the difference in outcome or odds ratio (OR) versus the counterfactual (as estimated using the NFFV schools) with 95% CI. The p-values are a test of the interaction between parental education and FFV.
Analysis of BMI_{SDS} and OW/OB: Pooled models include terms for cohort (intercept and slope). Adjusted model includes region, population density (all intercept and slope). +Pre-intervention adjusted model additionally includes adjustment for BMI_{SDS} prior to the intervention.

Analysis of WC and WtHR: Outcomes are from grade 3 only. Pooled models include a term for cohort. Adjusted model includes region and population density.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity; WC: waist circumference; WtHR: waist to height ratio; y/yrs: year(s).

S9 Fig. Estimates of the school fruit and vegetable subscription program (paid v no paid) on (a) BMI_{SDS}, (b) OW/OB, (c) WC, and (d) WtHR at 8.5 years stratified by highest parental education level.

Results are presented cohort (incl. pooled) and parental education for each model. Expressed as the difference in outcome or odds ratio (OR) versus the counterfactual (as estimated using the NFFV schools without the subscription program) with 95% CI. The p-values are a test of the interaction between parental education and the subscription program.
Analysis of BMI_{SDS} and OW/OB: Pooled models include terms for cohort (intercept and slope). Adjusted model includes region, population density (all intercept and slope). +Pre-intervention adjusted model additionally includes adjustment for BMI_{SDS} prior to the intervention.
Analysis of WC and WtHR: Outcomes are from grade 3 only. Pooled models include a term for cohort. Adjusted model includes region and population density.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; NFFV: no free fruit or vegetable; OR: odds ratio; OW/OB: overweight and obesity; WC: waist circumference; WtHR: waist to height ratio; y/yrs: year(s).

S10 Fig. Secondary analysis showing estimates of the FFV policy effect without NFFV schools that took part in the parental paid subscription program on (a) BMI_{SDS} and (b) OW/OB at age 13 years.

Results are presented by sex for each model and expressed as the difference in outcome or odds ratio (OR) versus the counterfactual at 13 years (as estimated using the NFFV schools) with 95% CI. Note data are from the 2017 cohort only.
Crude model: no adjustment. Adjusted model: includes region, population density, highest parental education (intercept and slopes); +Pre-intervention adjusted model: includes additional adjustment for BMI_{SDS} prior to the intervention.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit or vegetable; OR: odds ratio; OW/OB: overweight and obesity; y: year(s).

S11 Fig. Secondary analysis showing estimates of the FFV policy effect without NFFV schools that took part in the parental paid subscription program on (a) BMI_{SDS} and (b) OW/OB at age 13 years stratified by highest parental education level.

Results are presented by sex and parental education for each model. Expressed as the difference in outcome or odds ratio (OR) versus the counterfactual (as estimated using the NFFV schools) with 95% CI. The p-values are a test of the interaction between parental education and FFV.Note data are from the 2017 cohort only.
Adjusted model includes terms for region and population density (intercept and slopes). +Pre-intervention adjusted model includes additional adjustment for BMI_{SDS} prior to the intervention.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity; y: year(s).

S8 Table. National interventions and policies that were introduced during the time frame of our current study (2007 to 2017) and which may have affected weight outcomes.

S6 Text: National policy initiatives and co-interventions occurring over the time frame of the study

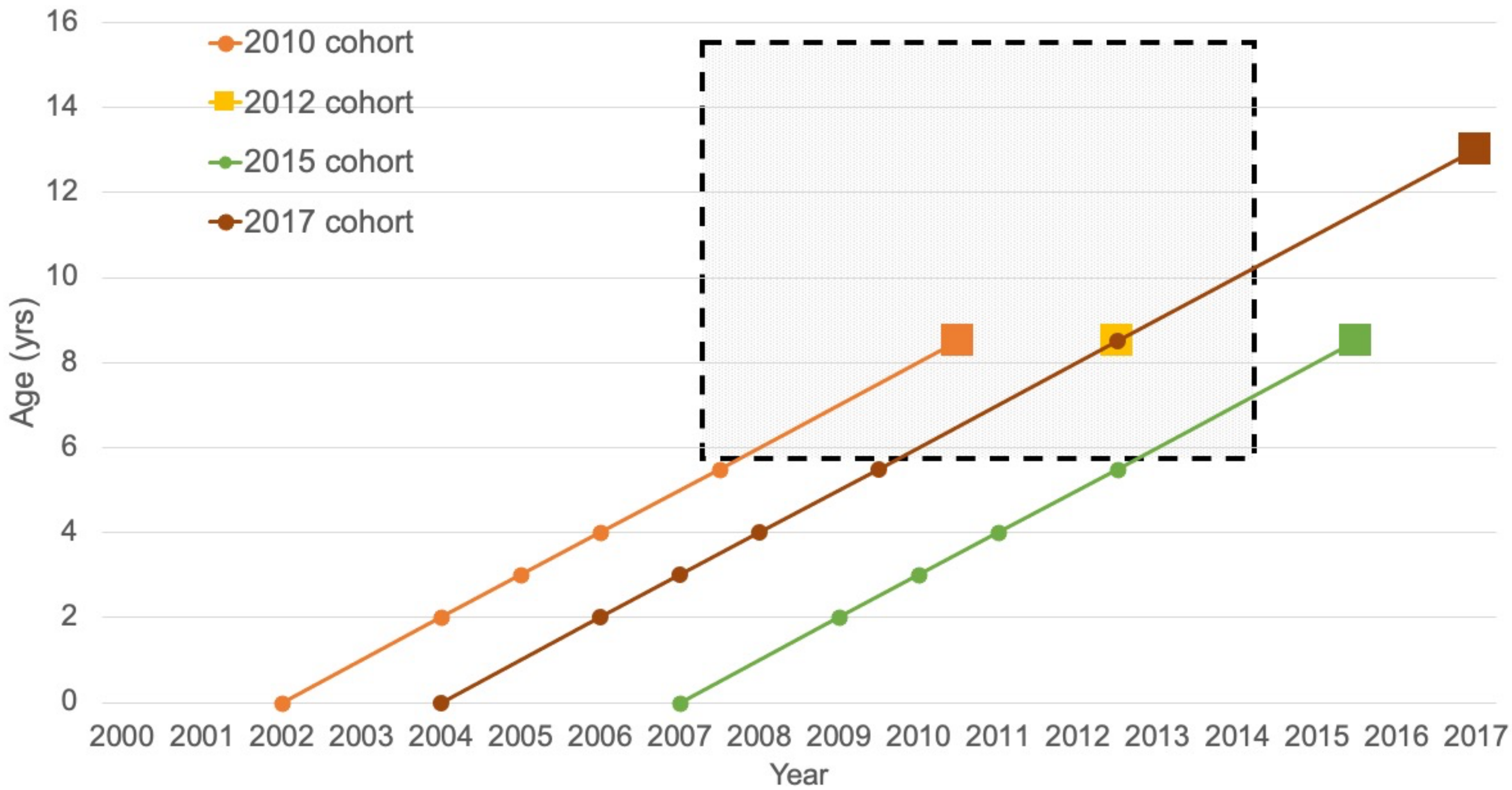
S7 Text. ROBINS-I tool for risk of bias in non-randomized comparisons

S12 Fig. Visualization of the ROBINS-I risk of bias for non-randomized interventions assessment of our study.

S9 Table. Summary of some of the analyses that were performed to check robustness of results and direction of bias.

Supporting information

Study design



S1 Fig. Schematic of the quasi-natural experimental design.

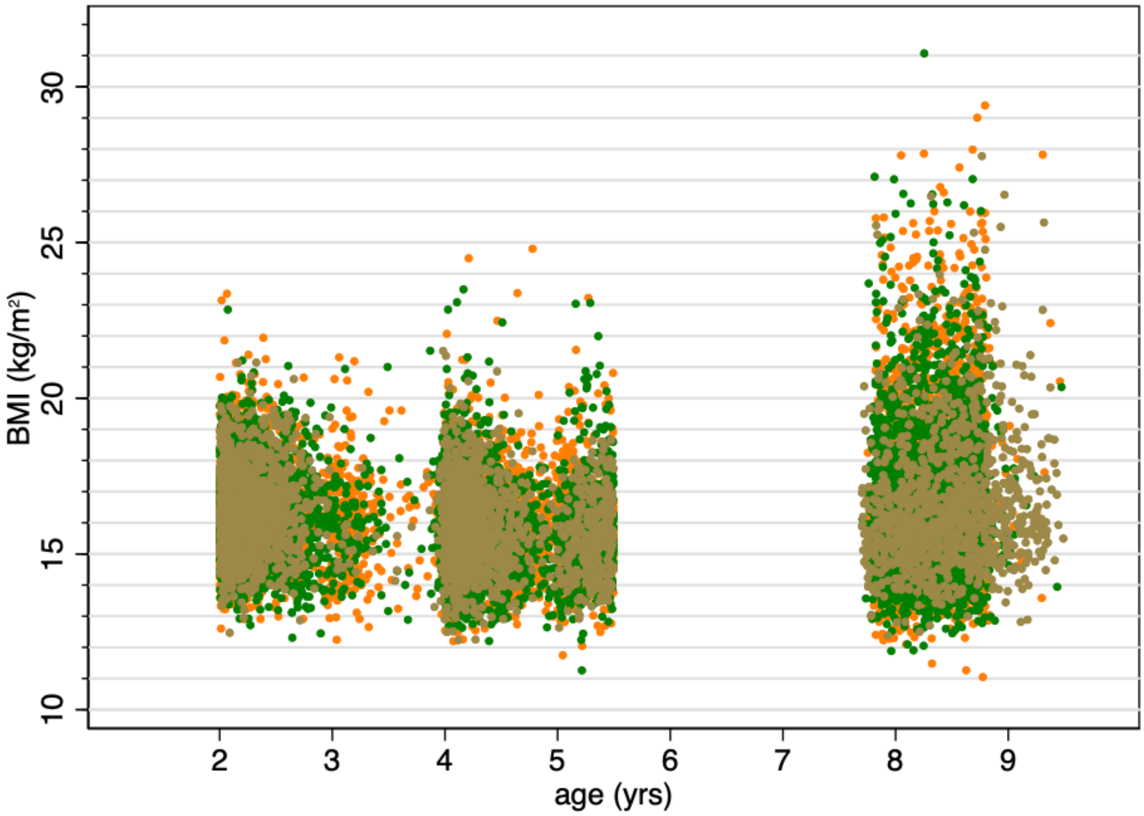
The dashed square indicates the period with the FFV policy; the squares indicate measurements in the NCGS (2010, 2012, and 2015) and NYGS (2017); and the dots indicate approximate (routine) measurements included in analysis. FFV: Free fruit and vegetables; NCGS; Norwegian Childhood Growth Study; NYGS: Norwegian Youth Growth Study; yrs: years.

Data Structure

S1 Table. Frequencies of schools, children and observations by county illustrating the hierarchical data structure of the three longitudinal cohorts (pooled) based on the analysis sample.

		FFV			NFFV			All		
Region†	County†	N Schools	N Child	N Obs	N Schools	N Child	N Obs	N Schools	N Child	N Obs
South-East	Akershus	1	5	11	18	1270	3433	19	1275	3444
	Oslo	5	218	559	8	352	915	13	570	1474
	Hedmark	1	1	2	0	0	0	1	1	2
	Oppland	0	0	0	1	1	2	1	1	2
	Vestfold	9	131	305	20	712	1799	29	843	2104
	Telemark	0	0	0	1	11	28	1	11	28
	Vest-Agder	8	123	343	23	1007	2835	31	1130	3178
West	Rogaland	7	257	797	23	691	2098	30	948	2895
	Hordaland	10	154	400	23	754	2174	33	908	2574
Mid	Møre og Romsdal	8	102	264	21	330	921	29	432	1185
	Sør-Trøndelag	13	213	614	14	401	1127	27	614	1741
	Nord-Trøndelag	0	4	11	1	5	14	1	9	25
North	Nordland	13	248	662	17	476	1372	30	724	2034
	Troms	13	186	439	10	158	383	23	344	822
	Total	88	1642	4407	180	6168	17101	268	7810	21508

†Region and county at recruitment.
FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls); Obs: observations.



S2 Fig. Plot of individual values used in the analysis samples of BMI in each cohort (2010: orange; 2015: green; 2017: brown).

BMI: body mass index; yrs: years.

Standardizing body mass index

S1 Text. Standardizing the BMI outcome (BMI standard deviation scores).
Growth is a continuous non-linear process. To linearize the functional form of the trajectories over the pre- and post-intervention period and thus meet the assumption for the comparison shown in S3 Fig (below), BMI was rescaled to internally derived age and sex standardized standard deviation scores (BMI_{SDS}). This was done using an approach similar to that outlined by Royston (1995)[1]. Briefly, a power for the transformation of BMI that best normalizes the outcome was selected using a Box-Cox procedure. A multilevel model was then fitted using a 2nd order polynomial function of age with random intercepts and slopes for each term of the age function. The polynomial function was selected from a family of second-degree polynomials, and the function containing the powers with the lowest deviance was used. The estimated variance of BMI from the model, which is a changing function of age, was then used to convert BMI (kg/m^2) to standard deviation scores. The models were a good fit- the distributions of the BMI_{SDS} were approximately normal conditional on age, and shared similar properties to a standard normal distribution.

S2 Table shows that this transformation linearized the pre-intervention slopes whereas modelling on the raw scale or using an external growth reference (e.g.; the World Health Organization's growth reference) to standardize to z-scores did not remove all of the non-linearity. Modelling on this internally standardized scale also improved the fit of the models used to estimate the policy effect.

S2 Table. Wald tests (p-values) of a non-linear term (quadratic) added to the functional form to model the shape of BMI from 2 to 5.5 years using three different scales, in each of the longitudinal cohorts and with cohorts pooled.

		BMI (kg/m^2)	Externally standardized BMI z-scores (WHO)	Internally standardized BMI_{SDS}
Boys	2010	<0.001	0.015	0.77
	2015	<0.001	0.395	0.24
	2017	0.052	0.003	0.17
	Pooled	<0.001	0.001	0.99
Girls	2010	0.009	0.064	0.28
	2015	<0.001	0.83	0.526
	2017	0.398	0.038	0.065
	Pooled	<0.001	0.055	0.272

BMI: Body mass index; BMI_{SDS}: body mass index standard deviation scores; WHO: World Health Organization[2].

[1] Royston P. Calculation of unconditional and conditional reference intervals for foetal size and growth from longitudinal measurements. Stat Med. 1995;14(13):1417-36. Epub 1995/07/15. doi: 10.1002/sim.4780141303. PubMed PMID: 7481181.
[2] WHO Growth, Reference, Study, Group. WHO Child Growth Standards: Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development. Geneva: World Health Organization; 2006.

Exposure to the free fruit and vegetable policy classification

S2 Text. Exposure to FFV policy classification

In assigning a duration of exposure to the FFV policy for each cohort, we assume that the elementary school attended at third grade recruitment is the same as attended during first or second grades or that the child had attended a school with the same obligation to the FFV policy. To see how strong this assumption is, we use information from the consent form of the 2017 cohort to give an indication of the number of elementary schools attended and how many were of the same FFV classification. This is not entirely comparable since the consent form in the 2017 cohort, which was administered when the children were in lower secondary school, only asked parents to list up to four elementary schools attended, no dates were attached so children may have attended these schools outside the first to third grade exposure period. Nonetheless, it gives an upper bound estimate of the amount of movement between FFV and NFFV schools and potential for misclassification.

A total of 164 (10%) of children had attended more than one elementary school, of these 69 (42%) had attended both an elementary-only school (NFFV school) and a combined school (FFV). Thus approximately 4% of the sample were exposed to both FFV and NFFV schools. This information was only available in the 2017 cohort.

S3 Table. Frequency of children by number of elementary schools reported attended from the 2017 cohort.

Number of schools attended	N (%)
1	1426 (89.7)
2	150 (9.4)
3	11 (0.7)
4	3 (0.2)

S4 Table. History of attendance (exposure) at FFV and NFFV schools in children that attended more than one school (n = 164) from the 2017 cohort.

Exposure history	N (%)
FFV only	13 (8)
NFFV only	82 (50)
FFV and NFFV	69 (42)
Total	164

FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls).

Further information about estimating the policy effect

S3 Text. Longitudinal estimation of the FFV policy effect
S3 Fig illustrates how the FFV policy effect at grade 3 (~8.5 years) was estimated using the longitudinal datasets (cohorts 2010, 2015, and 2017 for the BMI_{SDS} and OW/OB outcomes). The pre- and post-FFV policy trajectories were modelled using linear splines with a knot prior to the policy exposure at 5.5 years (see eq. (1) in main text). The splines are formulated as follows with age centered (c_age) at the pre-policy knot (c_age = age – 5.5y):

$$S_1 = \begin{cases} c\_age & c\_age \leq 0 \\ 0 & c\_age > 0 \end{cases}$$

$$S_2 = \begin{cases} 0 & c\_age \leq 0 \\ c\_age & c\_age > 0 \end{cases}$$

(eq. s1)

The grey area in S3 Fig represents the ages when children were introduced to FFV which was in first grade of school. To avoid bias in the estimate of the FFV post-intervention slope caused by including datapoints at ages when some children in FFV schools were exposed and some were not, all data around this period were removed leaving only third grade as the post-intervention measures for the analysis of outcomes at ~8 year, and third and eight grade measures for the analysis of outcomes at ~13 years. Removal of observations around the introduction of the intervention also prevents future measures from influencing the estimation of the pre-intervention slope which makes no sense causally and would introduce bias to the estimate of the policy effect. S2 Fig shows the individual data included in the analyses (see section on data structure).

To linearize the functional form of the relationship for the BMI outcome which has a complex shape early in life, we also derived internally standardized BMI standard deviation scores (BMI_{SDS}) – see S1 Text.

<u>Estimating the FFV policy effect at age 13 in the 2017 cohort</u>
To estimate the longer-term effect of the FFV policy at age 13 years in the 2017 cohort, the linear spline model illustrated in S3 Fig and equation (1) of the main text was extended to incorporate an extra knot in third grade (age 8.5 years). The model was simplified to constrain groups to have the same pre-intervention slope. As shown in Fig 1 (main text) and S6 Fig, and in Table 2 and S7 Table, this was a reasonable assumption. The basic model can thus be written as:

$$E(Y) = \beta_0 + \beta_1 S_1 + \beta_2 S_2 + \beta_3 S_3 + \gamma_0 I + \gamma_2 I * S_2 + \gamma_3 I * S_3$$

(eq. s2)

where I is a binary variable indicating FFV exposure, and S_1, S_2 and S_3 are linear splines of *age* (years) centered at the pre-policy age (*c_age*=*age* - 5.5) with knots at age 5.5 years (pre-policy) and 8.5 years (grade 3) as follows:

$$S_1 = \begin{cases} c\_age & c\_age \leq 0 \\ 0 & c\_age > 0 \end{cases}$$

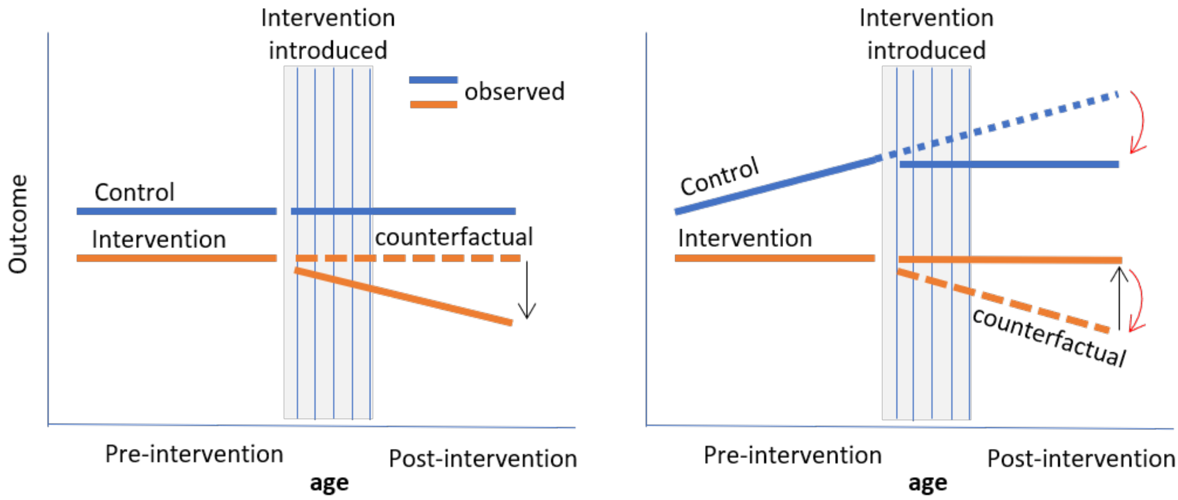
$$S_2 = \begin{cases} 0 & c_{age} \leq 0 \\ c_{age} - 3 & 0 < c_{age} \leq 3 \\ 3 & c_{age} > 3 \end{cases}$$

$$S_3 = \begin{cases} 0 & c\_age \leq 3 \\ c\_age & c\_age > 3 \end{cases}$$

(eq. s3)

$\beta_0, \beta_1, \beta_2$ and β_3 describe the outcome ($E(Y)$) at 5.5 years and the pre- (β_1) and post-intervention slopes (β_2, β_3) respectively in the control (NFFV) group. γ_0, γ_2 and γ_3 are the mean difference in intercept at 5.5 years and mean difference in post-intervention slopes between groups.

The counterfactual is the trajectory that the FFV group would have taken in absence of the intervention and is estimated by the post intervention slopes in the NFFV group. The difference between the FFV group and the counterfactual at age 13 years is thus an estimate of the policy effect at age 13 years and is given by $(\gamma_2 * 3 + \gamma_3 * 4.5)$.



S3 Fig. Illustration of the estimation of the free fruit and vegetable policy effect in the longitudinal analysis.

The counterfactual is that the slope in the intervention group would have changed the same way post-intervention as observed in the control group. This is shown by the dashed line and indicated by the red arrows. The effect is thus estimated by the difference between what was observed in the intervention group versus the counterfactual, as represented by the black arrow. The figure on the left shows a credible comparison for such a policy effect estimator where the pre-intervention slopes are similar. The situation on the right is less credible - the pre-intervention slopes and intercepts are quite different between groups, in this setting the counterfactual is less believable.

Additional information on the allocation of the free fruit and vegetable policy

S4 Text. Regional patterning of combined elementary and secondary (FFV) and elementary-only schools (NFFV)

S5 Table shows the national distribution of combined elementary and secondary schools (those obligated by the free school fruit and vegetable policy) by region. The North has the highest proportion of combined schools (FFV) and the South-East the lowest. This pattern was mirrored in our data sets (see Table 1 in main text and S1 Table).

S5 Table. Mean national distribution of combined (FFV) and pure elementary (NFFV) schools from 2010, 2012, and 2015, by region and total.

	Total	Elementary/NFFV schools (1-7th grade)		Combined/FFV schools (1-10th grade)	
Region	N	n	%	n	%
North	392	167	42.6	225	57.4
South-East	1090	835	76.6	255	23.4
West	565	414	73.2	151	26.8
Mid	420	291	69.4	129	30.6
Total	2467	1706	69.2	760	30.8

Source: The Norwegian Directorate of Education.
FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls).

Directed Acyclic Graph

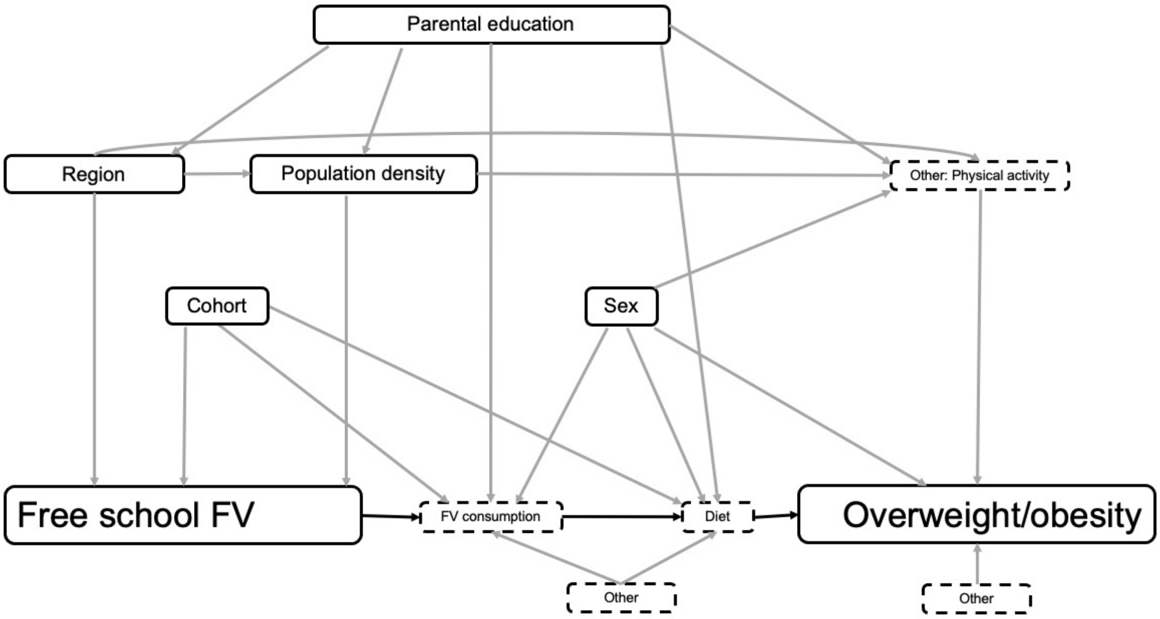
S5 Text. Directed Acyclic Graph

The allocation of FFV policy cannot be considered "as if" random due to differences in the distribution of combined (FFV) schools between regions. This is likely to be driven in part by differences in the population density between regions. Northern regions of Norway are more rural and combined (FFV) schools are more likely to be located in regions of lower population density – as reflected in our data (see Table 1 in the manuscript). A Directed Acyclic Graph (DAG) was thus constructed to determine what variables to adjust for to obtain a causal estimate of the FFV policy effect (S4 Fig).

The DAG in S4 Fig has an arrow from FFV school to obesity-related outcomes acting through the consumption of the fruit and vegetables and through diet. Region and population density have direct links to FFV allocation and are a sufficient adjustment set to estimate the causal effect of the FFV policy.

Cohort determines the duration of exposure to the FFV policy and may also affect intake of the fruit and vegetables and any secular dietary changes. One might therefore expect a different policy effect between cohorts. Similarly, there may be differences in response to the policy between boys and girls and between children of different socio-economic background (of which parental education is a marker), as indicated in the DAG. For these reasons, we also present results stratified on these factors.

A key assumption encoded in the DAG is that parental education is independent of FFV allocation conditional on region and population density. S6 Table shows that this assumption did not hold - in several region and population density strata there was a higher proportion of children from parents with a higher education attending elementary only (NFFV) schools, hence, education was additionally adjusted for. Pre-intervention BMI, which is not included in the DAG, may also capture other differences in the child's obesogenic environment linked to region, population density, and socio-economic factors, and so was adjusted for in an additional model.



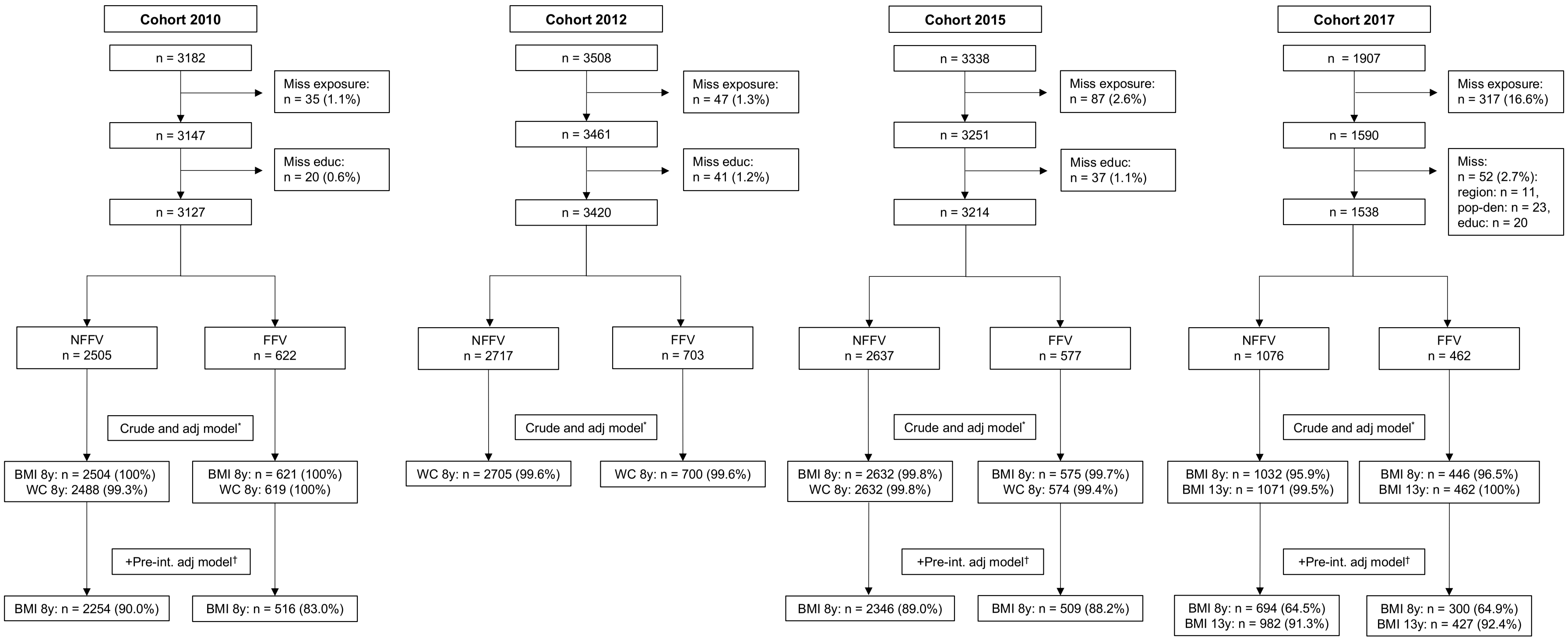
S4 Fig. Directed Acyclic Graph encoding the hypothesized causal relations between FFV allocation and weight status outcomes.

Dashed indicated unmeasured variables. FFV: free fruit and vegetables; FV: fruit and vegetables.

S6 Table. Association between FFV and education conditional (stratified) on region and population density (pooled across all cohorts).

Region	Population density	Group	<Higher education	Higher+ education	p†
South-East	Urban (> 50000)	NFFV	1818 (40.0%)	2845 (61.0%)	
		FFV	334 (50.2%)	332 (49.9%)	<0.001
	Semi-urban (15-50000)	NFFV	115 (44.6%)	143 (55.4%)	
		FFV	5 (100%)	0	0.014
	Rural (< 15000)	NFFV	10 (45.5%)	12 (54.6%)	
		FFV	21 (58.3%)	15 (41.7%)	0.34
West	Urban (> 50000)	NFFV	743 (42.5%)	1005 (57.5%)	
		FFV	163 (43.1%)	215 (56.9)	0.83
	Semi-urban (15-50000)	NFFV	34 (50.8%)	33 (49.3%)	
		FFV	40 (66.7%)	20 (33.3%)	0.069
	Rural (< 15000)	NFFV	91 (50.3%)	90 (49.7%)	
		FFV	71 (47.7%)	78 (52.4%)	0.64
Mid	Urban (> 50000)	NFFV	138 (25.8%)	396 (74.1%)	
		FFV	81 (32.5%)	168 (67.5%)	0.052
	Semi-urban (15-50000)	NFFV	97 (44.5%)	121 (55.5%)	
		FFV	39 (36.5%)	68 (63.5%)	0.17
	Rural (< 15000)	NFFV	148 (55.9%)	117 (44.2%)	
		FFV	45 (61.6%)	28 (38.4%)	0.38
North	Urban (> 50000)	NFFV	16 (28.6%)	40 (71.4%)	
		FFV	69 (66.4%)	35 (33.7%)	<0.001
	Semi-urban (15-50000)	NFFV	294 (46.2%)	343 (53.9%)	
		FFV	109 (34.1%)	211 (65.9%)	<0.001
	Rural (< 15000)	NFFV	62 (48.1%)	67 (51.9%)	
		FFV	94 (61.0%)	60 (39.0%)	0.029

†: Chi-squared test of association in each region-population density stratum.
FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls).



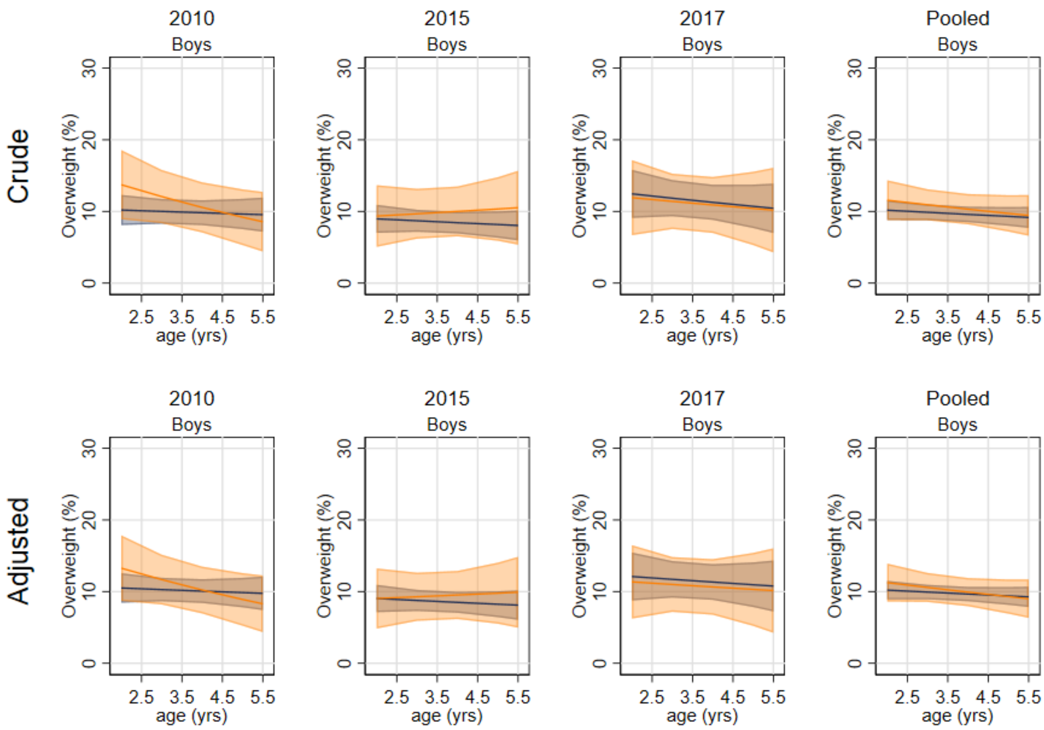
S5 Fig. Participant flow charts by cohort.

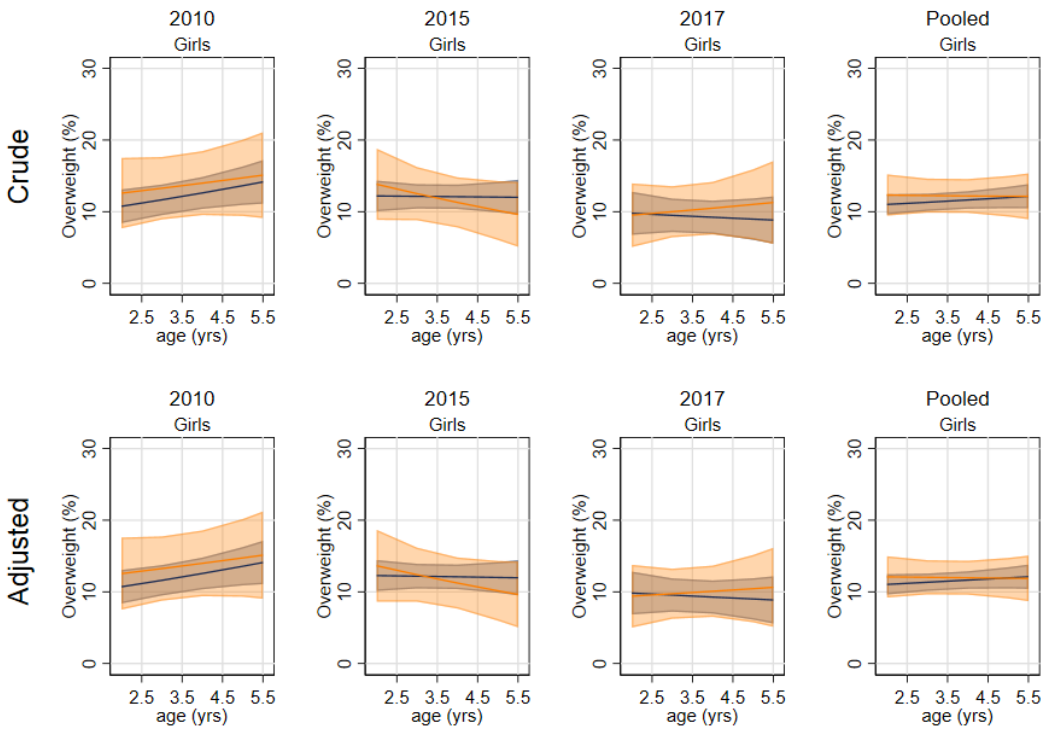
*: lost individuals are missing outcome.

†: Pre-intervention BMI adjusted model.

Adj: adjusted; BMI: body mass index; Educ: parental education; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls); pop-den: population density; WC: waist circumference; y: years.

Comparison of pre-intervention overweight/obesity trajectories





S6 Fig. Predicted pre-intervention (2 to 5.5 years) trajectories of overweight (including obesity) in boys and girls who would attend a FFV (orange) and a NFFV school (navy). The marginal proportions in each cohort and pooled cohorts and in the crude and adjusted models are presented. FFV: free fruit and vegetables; NFFV: no free fruit and vegetables (controls); yrs: years.

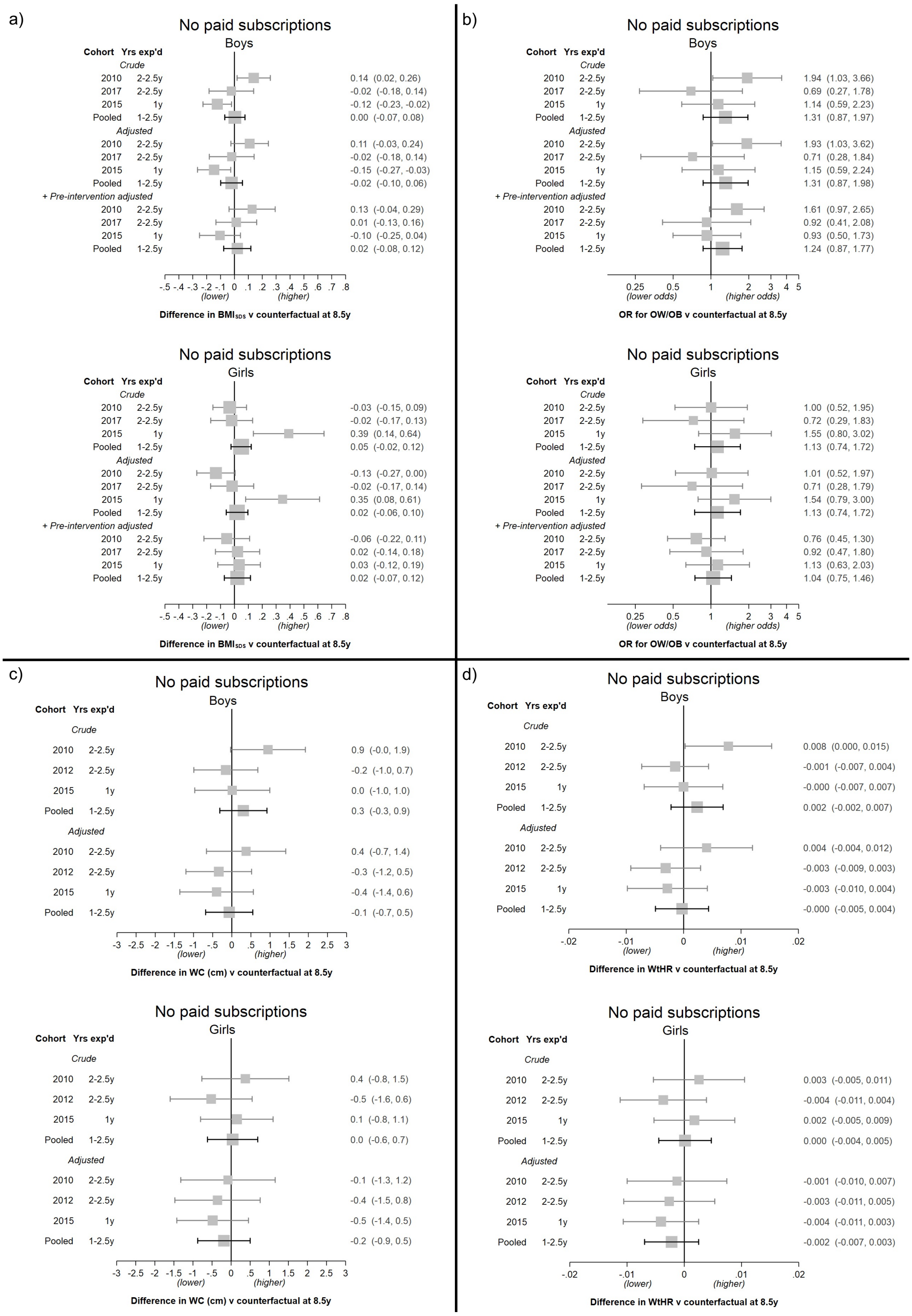
S7 Table. Odds ratios comparing pre-intervention (age 2 to 5.5 years) trajectories of overweight including obesity in boys and girls who would attend a FFV and a NFFV school.

		Crude†				Adjusted‡			
	Cohort	OR per year [a] (95% CI)	p	OR at 5.5y [b] (95% CI)	p	OR per year [a] (95% CI)	p	OR at 5.5y [b] (95% CI)	p
Boys	2010	0.79 (0.55, 1.13)	0.20	0.81 (0.28, 2.34)	0.7	0.79 (0.55, 1.14)	0.21	0.73 (0.26, 2.05)	0.54
	2015	1.13 (0.75, 1.71)	0.56	1.67 (0.56, 4.97)	0.35	1.11 (0.74, 1.69)	0.61	1.46 (0.49, 4.36)	0.49
	2017	1.01 (0.63, 1.63)	0.96	0.95 (0.27, 3.32)	0.94	1.00 (0.62, 1.63)	0.99	0.89 (0.25, 3.16)	0.86
	Pooled	0.94 (0.75, 1.20)	0.64	1.06 (0.55, 2.03)	0.9	0.93 (0.73, 1.18)	0.55	0.95 (0.50, 1.80)	0.87
Girls	2010	0.94 (0.63, 1.39)	0.76	1.18 (0.36, 3.84)	0.78	0.94 (0.65, 1.40)	0.77	1.20 (0.36, 3.98)	0.77
	2015	0.81 (0.54, 3.30)	0.29	0.62 (0.21, 1.83)	0.39	0.82 (0.55, 1.22)	0.33	0.63 (0.21, 1.88)	0.41
	2017	1.17 (0.71, 1.91)	0.53	1.64 (0.45, 5.93)	0.45	1.14 (0.69, 1.89)	0.60	1.45 (0.38, 5.48)	0.58
	Pooled	0.93 (0.73, 1.18)	0.55	1.00 (0.50, 1.97)	0.99	0.93 (0.73, 1.18)	0.56	0.96 (0.48, 1.91)	0.9

The ORs compare the slopes of the log odds of OW/OB from age 2 to 5.5 years and the odds of OW/OB at age 5.5 years (pre-intervention age).
† Crude pooled model includes adjustment for cohort (intercept and slope). All models include a random intercept for school and child.
‡ Adjusted model includes region, population density, highest parental education (intercept and slope); pooled adjusted model also includes terms for cohort (intercept and slope). All models include random intercepts for school and child.
[a] OR comparing slopes of log odds (log odds per year) of overweight: FFV/NFFV
[b] OR comparing log odds of overweight at 5.5y (pre-intervention): FFV/NFFV
CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; y: years.

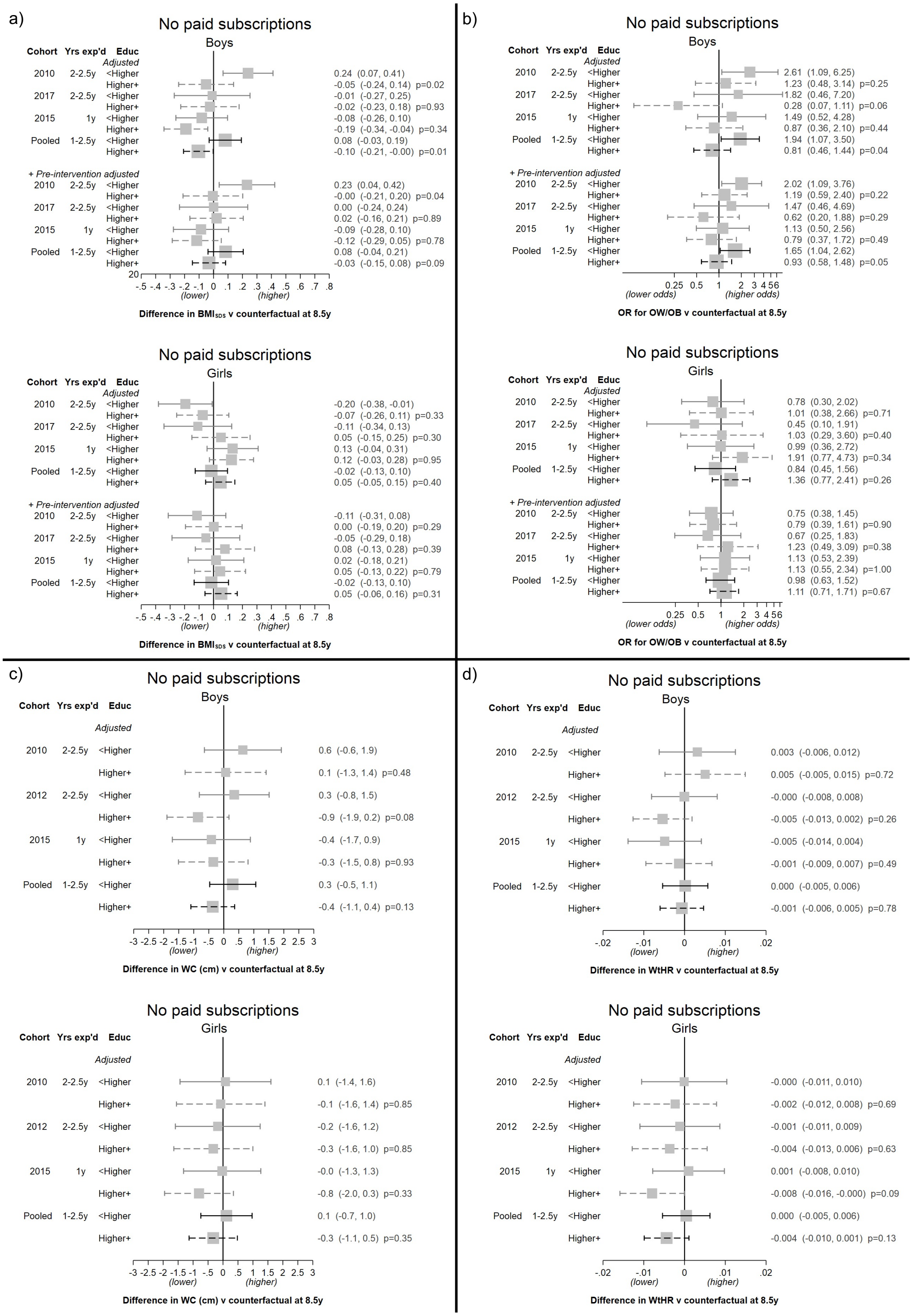
Secondary/supplementary analyses

Removal of no free fruit and vegetable schools (NFFV) that signed up to offer the parental paid fruit and vegetable subscription program at age 8.5 years



S7 Fig. Secondary analysis showing estimates of the FFV policy effect without NFFV schools that took part in the parental paid subscription program on (a) BMI_{SDS}, (b) OW/OB, (c) WC, and (d) WtHR at 8.5 years.

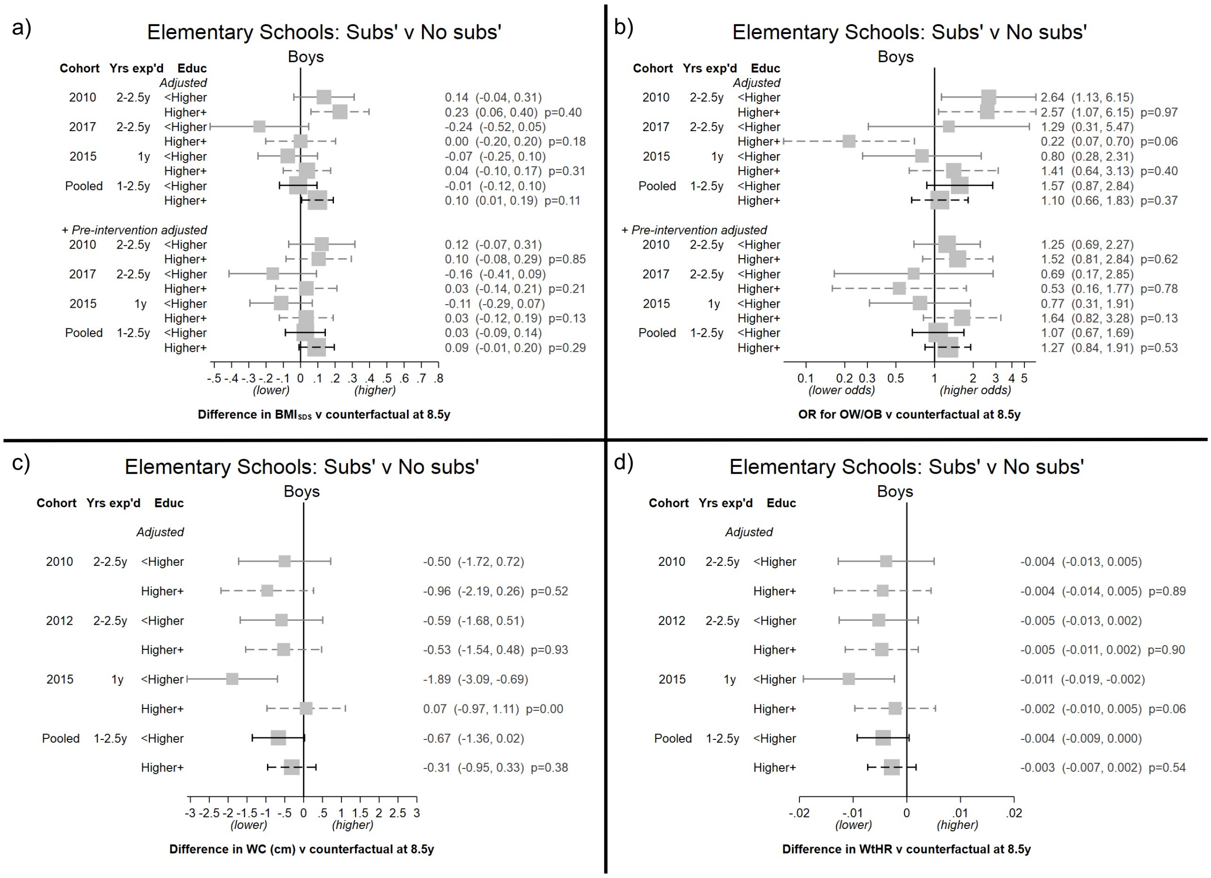
Results are presented by sex and cohort (incl. pooled) and for each model. Expressed as the difference in outcome or odds ratio (OR) versus the counterfactual (as estimated using the NFFV schools) with 95% CI.
Analysis of BMI_{SDS} and OW/OB: Pooled models include terms for cohort (intercept and slope). Adjusted model includes region, population density, highest parental education (all intercept and slope). +Pre-intervention adjusted model additionally includes adjustment for BMI_{SDS} prior to the intervention. Note: Pre-intervention slopes were constrained to be the same in each group for all models except for BMI_{SDS} in cohort 2015 girls.
Analysis of WC and WtHR: Outcomes are from grade 3 only. Pooled models include a term for cohort. Adjusted model includes region, population density, highest parental education.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity; WC: waist circumference; WtHR: waist to height ratio; y/yrs: year(s).



S8 Fig. Secondary analysis showing estimates of the FFV policy effect without NFFV schools that took part in the parental paid subscription program on (a) BMI_{SDS}, (b) OW/OB, (c) WC, and (d) WtHR at 8.5 years stratified by highest parental education level.

Results are presented by sex, cohort (incl. pooled) and parental education for each model. Expressed as the difference in outcome or odds ratio (OR) versus the counterfactual (as estimated using the NFFV schools) with 95% CI. The p-values are a test of the interaction between parental education and FFV.
Analysis of BMI_{SDS} and OW/OB: Pooled models include terms for cohort (intercept and slope). Adjusted model includes region, population density (all intercept and slope). +Pre-intervention adjusted model additionally includes adjustment for BMI_{SDS} prior to the intervention.
Analysis of WC and WtHR: Outcomes are from grade 3 only. Pooled models include a term for cohort. Adjusted model includes region and population density.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity; WC: waist circumference; WtHR: waist to height ratio; y/yrs: year(s).

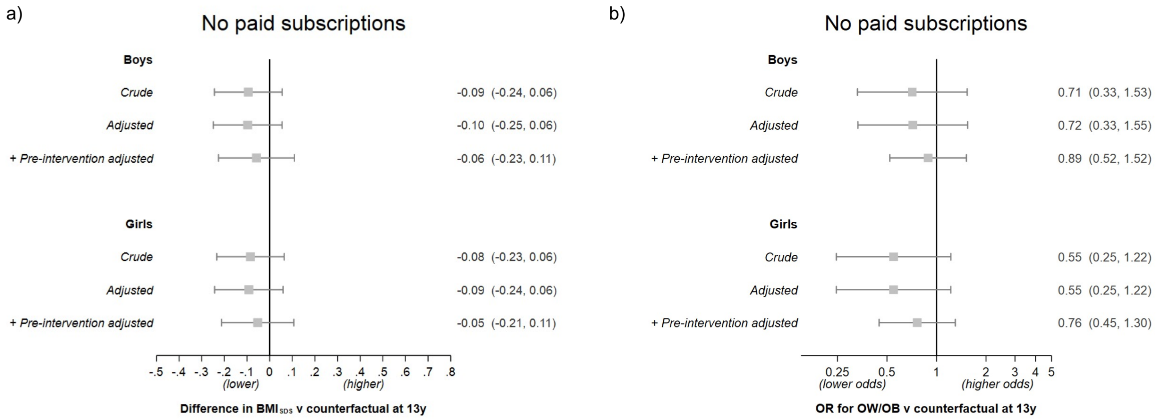
Post-hoc analysis of the parental paid fruit and vegetable school subscription program among elementary schools only



S9 Fig. Estimates of the school fruit and vegetable subscription program (paid v no paid) on (a) BMI_{SDS}, (b) OW/OB, (c) WC, and (d) WtHR at 8.5 years stratified by highest parental education level.

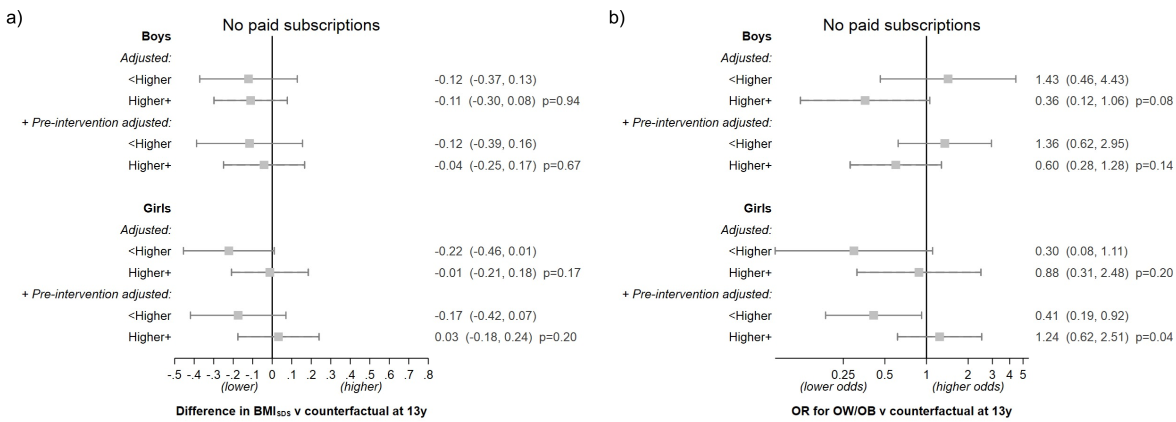
Results are presented cohort (incl. pooled) and parental education for each model. Expressed as the difference in outcome or odds ratio (OR) versus the counterfactual (as estimated using the NFFV schools without the subscription program) with 95% CI. The p-values are a test of the interaction between parental education and the subscription program.
Analysis of BMI_{SDS} and OW/OB: Pooled models include terms for cohort (intercept and slope). Adjusted model includes region, population density (all intercept and slope). +Pre-intervention adjusted model additionally includes adjustment for BMI_{SDS} prior to the intervention.
Analysis of WC and WtHR: Outcomes are from grade 3 only. Pooled models include a term for cohort. Adjusted model includes region and population density.
BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; NFFV: no free fruit or vegetable; OR: odds ratio; OW/OB: overweight and obesity; WC: waist circumference; WtHR: waist to height ratio; y/yrs: year(s).

Removal of NFFV schools that signed up to offer the parental paid fruit and vegetable subscription program at age 13 years



S10 Fig. Secondary analysis showing estimates of the FFV policy effect without NFFV schools that took part in the parental paid subscription program on (a) BMI_{SDS} and (b) OW/OB at age 13 years.

Results are presented by sex for each model and expressed as the difference in outcome or odds ratio (OR) versus the counterfactual at 13 years (as estimated using the NFFV schools) with 95% CI. Note data are from the 2017 cohort only. Crude model: no adjustment. Adjusted model: includes region, population density, highest parental education (intercept and slopes); +Pre-intervention adjusted model: includes additional adjustment for BMI_{SDS} prior to the intervention. BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit or vegetable; OR: odds ratio; OW/OB: overweight and obesity; y: year(s).



S11 Fig. Secondary analysis showing estimates of the FFV policy effect without NFFV schools that took part in the parental paid subscription program on (a) BMI_{SDS} and (b) OW/OB at age 13 years stratified by highest parental education level.

Results are presented by sex and parental education for each model. Expressed as the difference in outcome or odds ratio (OR) versus the counterfactual (as estimated using the NFFV schools) with 95% CI. The p-values are a test of the interaction between parental education and FFV.Note data are from the 2017 cohort only. Adjusted model includes terms for region and population density (intercept and slopes). +Pre-intervention adjusted model includes additional adjustment for BMI_{SDS} prior to the intervention. BMI_{SDS}: body mass index standard deviation scores; CI: confidence interval; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; OR: odds ratio; OW/OB: overweight and obesity; y: year(s).

Threats to the validity of the study

<u>National policy initiatives and co-interventions occurring over the time frame of the study</u>

S8 Table. National interventions and policies that were introduced during the time frame of our current study (2007 to 2017) and which may have affected weight outcomes.

Time varying confounding factors	**Population-level policies and interventions between 2007-2017**
Physical activity	Action plan on physical activity 2005-2009: included a goal to increase proportion of children and adolescents who are in moderate physical activity for 60 minutes each day. 2014-2015: Pilot to increase hours of physical activity in secondary schools (it is assumed the target population was grades 8 to 10). A total of 7 schools started in 2016, while 30 additional schools were included in 2017.
Increase healthy eating	Action plan on nutrition 2007-2011: Action plan on nutrition aiming to improve nutrition in the population towards the recommendations from health authorities by (relevant measures): focus on healthy meals in school by school meal guidelines; fruit and vegetables in school; limit access to soda in schools; limit marketing of unhealthy food and beverages to children; several pilots throughout the country with various models for offering school meals (breakfast and/or lunch); increase knowledge and skills about food, food preparation, nutrition and health in elementary schools. 2007-2013: Voluntary cooperation with the industry to restricting marketing of unhealthy food/beverages to children under the age of 13. Started in 2007, was re-enforced in 2013. 2011-date: Thirteen food-based advice from health authorities to the population, one is eat five-a-day (of fruit and vegetables). 2014: Establishment of National Centre for food, health and physical activity aimed to strengthen each kindergarten and school's role as a health promoting and preventive arena. 2014-2015: Point out the need for 20 min eating break; and strengthen practical cooking skills and facilitate healthy food and meals in schools and kindergarten. 2015-date: Matjungelen: initiative to make children into *agents of change* focusing on healthy and sustainable dietary choices. 2015: Revised national guidelines "food and meals in school": Specifies that all elementary and secondary schools should offer fruit and vegetables to pupils each day; baked goods and foods with high amounts of sugar/fats should only be used on special occasions; candy, chocolate, chips and other snack should be limited and not provided in schools. Action plan on nutrition 2017-2021: Aiming to improve diet according to nutritional recommendations. Relevant measures in the plan: Monitor work restricting marketing of unhealthy food and beverages to children; promote healthy meals in schools; focus on the need for a 20-minute lunch break; mobilize children as agents of change (Matjungelen) focusing on healthy and sustainable dietary choices; increase practical skills; and increase knowledge and resources to teachers in health economics.

S6 Text: National policy initiatives and co-interventions occurring over the time frame of the study

S8 Table lists national level policies and co-interventions that may have altered outcomes assessed in our study. It also includes, to the best of our knowledge, any known pilot studies that stemmed from national initiatives.

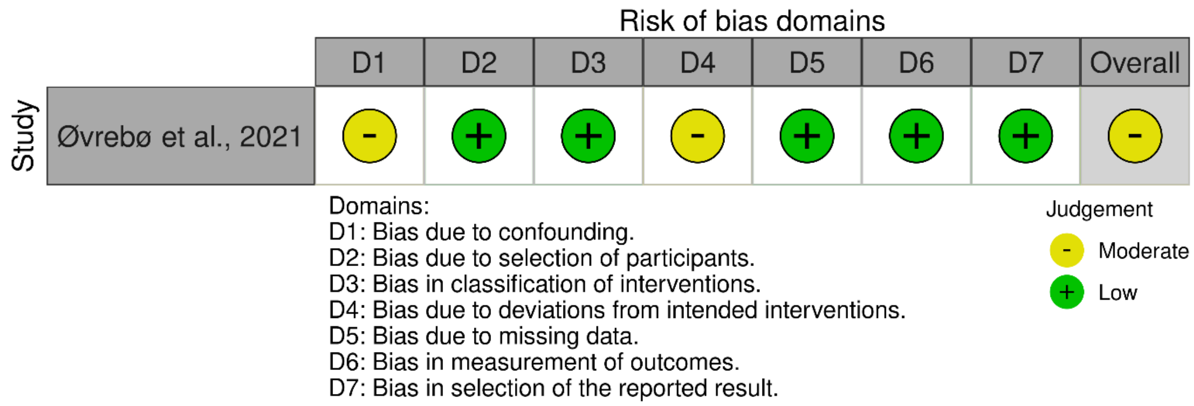
While there have been several national campaigns and policies that if effective, would have acted on the weight outcomes in our study, many occurred post-2014 and so would have only potentially influenced outcomes at age 13 in the 2017 cohort, and all would have reduced the obesogenic environment across all schools regardless of exposure to the free school fruit and vegetable policy. It seems unlikely that these co-interventions would have biased our comparisons between schools to an extent that would alter our conclusions. Therefore, the risk of bias from these co-interventions is assumed to be low.

<u>Risk of bias in non-randomized comparisons</u>

S7 Text. ROBINS-I tool for risk of bias in non-randomized comparisons

To help understand the potential risk of bias in our study and provide a framework for considering bias, two of the authors (BØ, AKW) completed, discussed and agreed on the ROBINS-I tool[3]. S12 Fig summarizes this assessment in our study. Risk of bias due to confounding (D1) is an obvious concern since the intervention cannot be considered "as if" random, but the use of a Directed Acyclic Graph (DAG) to determine a sufficient adjustment set to obtain a causal estimate, and the ability to adjust for pre-intervention differences in the outcome and triangulate the evidence with additional comparisons to check for residual confounding and inform the conclusions would suggest that while risk of confounding is moderate, the ability to adjust for further confounders or for more accurate indicators of potential confounders is unlikely to alter the magnitude of the estimates to an extent that it would materially alter the conclusions of our study. Risk of bias due to deviations from intended interventions (D4) is likely since our classification does not account for children who changed school. However, as stated, we predict that less than 4% of the sample would have attended both a FFV and NFFV school and so bias from this domain is also unlikely to be sufficient in magnitude to alter our conclusions. Other domains of bias assessed by ROBINS-I were considered low and the overall assessment was considered moderate since the study is not comparable to a well-performed randomized controlled trial.

[3] Sterne JA, Hernan MA, Reeves BC, Savovic J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016;355:i4919. Epub 2016/10/14. doi: 10.1136/bmj.i4919. PubMed PMID: 27733354; PubMed Central PMCID: PMCPMC5062054



S12 Fig. Visualization of the ROBINS-I risk of bias for non-randomized interventions assessment of our study[4].

Summary of analyses designed to test robustness of results and triangulate evidence

S9 Table. Summary of some of the analyses that were performed to check robustness of results and direction of bias.

Component	Target check	Potential direction and/or cause of bias	Analysis/ steps to combat/check	Results
Analytical strategy	Parameterization of longitudinal models	Unknown. Sensitivity of findings to bias caused by suboptimal model of functional form.	Re-run with an earlier (5.3y) and later (5.7y) knot point.	Findings unaltered – results available on request
Analysis strategy	Scale for modelling the BMI outcome	Unknown Suboptimal model fit	Used sex and age internally standardized BMI.	Main text and supporting information Improved the residual diagnostics compared the raw scale or externally standardized scale
Analysis strategy	Missing outcome and exposure data	Unknown (1) Outcomes in children missing exposure or covariables are MNAR (2) Participation in study linked to outcome – MNAR (3) Studies are retrospective cohorts, so bias could also be caused by missing pre-intervention data being MNAR.	NB; main longitudinal models give unbiased estimates if data are missing at random (1) Compare estimates in the unadjusted models when using complete cases and all available data (2) & (3) Differences in exclusions due to missing data between group may provide an indication.	Described in main text (1) Findings unaltered – results available on request (2) & (3) Proportions missing similar between groups – although does not mean MNAR.

[4]McGuinness, LA, Higgins, JPT. Risk-of-bias VISualization (robvis): An R package and Shiny web app for visualizing risk-of-bias assessments. Res Syn Meth. 2020; 1- 7. https://doi.org/10.1002/jrsm.1411

Confounding	Residual confounding	Away from null Nonrandom allocation of FFV policy. Higher BMI in FFV schools	(1) Models estimate in 3 steps and presented alongside each other (crude, adjusted, +pre-intervention adjusted) to check direction and magnitude of confounding	Main text
	Residual confounding		Post hoc analysis in elementary only schools (NFFV) comparing schools that offered paid FV subscriptions versus those that didn't	Main text and supporting information
Causal inference (triangulation)	Dose response relationship	If FFV is causal then we expect CI to overlap in a way that is either (a) consistent with a dose-response relationship or (b) Shows no heterogeneity between cohorts (if there is no extra benefit or unintended consequence from being exposed to policy for >1y)	Cohorts have different duration of exposure. Analysis stratified by cohort with formal test of interaction	Main text
Causal inference (triangulation)	Exposure classification.	Towards null If taking FFV is causal then we'd expect any effect to be diluted in our analysis since not all children take the FFV and some NFFV schools offered parents paid subscriptions.	Repeated analysis after removing the NFFV schools that signed up for parental subscription to FV. If point estimates are the same or stronger then it lends some support to main findings	Main text and supporting information

BMI: body mass index; CI: confidence intervals; FV: fruit and vegetables; FFV: free fruit and vegetables; NFFV: no free fruit and vegetables; MNAR: Missing not at random.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	5+7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-7*
Bias	9	Describe any efforts to address potential sources of bias	7-9 + supp. info
Study size	10	Explain how the study size was arrived at	S5 Fig
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8 + supp. info
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-9 + supp. info
		(*b*) Describe any methods used to examine subgroups and interactions	7-9 + supp. info
		(*c*) Explain how missing data were addressed	S9 Table
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	NA

		(*e*) Describe any sensitivity analyses	9-10 + supp. info

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10 + S5 Fig.
		(b) Give reasons for non-participation at each stage	S5 Fig
		(c) Consider use of a flow diagram	S5 Fig
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11
		(b) Indicate number of participants with missing data for each variable of interest	S5 Fig
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	6-7 + supp info
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*S5 Fig*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*NA*
		Cross-sectional study—Report numbers of outcome events or summary measures	*S5 Fig*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-21 + supp. info
		(*b*) Report category boundaries when continuous variables were categorized	14-21 + supp. info
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	21 + supp info
Discussion			
Key results	18	Summarise key results with reference to study objectives	21-22
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	24-25
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	23-24
Generalisability	21	Discuss the generalisability (external validity) of the study results	24-25
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	26

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Paper III and supplemental material

Øvrebø B, Halkjelsvik TB, Meisfjord JR, Bere E, Hart RK. The effects of an abrupt increase in taxes on candy and soda in Norway: an observational study of retail sales. Int J Behav Nutr Phys Act. 2020 Sep 14;17(1):115.

Øvrebø et al. International Journal of Behavioral Nutrition and Physical Activity (2020) 17:115
https://doi.org/10.1186/s12966-020-01017-3

International Journal of Behavioral Nutrition and Physical Activity

RESEARCH **Open Access**

The effects of an abrupt increase in taxes on candy and soda in Norway: an observational study of retail sales

Bente Øvrebø[1,2,3*], Torleif B. Halkjelsvik[2,4], Jørgen R. Meisfjord[3], Elling Bere[1,2,3] and Rannveig K. Hart[2,3]

Abstract

Background: Fiscal policies are used to promote a healthier diet; however, there is still a call for real-world evaluations of taxes on unhealthy foods and beverages. We aimed to evaluate the effect of an abrupt increase, of respectively 80 and 40%, in the excising Norwegian taxes on candy and beverages on volume sales of candy and soda. We expected sales to fall.

Methods: We analyzed electronic point of sale data covering approximately 98% of volume sales of grocery stores in Norway. In two pre-registered models with weekly (log-)sales of taxed candy and soda from 3884 individual stores, we modeled the difference between the jump (discontinuity) in the trend around the time of the increase in taxes and the corresponding jump in the trend in a control season from the previous years (Model 1). In addition, we modeled the difference between the intervention and the control season in their changes in average sales (Model 2).

Results: Model 1 showed a 6.1% (one-sided 95% CI: not applicable (NA), 23.4, *p*-value = 0.26) increase and a − 3.9% (95% CI: NA, 4.9, p-value = 0.23) reduction in the differences in the jump in the trends, for candy and soda, respectively. The second model showed a relative decrease of − 4.9% (95% CI: NA, 1.0, *p*-value = 0.08) in the average sales of candy and an increase of 1.5% (95% CI: NA, 5.0, p-value = 0.24) in sales of soda. Supplementary analyses suggested that the results were sensitive to clustering on the time dimension.

Conclusions: When using two different quasi-experimental designs to model changes in volume sales of taxed candy and soda, we were not able to detect reductions in sales that coincided with an increase in the taxes. Variation across time makes it difficult to detect potentially small changes in sales even when using an entire country's worth of sales data on the level of individual stores. We speculate that the tax increases were too modest to affect the prices to alter sales sufficiently.

Keywords: Public health tax, Sugary drink tax, SSB-tax, Retail sales, Sin tax, Quasi-experiment

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Background

The prevalence of overweight and obesity is a burden worldwide [1]. Overweight and obesity are associated with excessive intake of energy-dense and nutrient-poor foods [2], which may lead to increased risk of morbidity and mortality and other negative consequences affecting the individual and society in general (e.g., financial strain) [3–5]. To promote a healthier diet and tackle obesity and non-communicable diseases, the World Health Organization recommends the use of fiscal policies [6].

Historically, taxes on unhealthy products have been motivated by revenues, but lately, several countries have implemented taxes that aim to shift consumer consumption towards a healthier diet [7], with taxes on sugar-sweetened beverages (SSBs) being the most common.

A systematic review and meta-analysis evaluating the prospective impact of food pricing on dietary consumption supports taxation as a method to reduce the intake of unhealthy foods and beverages [8]. Furthermore, taxation of SSBs has been reported to lower sales of SSBs with the potential to reduce energy and sugar intake [9]. However, a large proportion of studies on the effect of taxes on unhealthy foods and beverages are modeling or simulation studies, few are based on real-world evaluations [9, 10]. Nonetheless, a recent systematic review and meta-analysis using only real-world evaluations of SSB-taxes reported an average decline in unhealthy beverage purchases and dietary intake of 10% with a SSB-tax of 10% [11]. However, the results were strongly heterogeneous across study contexts and tax designs.

Compared to taxes on beverages, fewer countries have implemented and evaluated taxes on unhealthy foods. Mexico reported a 5.3% reduction in purchases of taxed foods after implementing an 8% tax on energy-dense nutrient-poor foods [12], whereas Hungary with a public health tax [13] and Denmark with a tax on saturated fat have reported smaller effects [14]. There is still a need for real-world evaluations of taxes on foods and beverages, especially taxes on unhealthy foods, to understand their effects in different contexts [10, 11, 15].

In November 2017, Norwegian budget negotiations led to an abrupt 80% increase in the tax on chocolate and sugar products, from 20.19 NOK (2.09 EUR) per kg to 36.92 NOK (3.82 EUR) per kg; and a 40% increase in the tax on non-alcoholic beverages, from 3.34 NOK (0.35 EUR) per liter to 4.75 NOK (0.49 EUR) per liter [16]. Both increases were implemented on January 1st, 2018. Although the taxes were increased mainly to create revenues, the potential public health benefits were emphasized by the government. With the abrupt increase in the taxes, a natural experiment setting emerged.

This study aimed to identify the effect of the abrupt increases in the existing Norwegian taxes on chocolate and sugar products and non-alcoholic beverages on the sales of these products. We expected the sales of taxed products to fall; thus, our hypotheses were directional.

Methods

Study design

We evaluated the potential changes in sales during an intervention season, representing the periods before and after the abrupt increase in taxes on January 1st, 2018 (weeks 30–52 in 2017 and 1–23 in 2018), against the changes in sales during a control season (weeks 30–52 in 2016 and 1–23 in 2017). To avoid the high variability in sales during Christmas and the subsequent weeks, we excluded four weeks on each side of the cutoff (January 1st) in each season. The weeks included in the main analysis are presented in Figure S1 (see Supplementary Figure S1, Additional file 1). The outcome variables were weekly volume sales of candy and soda covered by the taxes. The effects were estimated by two types of quasi-experimental designs. In Model 1 (difference-in-discontinuity), the (geometric) average sales over time were modeled flexibly with splines before and after January 1st (excluding the window of eight weeks) and allowed for different slopes in the control and intervention seasons. The effect estimate in Model 1 represents the difference between the two seasons in the breaks (jumps) of their trends before and after the time of the intervention. In Model 2, time was modeled as fixed effects per week number across the two seasons, and the effect estimate represents the difference between seasons in changes of the (geometric) average sales from the period before to after January 1st.

Data and setting

We used longitudinal retail data, consisting of grocery stores sales data as registered at checkout scanners in the period June 2016 to June 2018 from the four largest chains in Norway, collected by the Nielsen Company Norway. Data consisted of sales in value (NOK) and volume, aggregated by product category, store, and week. When compared against the official retail sales from Statistics Norway [17], the total data set covers about 98% of the annual sales in Norwegian grocery stores [18]. This is an approximate estimate of the proportion of sales, as definitions of a grocery store may vary.

The taxes do not differentiate between sugar or artificial sweetener content. Thus, irrespective of the type of sweetener, we formed two groups of taxed products that served as our primary outcomes: candy and soda. We excluded seasonal products, products that are not typically associated with candy (marzipan, energy tablets, etc.), and bulk candy (not provided in volume sales). The taxed candy product group consisted of the following subcategories: pastilles, other sugary products, bubblegum, sweets, caramels, chocolate (bars, figures, boxes, etc.) and licorice. In the soda product category, we included all subcategories of prepared soda with added sugars and artificial sweeteners. For each grocery store, we summed up the weekly volume sales within each of the two product groups, candy in kg and soda in liter, and used the natural log of these sums in the analyses. Thus, the analyses were based on the aggregated volume sales of various product groups, not their nutritional content (for which data was not available).

Statistical methods

The analyses were conducted in Stata version 15.1 software (StataCorp. 2017. *Stata Statistical Software: Release 15.* College Station, TX: StataCorp LLC). Details on the data preparation and statistical models are described in the pre-registered analysis plan available online (https://osf.io/pz4eg/) [19]. For each of the product groups (candy and soda), we ran two different models: Model 1 with splines and Model 2 with week number as fixed effects. Model 1 was an ordinary least squares regression with sales in log-volume as the outcome:

$$\begin{aligned}\ln(y)_{i,t} = a_{shop} + \beta_1\left(X_{season,i,t} * X_{dur \geq 0i,t}\right) \\ + \beta_2 X_{season,i,t} + \beta_3 X_{dur \geq 0i,t} + \beta_4 X_{contr} \\ + \gamma f\left(X_{dur,i,t}\right) + \delta f\left(X_{dur,i,t} * X_{season,i,t}\right) + e_{i,t}.\end{aligned}$$

β_1 is the parameter of interest (tax effect) and captures the difference between the discontinuity in the intervention and control season, comparing the jump from late November to early February (a local effect). β_2 captures differences in the level between intervention and control season. β_3 captures the shared jump from late November to early February across the intervention and control season. β_4 is a vector of controls, including dummies for Halloween and Easter, and the value of sales of non-edible products (an exogenous proxy for total sale). a_{shop} captures fixed effects at the shop level. We modeled time trends by restricted cubic splines using the *mkspline* function in Stata with a total of three knots; one before the cutoff (week number 30), one at the cutoff (week number 5) and one after the cutoff (week number 23). γ captures shared time trends (the splines), and δ captures how the intervention season deviates from this trend.

Model 2 modeled time by fixed effects of week number:

$$\begin{aligned}\ln(y)_{i,t} = a_{week} + a_{shop} + \beta_1\left(X_{season,i,t} * X_{dur \geq 0i,t}\right) \\ + \beta_2\left(X_{season,i,t}\right) + \beta_4 X_{contr} + e_{i,t}\end{aligned}$$

Fixed effects at the week number level (a_{week}) replaced joint and separate trend modeling. We controlled for Easter and a proxy of total sales (β_4), as described above. Halloween fell on the same week number and was thus not included because Model 2 includes fixed effects of week number. As there are only two seasons, the model resembles an interrupted time series design (the season dummy captures the linear time trend), but it is parameterized as a difference-in-difference model. While Model 1 captured the local change around the cutoff, accounting for trends within seasons, Model 2 gave the difference between the intervention and control season in their average change from before to after the cutoff.

To account for dependencies (e.g., autocorrelation) within geography and time, respectively, we estimated robust standard errors with two-way clustering on time and at the level of municipalities using the Stata user-written function *reghdfe* [20]. As we were only interested in the potential fall in sales, we report one-sided 95% CIs.

We ran several sensitivity tests, as described in the results section. Further, in the descriptive analyses of changes in price, we calculated the price per volume for each subcategory within the two product groups and reported the means of these subcategories for taxed candy and soda, respectively.

Ethics

The study does not qualify as human participant research or medical research. No ethical approval was needed according to national legislation.

Results

Sales data from 3884 stores were used in the analysis. Descriptive mean weekly sales of taxed candy and soda in the control and intervention season are presented in Fig. 1. The figure indicates similar trends in sales with an increase in sales in the weeks before week 52 and with a drop in sales from week 1. After week 1, the sales increase in both product groups.

Descriptive results of weekly volume sales for both product groups by each season are presented in Table 1. The upper panel shows the average sales per week before and after January 1st for the full seasons (week 27 to 52 and week 1 to 26 the following year), and the lower panel shows the average weekly sales for the seasons used in the main analyses (excluding seven weeks during the summer and excluding an eight-week window centered on January 1st).

Model 1 (estimating the local effect) yielded a 6.1% increased volume sale of taxed candy in the intervention season compared to the control season, and a reduction in sales of soda corresponding to a difference of − 3.9% (Table 2). These numbers represent the differences in the estimated jumps in the trends, as illustrated in Fig. 2. As one coefficient was in the opposite direction of our predictions, and the other yielded a one-sided p-value of 0.23, the results were inconclusive.

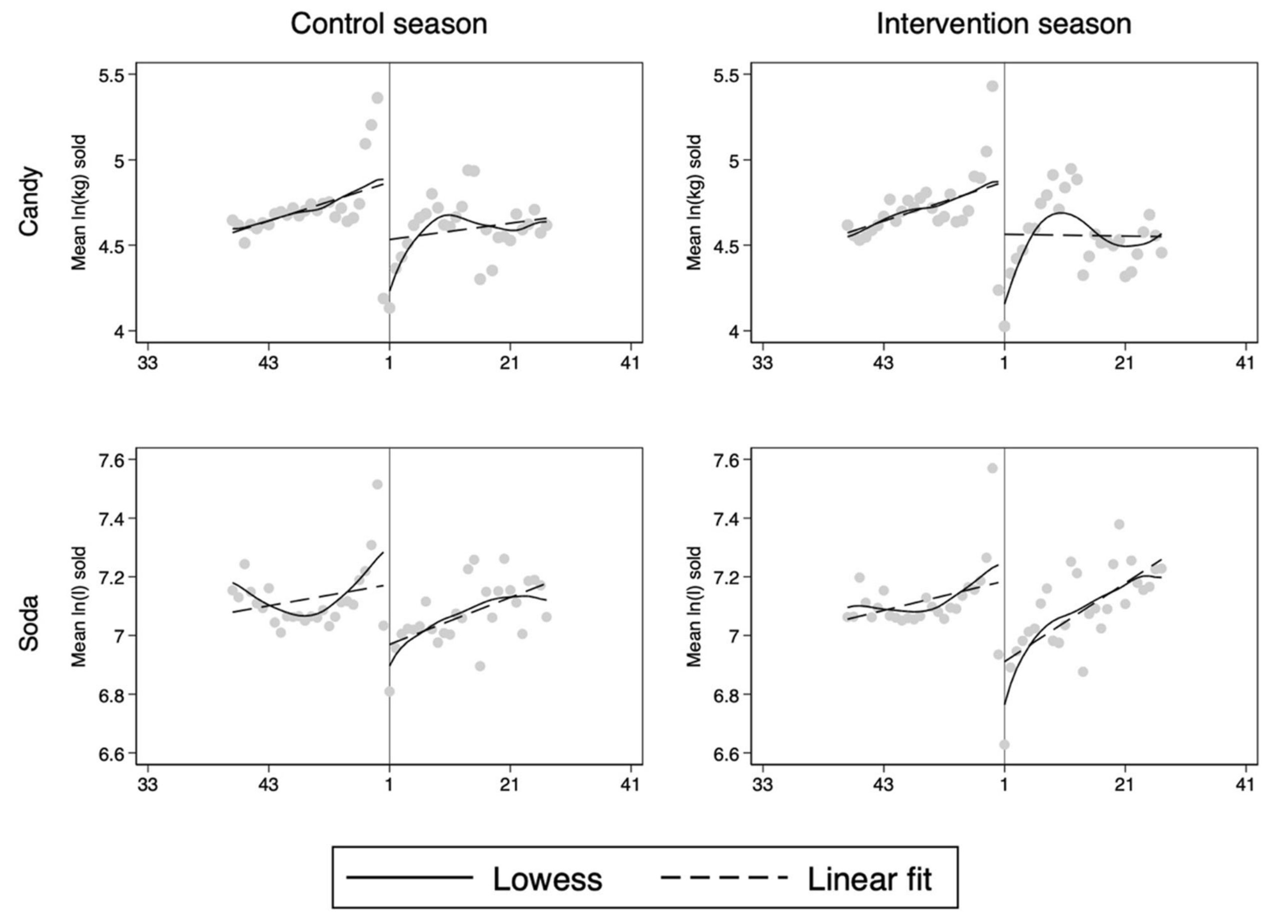

Fig. 1 Mean ln (volume) weekly sales of taxed candy (top) and taxed soda (bottom). X-axis show week number of the year. Lowess and linear fits are for illustrative purposes

Model 2 estimated the difference in changes between the average sales before and after the cutoff (rather than the local jump around the cutoff). Analysis with Model 2 revealed a reduction in sales of candy corresponding to a difference of − 4.9% when comparing the intervention season to the control season (one-sided p-value = 0.08).

Table 1 Descriptive mean (±SD) weekly store volume sales of taxed candy and taxed soda

	Taxed candy (kg)		**Taxed soda (liter)**	
	Control	**Intervention**	**Control**	**Intervention**
Complete seasons				
Pre	165 (62)	162 (52)	1882 (333)	1864 (370)
Post	143 (31)	140 (39)	1790 (210)	1812 (266)
Change	- 21 (−13.0%)	- 22 (−13.7%)	- 92 (−4.9%)	- 52 (−2.8%)
Seasons as in analyses				
Pre	148 (11)	152 (14)	1778 (116)	1788 (152)
Post	150 (31)	148 (42)	1818 (210)	1873 (238)
Change	2 (1.1%)	- 4 (−2.6%)	40 (2.3%)	85 (4.8%)

Pre/post signifies pre or post the cutoff (January 1st). *SD* Standard deviation

The analysis of soda yielded a 1.5% increase in sales, contrary to our prediction (see Table 2). The coefficients of the two analyses using Model 2 were in the opposite direction of the local model (Model 1). A table that includes all regression coefficients in the main analyses is presented in Supplementary Table S2 in Additional file 1.

Due to the null results of our main analyses, we did not analyze potential substitute products and we did not emphasize one model over the other, as described in the preregistration [19].

Supplementary analyses

As it is likely that the effect of the taxes varies with cross-border shopping possibilities, we conducted a subsample analysis excluding municipalities categorized as high cross-border shopping municipalities (see Supplementary Text S3, Additional file 1). Results were not different from the main analyses (Supplementary Text S4 and Table S5, Additional file 1).

Table 2 Exponentiated regression coefficients of the tax effect for the main models

	Candy		Soda	
	Model 1 (local)	**Model 2 (average)**	**Model 1 (local)**	**Model 2 (average)**
Tax effect	1.061	0.951	0.961	1.015
One-sided 95% CI	[NA, 1.234]	[NA, 1.010]	[NA, 1.049]	[NA, 1.050]
One-tailed *p*-value	0.26	0.08	0.23	0.24

CI Confidence intervals. *NA* Not applicable due to one-sided CIs

To evaluate robustness in terms of the choice of periods, we excluded an additional two weeks on each side of the cutoff in each season, resulting in the exclusion of twelve weeks per season. Analyses of these data gave similar results as the main analyses, except in Model 1 for taxed candy, which showed an estimated local increase in sales of 16% in the intervention season (see Supplementary Table S6, Additional file 1).

In addition to the above pre-registered sensitivity analyses, we ran analyses based on Model 2, where the changes in the intervention season were compared against the average changes of all previous seasons for which we were able to obtain reliable data (2012–2017, five seasons). The analysis yielded coefficients corresponding to a – 3.9% one-sided 95% CI [NA, – 0.1] reduction in sales of candy (one-sided *p*-value = 0.05) and a 5.5% [NA, 9.3] increase in soda sales, one-sided p-value = 1.0, see Supplementary Table S7, Additional file 1.

Factors that change sales differentially in the control and treatment seasons (e.g., if the weather was warmer in the second part of the control season) could confound our results. Such changes would also affect product groups similar to the taxed products and can be netted out in a triple difference (DiDiD) design. To estimate DiDiD models, we included observations of sales of similar, non-taxed products into our data sets, comparing candy to snacks and soda to bottled water. The DiDiD

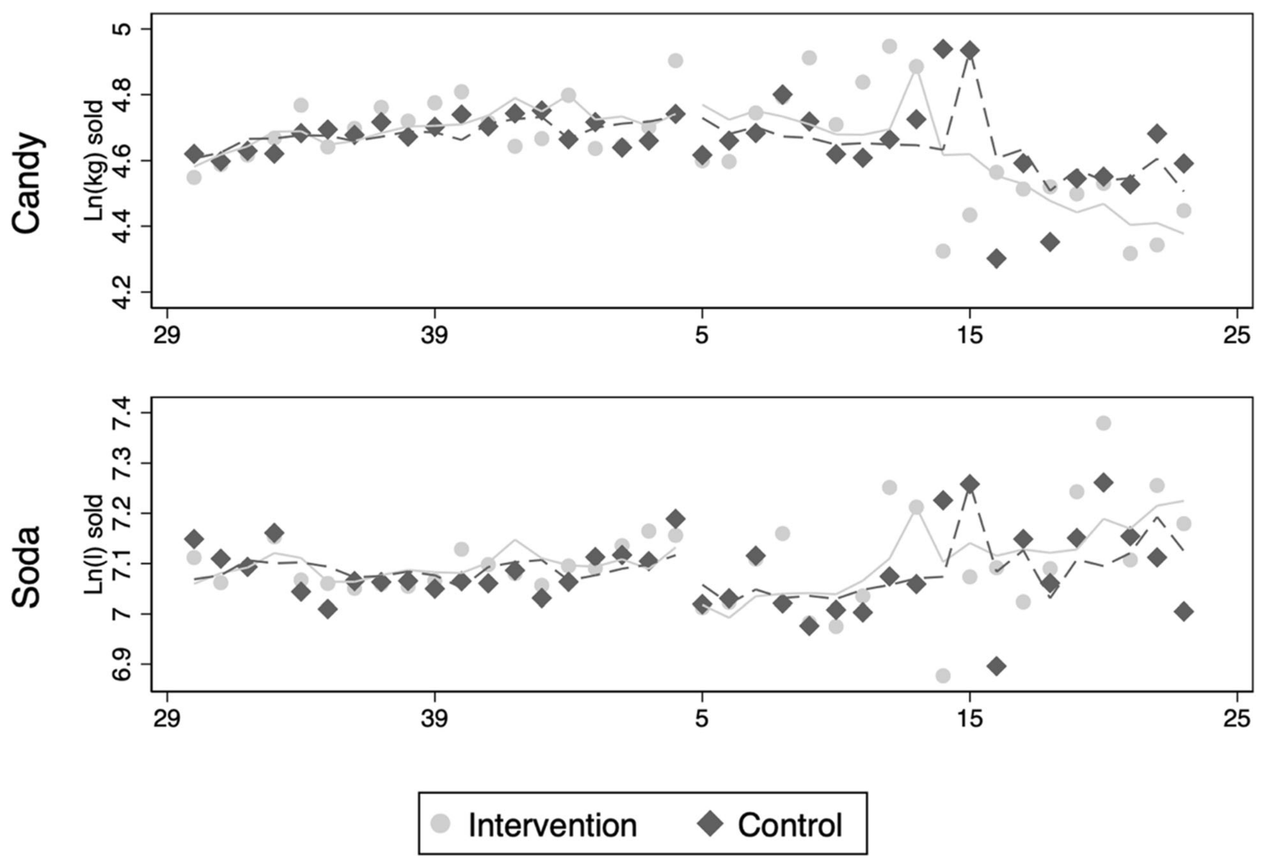

Fig. 2 Sales of taxed candy (top) and taxed soda (bottom). Figures show intervention season (light grey line = predicted values) and control season (dashed dark line = predicted values) from Model 1. Dots represent weekly mean observations. X-axis show week number of the year

effect estimate from this analysis shows how a taxed product group deviates from a control product group in terms of differences between the pre-post change in the intervention season and the pre-post change in the control season. These analyses showed an estimated − 7.2% [NA, 0.5] (p-value = 0.06) reduction for candy and 0.8% [NA, 17.3] (p-value = 0.47) increase for soda (See Supplementary Table S8, Additional file 1).

To explore how clustering on time influenced the uncertainty of the estimates in the main models, we inspected CIs and p-values based on standard errors that only accounted for clustering on municipalities (not on time as in the main analyses). This reduced the uncertainty substantially (e.g., Model 2 for candy gave 0.951 [NA, 0.959], p-value < 0.001), and suggests that the high level of uncertainty in the estimates is mainly driven by dependencies within time (e.g., co-movements in sales across the stores).

Impact on prices

When hypothesizing a fall in sales, we presumed that the prices on taxed products would be higher after the intervention (the tax increases). The volume price of taxed candy increased 5.8 percentage points more in the intervention season in comparison to the control season, and the same figure for taxed soda was 8.0 percentage points (see Table 3).

Discussion

In the context of an abrupt increase in taxes on candy and soda implemented January 1st, 2018, in Norway, we assessed the differences between the season of the intervention and a control season in terms of changes in sales of taxed products from the periods before and after January 1st. Using two different quasi-experimental models to analyze changes in volume sales, we were not able to consistently detect reductions that coincided with the increases in the taxes. The uncertainty of the effect estimates was high, which can be attributed to high variation in sales over time (that is not captured by modeling of covariates, seasonality, and trends). There was no reliable local effect before to after the intervention, and no decline in the average sales of soda, but the reform may have had a small but meaningful effect on the average sales of candy. However, the statistical evidence is weak. The average model (Model 2) suggested a reduction of 4.9% in sales (p-value = 0.08), but the results of the local model (Model 1) was in the opposite direction. The supplementary analysis of taxed candy with additional control seasons back to 2012 yielded a reduction in sales of 3.9% (p-value = 0.05), and the analysis of candy with snacks as a control product gave a 7.2% reduction (p-value = 0.06). P-values in this range are not unexpected given the four main analyses and the twelve supplementary analyses.[1] Descriptive analyses showed that the price per volume across subcategories of candy and soda increased during the intervention season by respectively 5.8 and 8.0 percentage points beyond the changes in the control season.

Table 3 Mean (±SD) weekly volume price of taxed products with the season as in analysis (NOK)

	Taxed candy (price per kg)		Taxed soda (price per liter)	
	Control	**Intervention**	**Control**	**Intervention**
Pre	289.7 (3.8)	298.2 (6.2)	22.4 (0.4)	22.6 (0.6)
Post	296.4 (4.6)	322.3 (4.1)	21.7 (1.0)	23.7 (0.9)
Change	6.7 (2.3%)	24.1 (8.1%)	−0.7 (−3.1%)	1.1 (4.9%)

Pre/post signifies pre or post the cutoff (January 1st). *NOK* Norwegian currency (kroner). *SD* Standard deviation

The present results partly contrast with some of the past literature on the impact of taxes on unhealthy foods and beverages, especially concerning beverages. Empirical studies from Mexico and the US reveal reductions in sales or purchases of beverages after implementation of taxes on beverages, however, with varying effects [21–24]. Findings from the tax on beverages in Philadelphia in the US, indicated an overall reduction of 38% in sales of taxed beverages, despite large increases in volumes sales in bordering zip codes [24]. Furthermore, sales in Berkeley one-year post implementation of a SSB-tax declined by 9.6%; however, it increased by 6.9% in non-Berkeley stores [25]. Average weekly sales in Barbados decreased with 4.3% following implementation of a SSB-tax, compared to expected sales without a tax [21]. A study using self-scanned purchases from a panel of 6253 Mexican households reported a 6% reduction in taxed beverages after the implementation of a SSB-tax [23]. As an example of more inconclusive results, the evaluation of a French soda tax reported mixed evidence from analyses of purchase responses [26].

In comparison with some of the results on beverages, evaluations of taxes on unhealthy food products show smaller reductions or substitution effects in purchases [12–14, 27]. For example, evaluations of the tax on energy-dense foods in Mexico revealed a decrease in purchases of 5.3% on taxed foods (in 2014–2016) when compared to a period without taxes (2008–2012) [12].

In contrast to our findings, Steen and Ulsaker (2019) reported a 23% reduction in chocolate sales and an 11% reduction in soda sales when evaluating the same increases in the Norwegian tax on a smaller sample from the same data as used in the present study [28].

[1]Although our tests are not independent, the high probability of obtaining at least one p-value below 0.05 can be illustrated by assuming a true null and 16 independent tests, $1-(0.95)^{16}$, which gives a probability of 56%.

One difference between several of the studies cited above, and the present one is that we have accounted for dependencies within each time unit by calculating standard errors that are cluster-robust at the dimensions of both time and geography. To illustrate the impact of such dependencies, we ran a model without adjusting for clustering on time, and we obtained a substantial reduction in the estimated uncertainty. However, the inference in that model assumes independence among the observations between the geographical clusters, which means that unmodelled co-movement in the sales at the national or cross-regional level (due to sales promotions, weather, sports events, etc.) produce pseudo-replication. For more details on cluster-robust inference, see Cameron et al. (2006) [29] and Abadie et al. (2017) [30]. Note, however, that several studies use aggregated data for which clustering is not an issue [12, 21].

Taxing unhealthy foods and beverages have become more common, yet it is still difficult to compare effects between countries. The contexts differ in terms of initial intake levels of the taxed products, the level and design of the tax, product market, economy, and cross-border shopping. Furthermore, other uncertainties and differences related to price transmission, consumer response, and substitution patterns make comparisons challenging.

Although the meta-analysis by Teng et al. (2019) reported that the equivalent of a 10% SSB-tax was associated with an average decline in beverage purchases and dietary intake of 10%, they concluded that context and tax design might be just as important as the tax level in designing SSB-taxes for maximum impact [11]. Other studies suggest that for taxes to affect consumption, taxes need to increase prices for consumers with 20% or more [6, 10], which is substantially more than our estimated differences from pre to post tax of 5.8 and 8.0 percentage points for candy and soda respectively.

The increase in the taxes should have made an 80-g chocolate bar increase with about 1.5 NOK (0.14 EUR) which includes the value added tax of 15%, and a 0.5-l soda should have increased with about 0.8 NOK (0.08 EUR). The absolute price of the products varies substantially between periods, different types of products, and brands. The absolute change in price for the taxed products is unknown as the stores set the price on products, whereas the taxes are levied producers of the products. Although we reported the changes in price per volume, we do not have access to details about differences in sales between brands. Therefore, our estimate of the changes in price may not accurately reflect how much of the tax was passed on to the consumers. Furthermore, Norwegians use a small part of their income on foods and nonalcoholic beverages (about 12%) and are considered to have high purchasing power [31]. Altogether, this suggests that the tax level of unhealthy products in Norway needs to be substantially higher for the consumer to affect purchase behavior to a larger extent. Nevertheless, the taxes were mainly increased to create revenues. Thus, the increases in the taxes had the intended effect. Taxes with the aim of improving public health, need to be designed accordingly.

Strengths and limitations

This study is from a real-world setting, and our data consist of almost all annual sales in Norwegian grocery stores, which we consider as strengths. Additionally, in a study like the present one, where the choices are numerous regarding taxed product groups, comparison products, control periods, length of the intervention period, and statistical modeling, the pre-registration of methods and hypothesis is a major strength. This precludes the possibility that we have tweaked our model to obtain more interesting results or results in line with political, government, or business interests.

The differences in the signs of the coefficients between Model 1 (local effect) and Model 2 (average effect) may be attributed to the high variability in sales over time. As sales vary by weather conditions, marketing campaigns, holidays, etc., we could have obtained higher precision if we had achieved better control of variables that influence sales. The analysis that used data back to 2012 gave a more powerful test, but it also implicated seasons that were more distal to the intervention, and this data may exhibit different seasonal patterns. Furthermore, the actual impact of the tax increases on consumer prices is uncertain. It has been suggested that it can take at least 6 months until taxes are fully passed onto consumer prices [32].

In the present study, we used differences in changes as means to draw conclusions about the causal impact of the tax policy. Although we modeled the preexisting trends in sales and controlled for a proxy of total sales, we cannot control for unknown factors that selectively affect sales of the taxed product groups in the year of the intervention. This is, however, an inherent limitation of all observational studies of this kind. Furthermore, retail data from small, independent stores with foreign products are not included, nor is data from kiosks and gas stations. As taxed products are sold in these venues, we cannot exclude possible effects of the taxes in these outlets. A limitation concerning the use of retail sales data is that we cannot assess the potential impact on actual consumption for different types of consumers.

Conclusion

Our results are inconclusive, as we could not consistently detect changes in sales of taxed products after an abrupt increase in taxes on candy and soda. High variation in sales across time resulted in high uncertainty of the effect estimates, which underscores the importance of adjusting standard errors for clustering on the time dimension in policy evaluations. We speculate that the tax increases were too modest to affect the prices to alter sales sufficiently.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12966-020-01017-3.

Additional file 1: Supplementary Figure S1. Weeks included in the main analysis, excluding the weeks with high variability sales. **Supplementary Table S2.** Exponentiated regression coefficients [95% CI], main analyses. **Supplementary Text S3.** Categorization of high cross-border municipalities. **Supplementary Text S4.** Analyses excluding high cross-border municipalities. **Supplementary Table S5.** Exponentiated regression coefficients [95% CI], excluding cross-border municipalities. **Supplementary Table S6.** Exponentiated regression coefficients [95% CI], 12-week exclusion around the cutoff. **Supplementary Table S7.** Exponentiated regression coefficients [95% CI], additional control seasons. **Supplementary Table S8.** Exponentiated regression coefficients [95% CI], analyses with control products (difference-in-difference-in-differences).

Abbreviations

CI: Confidence interval; DiDiDi: Difference-in-difference-in-difference, triple difference design; EUR: Euro; NA: Not applicable; NOK: Norwegian kroner; SD: Standard deviation; SSB: Sugar-sweetened beverages

Acknowledgements

Not applicable.

Authors' contributions

RKH, TBH, and EB designed the study; JRM contributed with extensive data knowledge and data acquisition; BØ and RKH prepared the data, analyzed the data, and generated figures and tables; BØ, TBH, and RKH drafted the manuscript; and all authors made significant intellectual contributions, read, revised and approved the final version of the manuscript.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are proprietary (Nielsen Company Norway).

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

Authors have nothing to declare.

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Publisher's Note

Additional File 1

Supplementary Figure S1: Weeks included in the main analysis, excluding the weeks with high variability sales.

Supplementary Table S2: Exponentiated regression coefficients [95% CI], main analyses.

Supplementary Text S3: Categorization of high cross-border municipalities.

Supplementary Text S4: Analyses excluding high cross-border municipalities.

Supplementary Table S5: Exponentiated regression coefficients [95% CI], excluding cross-border municipalities.

Supplementary Table S6: Exponentiated regression coefficients [95% CI], 12-week exclusion around the cutoff.

Supplementary Table S7: Exponentiated regression coefficients [95% CI], additional control seasons.

Supplementary Table S8: Exponentiated regression coefficients [95% CI], analyses with control products (difference-in-difference-in-differences).

Supplementary Figure S1:

Figure S1. Weeks included in the main analysis, excluding the weeks with high variability sales.

Pre/post signifies pre or post the cut-off (January 1st). Tax increases were implemented from January 1st 2018.

	Pre																			High variability sales period								Post																		
Control season																																														
Year	**2016**																							**2017**																						
Week number	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Month	July		August					September				October				November					December				January				February					March					April				May			June
Intervention season																																														
Year	**2017**																							**2018**																						
Week number	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Month	July			August					September			October					November					December			January				February					March					April					May		June

Supplementary Table S2 - Main analyses

Table S2. Exponentiated regression coefficients [95% CI], main analyses.

	Candy		Soda	
	Model 1 (local)	Model 2 (average)	Model 1 (local)	Model 2 (average)
Tax effect	1.061	0.951	0.961	1.015
	[NA, 1.234]	[NA, 1.010]	[NA, 1.049]	[NA, 1.050]
Nonedible products	1.867***	1.865***	1.757***	1.768***
	[1.731, 2.013]	[1.735, 2.005]	[1.601, 1.929]	[1.612, 1.941]
Easter		1.456***		1.236***
		[1.256, 1.689]		[1.160, 1.317]
Easter2017	1.397***		1.218***	
	[1.310, 1.490]		[1.159, 1.279]	
Easter2018	1.329***		1.169***	
	[1.232, 1.432]		[1.105, 1.236]	
Halloween2016	0.970*		0.992	
	[0.942, 0.998]		[0.964, 1.022]	
Halloween2017	1.061		0.992	
	[0.994, 1.132]		[0.962, 1.023]	
Dur_cubic1	1.011***		1.002	
	[1.006, 1.016]		[0.996, 1.008]	
Dur_cubic2	0.986***		1.004	
	[0.979, 0.992]		[0.997, 1.012]	
Dur_cubic1_t	1.007		1.002	
	[0.998, 1.016]		[0.995, 1.009]	
Dur_cubic2_t	0.984**		1.002	
	[0.973, 0.996]		[0.992, 1.012]	
Shop FE	Yes	Yes	Yes	Yes
Week FE	No	Yes	No	Yes
Number of time clusters	76	76	76	76
Number of municipality clusters	428	428	428	428
Number of shops	3884	3884	3884	3884
Number of observations	278977	278977	278982	278982

* p <0.05, ** p <0.01, *** p <0.001. CI: Confidence interval. Dur_cubic1/Dur_cubic2: restricted cubic splines, shared time trends. Dur_cubic2_t/Dur_cubic2_t: deviation from time trend in intervention season. FE: Fixed effect. NA: Not applicable due to one-sided Ci.

Supplementary Text S3 - Categorization of high cross-border municipalities

We categorized municipalities as high cross-border in two steps: (1) Meat is one of the products mainly bought across the border[1]; thus, bacon was used as a meat indicator as this product is marketed as a border-shopping product. We calculated bacon sales before the tax increases (with 2017 data) as weekly proportions of all weekly sales (in NOK) within each store, and flagged municipalities where the proportion was under the 25-percentile (<0.9%). (2) From the municipalities flagged with low bacon sales, we categorized municipalities with easy access to cross-border shopping areas (by ferry or car). Easy access by car was estimated as <90 minutes driving distance from one of the four main cross-border areas or <60 minutes from a main ferry harbor to Denmark.

Supplementary Text S4 – Analyses excluding high cross-border municipalities

Of the 107 municipalities with the lowest bacon sales, 47 municipalities had a <90-minute drive to one of the four major cross-border shopping areas and 16 municipalities had <60 minutes driving distance to a major ferry terminal. Thus, 63 municipalities (of 428) were categorized as high cross-border municipalities. Of 3884 individual shops, 1098 were removed, thus in the analyses without high cross-border municipalities, 2786 unique shops were included. The results are shown in Supplementary Table S5.

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[1] Steen, F., Friberg, R., Ulsaker, S., *Hump-shaped Cross-price Effects and the Extensive Margin in Cross-border Shopping.* NHH Dept. of Economics Discussion Paper., 2018.

Supplementary Table S5 – Analyses excluding high cross-border municipalities

Table S5. Exponentiated regression coefficients [95% CI], excluding cross-border municipalities.

	Candy		Soda	
	Model 1 (local)	Model 2 (average)	Model 1 (local)	Model 2 (average)
Tax effect	1.054	0.967	0.970	1.015
	[NA, 1.229]	[NA, 1.026]	[NA, 1.061]	[NA, 1.051]
Nonedible products	1.869***	1.859***	1.754***	1.757***
	[1.731, 2.019]	[1.727, 2.001]	[1.593, 1.930]	[1.598, 1.931]
Easter		1.513***		1.309***
		[1.320, 1.734]		[1.246, 1.375]
Easter2017	1.428***		1.261***	
	[1.339, 1.524]		[1.201, 1.325]	
Easter2018	1.379***		1.235***	
	[1.278, 1.488]		[1.166, 1.307]	
Halloween2016	0.961**		0.989	
	[0.933, 0.990]		[0.959, 1.020]	
Halloween2017	1.052		0.987	
	[0.985, 1.124]		[0.957, 1.018]	
Dur_cubic1	1.009***		1.001	
	[1.004, 1.014]		[0.994, 1.007]	
Dur_cubic2	0.987***		1.006	
	[0.980, 0.994]		[0.998, 1.014]	
Dur_cubic1_t	1.006		1.002	
	[0.997, 1.016]		[0.994, 1.009]	
Dur_cubic2_t	0.986*		1.001	
	[0.975, 0.998]		[0.991, 1.011]	
Shop FE	Yes	Yes	Yes	Yes
Week FE	No	Yes	No	Yes
Number of time clusters	76	76	76	76
Number of municipality clusters	365	365	365	365
Number of shops	2786	2786	2786	2786
Number of observations	201461	201461	201466	201466

* p <0.05, ** p <0.01, *** p <0.001. CI: Confidence interval. Dur_cubic1/Dur_cubic2: Restricted cubic splines, shared time trends. Dur_cubic2_t/Dur_cubic2_t: Deviation from time trend in intervention season. FE: Fixed effect. NA: Not applicable due to one-sided CI.

Supplementary Table S6 – Analyses with an additional number of weeks excluded

Table S6. Exponentiated regression coefficients [95% CI], 12-week exclusion around the cutoff.

	Candy		Soda	
	Model 1 (local)	Model 2 (average)	Model 1 (local)	Model 2 (average)
Tax effect	1.159	0.961	0.965	1.019
	[NA, 1.323]	[NA, 1.027]	[NA, 1.071]	[NA, 1.058]
Nonedible products	1.875***	1.879***	1.769***	1.780***
	[1.736, 2.026]	[1.745, 2.023]	[1.610, 1.945]	[1.620, 1.956]
Easter		1.457***		1.237***
		[1.260, 1.686]		[1.160, 1.318]
Easter2017	1.379***		1.219***	
	[1.287, 1.479]		[1.158, 1.282]	
Easter2018	1.278***		1.175***	
	[1.178, 1.386]		[1.100, 1.255]	
Halloween2016	0.967*		1.010	
	[0.935, 0.999]		[0.976, 1.045]	
Halloween2017	1.110***		1.013	
	[1.057, 1.166]		[0.981, 1.045]	
Dur_cubic1	1.014***		0.999	
	[1.008, 1.020]		[0.992, 1.006]	
Dur_cubic2	0.981***		1.006	
	[0.972, 0.989]		[0.997, 1.016]	
Dur_cubic1_t	1.003		1.001	
	[0.994, 1.012]		[0.993, 1.009]	
Dur_cubic2_t	0.983*		1.003	
	[0.970, 0.997]		[0.991, 1.016]	
Shop FE	Yes	Yes	Yes	Yes
Week FE	No	Yes	No	Yes
Number of time clusters	68	68	68	68
Number of municipality clusters	428	428	428	428
Number of shops	3883	3883	3883	3883
Number of observations	249585	249585	249589	249589

* p <0.05, ** p <0.01, *** p <0.001. CI: Confidence interval. Dur_cubic1/Dur_cubic2: Restricted cubic splines, shared time trends. Dur_cubic2_t/Dur_cubic2_t: Deviation from time trend in intervention season. FE: Fixed effect. NA: Not applicable due to one-sided CI.

Supplementary Table S7 – Model 2 with additional control seasons

Table S7. Exponentiated regression coefficients [95% CI], additional control seasons.

	Candy	**Soda**
	Model 2 (average)	Model 2 (average)
Tax effect	0.951*	1.055
	[NA, 0.999]	[NA, 1.093]
Nonedible products	1.991***	1.883***
	[1.918, 2.068]	[1.804, 1.965]
Easter	1.386***	1.268***
	[1.203, 1.598]	[1.190, 1.350]
Intervention season	1 (reference)	1 (reference)
	[1, 1]	[1, 1]
Season 2016-2017	0.944**	0.977
	[0.911, 0.977]	[0.948, 1.006]
Season 2015-2016	0.940**	0.978
	[0.904, 0.977]	[0.945, 1.011]
Season 2014-2015	0.995	1.000
	[0.960, 1.031]	[0.968, 1.032]
Season 2013-2014	0.966	0.991
	[0.930, 1.004]	[0.961, 1.021]
Season 2012-2013	1.002	1.005
	[0.968, 1.037]	[0.976, 1.034]
Shop FE	Yes	Yes
Week FE	Yes	Yes
Number of time clusters	228	228
Number of municipality clusters	430	430
Number of shops	4797	4797
Number of observations	836841	836845

* p <0.05, ** p <0.01, *** p <0.001. CI: Confidence interval. FE: Fixed effect. NA: Not applicable due to one-sided CI.

Supplementary Table S8 – Model 2 with control products snacks and water

Table S8. Exponentiated regression coefficients [95% CI], analyses with control products (difference-in-difference-in-differences).

	Candy vs. snacks	**Soda vs. water**
	Model 2 (average)	Model 2 (average)
Tax effect	0.928	1.008
	[NA, 1.005]	[NA, 1.173]
Intervention season	1.049***	1.058
	[1.020, 1.079]	[0.974, 1.150]
Intervention season by cutoff	1.010	1.043
	[0.961, 1.063]	[0.929, 1.171]
Intervention season by product category	0.971	0.927
	[0.915, 1.030]	[0.791, 1.087]
Easter	1.316***	1.051
	[1.194, 1.452]	[0.978, 1.129]
Week FE	Yes	Yes
Shop by product category FE	Yes	Yes
Number of time clusters	76	76
Number of municipality clusters	428	428
Number of shops	7769	7767
Number of observations	557977	554742

* p <0.05, ** p <0.01, *** p <0.001. CI: Confidence interval. FE: Fixed effect. NA: Not applicable due to one-sided CI. The effect of product category is absorbed in Shop by product category FE. Tax Effect = three-way interaction between Intervention season, cutoff, and product category.

Appendix 1

Questionnaire from Fruit and Vegetables Make the Marks project, baseline 2001

[in Norwegian]

Spørreskjema om

frukt og grønt

KJÆRE ELEV!

Dette er et spørreskjema om frukt og grønnsaker.

Det er viktig at du besvarer spørsmålene så ærlig som mulig. Vi vil gjerne at du besvarer alle spørsmålene, men er det spørsmål du ikke kan eller vil svare på kan du la være.

Alle svarene er hemmelige. Det er ingen du kjenner som får vite hva du har svart. Du skal ikke skrive navnet ditt på skjemaet.

Hvordan skal du svare? I del A skal du tenke tilbake til i går, og skrive ned hva og hvor mye du spiste av forskjellige frukter, grønnsaker, juice og poteter. Her er det viktig at du følger instruksjonene til prosjektmedarbeideren som går igjennom skjemaet. I de neste delene skal du for hvert spørsmål finne det svaret som passer best for deg, og der skal du sette et kryss.

Er det noe du lurer på, kan du spørre prosjektmedarbeideren fra Universitetet i Oslo.

Det er helt frivillig å svare på disse spørsmålene, og du kan trekke deg når som helst.

TAKK FOR HJELPEN!

Knut-Inge Klepp
professor

Elling Bere
stipendiat

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1. Er du gutt eller jente?

☐ Gutt ☐ Jente

2. Abonnerer du på Skolefrukt?

☐ Ja ☐ Nei

3. Hvilken dag er det i dag?

☐ Mandag ☐ Tirsdag ☐ Onsdag ☐ Torsdag ☐ Fredag

4. Var du på skolen i går?

☐ Ja ☐ Nei

Del A

Hva spiste du i går?

Først ber vi deg om å svare på noen spørsmål om hvor mye frukt og bær, grønnsaker, juice og poteter du spiste eller drakk **i hele går**. Det er viktig at du skriver opp alt.

Dagen i går er delt opp i 5 perioder: Frokost, på skolen, etter skolen, middag og kvelds.

For hver periode skal du føre opp hvor mye frukt og bær, grønnsaker og poteter du spiste og hvor mye juice du drakk. For å skrive ned hvor mye du spiste og drakk skal du tenke på følgende:

Frukt og **bær** måles i antall (f.eks. ett eple, en banan) eller i porsjon (f.eks. en porsjon fruktsalat)

Grønnsaker måles i antall (f.eks. en gulrot) eller i porsjon (f.eks. en porsjon salat, en porsjon brokkoli)

Poteter måles i antall (f.eks. 2 poteter) eller i porsjon (f.eks. en porsjon potetstappe eller en porsjon stekte poteter)

Juice måles i antall glass (f.eks. ett glass eplejuice)

Hvis du spiste noe som ikke kan måles i antall eller i porsjoner, må du beskrive best mulig hvor mye du spiste (f.eks. 2 never bringebær, 1½ skive kålrot eller 3 ringer paprika). Hvis du er veldig usikker spør prosjektmedarbeideren eller læreren.

Tenk tilbake til i går tidlig

Frokost

1. Spiste du frokost i går tidlig?

☐ Ja ☐ Nei

2. Spiste du frukt eller bær før du begynte på skolen i går tidlig?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **frukt** og **bær** du spiste her:

3. Spiste du grønnsaker før du begynte på skolen i går tidlig?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **grønnsake**r du spiste her:

4. Drakk du juice før du begynte på skolen i går tidlig?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **juice** du drakk her:

Tenk på den tiden da du var på skolen i går

På skolen

5. Spiste du skolemat/lunsj i går?

☐ Ja ☐ Nei

6. Spiste du frukt eller bær til skolematen eller i friminuttene i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **frukt** og **bær** du spiste her:

7. Spiste du grønnsaker til skolematen eller i friminuttene i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **grønnsaker** du spiste her:

8. Drakk du juice til skolematen eller i friminuttene i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **juice** du drakk her:

Tenk tilbake til tiden etter skoletid i går, men før middag

Etter skolen

9. Spiste du frukt eller bær etter skoletid, men før middag i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **frukt** og **bær** du spiste her

10. Spiste du grønnsaker etter skoletid, men før middag i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **grønnsaker** du spiste her:

11. Drakk du juice etter skoletid, men før middag i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **juice** du drakk her:

Tenk tilbake til middagstid i går

Middag

12. Spiste du middag i går?

☐ Ja ☐ Nei

13. Spiste du potet til middag i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned i hvilken form og hvor mye **potet** du spiste her:

14. Spiste du grønnsaker til middag i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **grønnsaker** du spiste her:

15. Drakk du juice til middag i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **juice** du drakk her:

16. Spiste du frukt eller bær til middag eller som dessert i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **frukt** og **bær** du spiste her:

Tenk tilbake til etter middag i går

Kvelds

17. Spiste du kveldsmat i går kveld?

☐ Ja ☐ Nei

18. Spiste du frukt eller bær etter middag eller til kvelds i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **frukt** og **bær** du spiste her:

19. Spiste du grønnsaker etter middag eller til kvelds i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **grønnsaker** du spiste her:

20. Drakk du juice etter middag eller til kvelds i går?

☐ Ja ☐ Nei

Hvis ja, skriv ned hva slags og hvor mye **juice** du drakk her:

Del B

Dine meninger om frukt og grønnsaker

Nå kommer en rekke utsagn om frukt og grønnsaker. Hvor enig er du i de forskjellige utsagnene? Alternativene er **helt uenig**, **litt uenig**, **litt enig** eller **helt enig**. Hvis du ikke har noen mening, eller du ikke vet hva du skal svare, så krysser du av for **verken enig eller uenig**. Ikke bruk lang tid på hvert spørsmål. Her er det ikke noe svaralternativ som er riktig eller galt. Svar slik du føler passer best for deg. Ikke bry deg om at noen spørsmål kan virke litt rare.

HUSK: Kun ett kryss for hvert spørsmål!

1. Jeg spiser alltid opp grønnsakene mine til middag

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

2. Min heimkunnskapslærer synes at jeg skal spise mer frukt og grønnsaker

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

3. Det vil være lett for meg å spise mer enn 5 porsjoner frukt og grønnsaker hver dag

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

4. Hjemme har vi vanligvis frukt stående fremme i en skål

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

5. Å spise mer frukt og grønnsaker gjør at jeg føler meg mer opplagt

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

6. Det er lettere å spise søtsaker enn frukt og grønnsaker som snacks/mellommåltid

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

7. Min far spiser mye frukt og grønnsaker

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

8. Det er sannsynlig at jeg vil spise mer frukt om 3 måneder enn det jeg gjør nå

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

9. Det hender ofte at jeg finner meg frukt og grønnsaker hjemme mellom måltider

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

10. Å spise mer frukt og grønnsaker vil gjøre meg sunnere

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

11. Det er viktig for meg å være flink på skolen

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

12. Min mor spiser mye frukt og grønnsaker

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

13. Jeg ønsker å spise mer frukt og grønnsaker enn det jeg gjør nå

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

14. Det hender at jeg kutter opp frukt eller grønnsaker til meg selv som snacks

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

15. Det er viktig for meg å være sunn

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

16. Frukt og grønnsaker passer veldig godt som snacks/mellommåltid

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

17. Min heimkunnskapslærer spiser mye frukt og grønnsaker

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

18. Jeg ønsker å spise minst 5 porsjoner frukt og grønnsaker hver dag

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

19. Jeg spiser alltid frukt eller grønnsaker til skolematen

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

20. Hjemme har vi vanligvis alltid frukt og grønnsaker i kjøleskapet

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

21. Mange av mine venner, søsken og klassekamerater synes at jeg skal spise mer frukt og grønnsaker

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

22. Det ville være lett for meg å spise frukt eller grønnsaker til hvert måltid, hver dag, hvis jeg bestemte meg for å gjøre det

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

23. Hjemme har vi som regel grønnsaker til middag hver dag

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

24. Jeg spiser for lite frukt og grønnsaker

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

25. Det å spise mer frukt og grønnsaker gjør at jeg blir flinkere på skolen

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

26. Vanligvis gjør jeg det min heimkunnskapslærer synes jeg skal gjøre

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

27. Jeg vil spise mer frukt og grønnsaker enn det jeg gjør nå

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

28. Jeg har kjøpt frukt på butikken for mine egne penger

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

29. Mer frukt og grønnsaker gjør at måltidene smaker bedre

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

30. Min mor synes at jeg skal spise mer frukt og grønnsaker

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

31. Dersom jeg bestemmer meg for det, kan jeg lett spise mer frukt og grønnsaker

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

32. Jeg synes at frukt og grønnsaker er billig sammenlignet med annen mat

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

33. Jeg spiser frukt og grønnsaker til hvert måltid

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

34. Frukt er noe av det beste jeg vet

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

35. Vanligvis gjør jeg det min far synes jeg skal gjøre

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

36. Dersom jeg ønsker det, vil det være lett for meg å spise mer frukt og grønnsaker når jeg er sammen med venner enn det jeg gjør nå

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

37. Det hender at mor/far kutter opp frukt eller grønnsaker til meg som snacks

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

38. Jeg spiser nok frukt og grønnsaker

- [ ] Helt uenig
- [ ] Litt uenig
- [ ] Verken enig eller uenig
- [ ] Litt enig
- [ ] Helt enig

39. Jeg er glad i rå grønnsaker

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

40. Vanligvis gjør jeg det min mor synes jeg skal gjøre

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

41. Dersom jeg ønsker det, vil det være lett for meg å spise mer frukt og grønnsaker på skolen enn det jeg gjør nå

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

42. Hjemme får jeg lov til å spise frukt og grønnsaker når jeg vil

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

43. Jeg trenger å spise mer frukt og grønnsaker

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

44. Jeg synes at frukt og grønnsaker er dyrt

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

45. Vanligvis gjør jeg det mine venner, søsken og klassekamerater synes jeg skal gjøre

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

46. Det vil være lett for meg å spise frukt eller grønnsaker, når alle andre spiser sjokolade og annet snop på lørdagskvelder

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

47. Hjemme har vi vanligvis alltid juice stående i kjøleskapet

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

48. Spiser jeg mer frukt og grønnsaker blir jeg sjeldnere syk

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

49. Det er sannsynlig at jeg vil spise mer grønnsaker om 3 måneder enn det jeg gjør nå

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

50. Mange av mine venner, søsken og klassekamerater spiser mye frukt og grønnsaker

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

51. Dersom jeg ønsker det, vil det være lett for meg å spise mer frukt og grønnsaker hjemme enn det jeg gjør nå

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

52. Min far synes at jeg skal spise mer frukt og grønnsaker

- ☐ Helt uenig
- ☐ Litt uenig
- ☐ Verken enig eller uenig
- ☐ Litt enig
- ☐ Helt enig

Del C

Hva spiser du vanligvis?
Når du fyller ut disse spørsmålene skal du tenke på hva du vanligvis spiser/drikker. Tenk gjerne på hva du har spist/drukket de siste 3 månedene. Tenk på både hva du spiser hjemme, på skolen og i fritiden. Kryss av i den ruten du føler passer best for deg.

HUSK: Kun ett kryss for hvert spørsmål!

1. Hvor ofte spiser du potet?

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

2. Hvor ofte spiser du grønnsaker til middag?

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

3. Hvor ofte spiser du grønnsaker på brødskivene? (f.eks. agurk, tomat, paprika)

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

4. Hvor ofte spiser du andre grønnsaker?
(f.eks. gulrot til skolematen)

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

5. Hvor ofte spiser du eple, appelsin, pære og banan?

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

6. Hvor ofte spiser du annen frukt og bær?
(andre frukter og bær enn eple, appelsin, pære og banan)

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

7. Hvor ofte spiser du pommes frites?

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

8. Hvor ofte spiser du potetgull?

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

9. Hvor ofte spiser du godterier?
(sjokolade, blandet godt osv.)

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

10. Hvor ofte drikker du juice?

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

11. Hvor ofte drikker du saft?

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

12. Hvor ofte drikker du brus med sukker?

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

13. Hvor ofte drikker du brus uten sukker?

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

14. Hvor ofte drikker du vann?

- ☐ Aldri
- ☐ Sjeldnere enn 1 gang i uken
- ☐ 1 gang i uken
- ☐ 2 ganger i uken
- ☐ 3 ganger i uken
- ☐ 4 ganger i uken
- ☐ 5 ganger i uken
- ☐ 6 ganger i uken
- ☐ Hver dag
- ☐ Flere ganger hver dag

15. Hvor ofte har du med deg frukt eller grønnsaker hjemmefra på skolen?

- ☐ Hver skoledag
- ☐ 4 dager i uken
- ☐ 3 dager i uken
- ☐ 2 dager i uken
- ☐ 1 dag i uken
- ☐ Sjeldnere enn en dag i uken
- ☐ Aldri
- ☐ Vet ikke

16. Hvor ofte spiser du frukt og grønnsaker på skolen?

- ☐ Hver skoledag
- ☐ 4 dager i uken
- ☐ 3 dager i uken
- ☐ 2 dager i uken
- ☐ 1 dag i uken
- ☐ Sjeldnere enn en dag i uken
- ☐ Aldri
- ☐ Vet ikke

17. Hvor mange porsjoner frukt og grønnsaker tror du at en på din alder bør spise hver dag?

- ☐ Ingen
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ Mer enn 5

18. Hvor mange porsjoner frukt og grønnsaker tror du at du spiser hver dag?

- ☐ Ingen
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ Mer enn 5

Del D

Noen spørsmål om deg og ditt

1. Vennligst sett kryss ved de personene som bor hjemme hos deg. (Hvis din mor og far ikke bor sammen, svar da for det hjemmet der du bor det meste av tida.)

På dette spørsmålet kan du sette to kryss!

- ☐ Mor
- ☐ Far
- ☐ Stemor
- ☐ Stefar

HUSK: Kun ett kryss for hvert spørsmål!

2. Har du noen gang prøvd å røyke?
(Minst en sigarett)

- ☐ Ja
- ☐ Nei

3. Har du noen gang prøvd å drikke alkohol?
(Det vil si øl, vin eller brennevin som f.eks. sprit, whisky eller lignende)

- ☐ Ja
- ☐ Nei
- ☐ Vet ikke

4. Hvordan liker du deg på skolen akkurat nå for tiden?

- ☐ Liker meg veldig godt
- ☐ Liker meg ganske godt
- ☐ Liker meg ikke særlig godt
- ☐ Liker meg ikke i det hele tatt

5. Utenom skoletid: Hvor mange timer per dag pleier du å se på TV og/eller sitte foran PC'en?

- ☐ Ingen
- ☐ Mindre enn en ½ time om dagen
- ☐ ½ - 1 time
- ☐ 2 - 3 timer
- ☐ 4 timer
- ☐ Mer enn 4 timer

6. Utenom skoletid: Hvor mange GANGER i uken driver du idrett, eller mosjonerer du så mye at du blir andpusten og/eller svett?

- ☐ Hver dag
- ☐ 4 - 6 ganger i uken
- ☐ 2 - 3 ganger i uken
- ☐ En gang i uken
- ☐ En gang i måneden
- ☐ Mindre enn en gang i måneden
- ☐ Aldri

7. Prøver du å slanke deg?

- ☐ Nei, vekten min er passe
- ☐ Nei, men jeg trenger å slanke meg
- ☐ Ja

8. Er du allergisk mot frukt eller grønnsaker?

- ☐ Nei
- ☐ Usikker/vet ikke
- ☐ Ja, men bare mot noen få sorter
- ☐ Ja, mot flere sorter

Hvis ja, skriv her hva du er allergisk mot:

Del E

Kryss av for om disse påstandene er riktige eller feil

HUSK: Kun ett kryss for hvert spørsmål!

1. En agurkskive på brødet teller som en porsjon frukt og grønnsaker

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

2. Frukt og grønnsaker beskytter mot astma og allergier

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

3. Frukt og grønnsaker kan forhindre at noen får kreft

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

4. Eplejuice er tilsatt sukker

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

5. "5 om dagen" betyr at jeg bør spise 5 måltider om dagen

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

6. Frukt og grønnsaker beskytter mot hjerte og kar sykdommer

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

7. Frukt og grønnsaker inneholder mye antioksidanter

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

8. Antioksidanter er stoffer som skader kroppen

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

9. Norske 6. og 7. klassinger spiser like mye frukt og grønnsaker som 6. og 7. klassinger i Sør-Europa

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

10. Eplenektar er tilsatt sukker

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

11. Frukt og grønnsaker inneholder ikke fiber

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

12. I Norge anbefales det at voksne spiser minst 750 gram frukt og grønnsaker hver dag

- ☐ Riktig
- ☐ Feil
- ☐ Vet ikke

Del F

Til slutt stiller vi noen spørsmål om frukt og grønnsaker på skolen

1. Hva mener du om det å få utdelt en frukt eller en grønnsak på skolen hver dag?

- [ ] Det er veldig bra
- [ ] Det er bra
- [ ] Jeg har ikke noen mening om det
- [ ] Det er en dårlig ordning

2. Tror du at du, etter dette skoleåret, spiser mer frukt og grønnsaker enn før?

- [ ] Ja, mye mer
- [ ] Ja, noe mer
- [ ] Nei
- [ ] Vet ikke

De siste spørsmålene skal bare besvares av de som har hatt heimkunnskap dette skoleåret

3. Hva synes du om faget heimkunnskap?

- [ ] Veldig bra
- [ ] Bra
- [ ] Mindre bra
- [ ] Dårlig

4. Hva synes du om undervisningen om frukt og grønnsaker?

- [ ] Veldig bra
- [ ] Bra
- [ ] Mindre bra
- [ ] Dårlig
- [ ] Hadde ikke slik undervisning

5. Synes du frukt- og grønnsaksrettene dere lagde smakte godt?

- [ ] Ja, de aller fleste rettene
- [ ] Ja, noen retter
- [ ] Nei
- [ ] Vi lagde ikke frukt og grønnsaksretter

6. Har du blitt flinkere til å lage frukt- og grønnsaksretter i løpet av dette skoleåret?

- [ ] Ja, mye flinkere
- [ ] Ja, noe flinkere
- [ ] Nei
- [ ] Vet ikke

7. Har heimkunnskapsundervisningen fått deg til å se mer positivt på frukt og grønnsaker?

- [ ] Ja, mye mer
- [ ] Ja, noe mer
- [ ] Nei
- [ ] Vet ikke

Noen av dere har fått 6 "SPIS MER - frukt og grønnsaker" nyhetsbrev dette skoleåret.

8. Har du lest disse nyhetsbrevene?

- [ ] Ja, alle
- [ ] Ja, noen
- [ ] Nei
- [ ] Har ikke fått nyhetsbrev

9. Har dere hengt opp nyhetsbrevene hjemme hos deg?

- [ ] Ja, alle
- [ ] Ja, noen
- [ ] Nei
- [ ] Har ikke fått nyhetsbrev

10. Har dere prøvd oppskrifter fra nyhetsbrevene hjemme hos deg?

- [ ] Ja, mange
- [ ] Ja, noen
- [ ] Nei, ingen
- [ ] Har ikke fått nyhetsbrev

Har du noen kommentarer eller meninger om Frukt og grønt i 6.? Da kan du skrive det på denne siden. Eller du kan tegne noe i forbindelse med frukt og grønnsaker!

13712

Appendix 2

Questionnaire from Fruit and Vegetables Make the Marks project, follow-up 2016

[in Norwegian]

Kosthold og levevaner

Kjære deltager,

Takk for at du har deltatt i våre tidligere spørreundersøkelser om kosthold og levevaner i forskningsprosjektet FVMM*. Dette spørreskjemaet er en fortsettelse av forskningsprosjektet og omhandler forbruk av, og holdninger til, forskjellige mat- og drikkevarer, hovedsakelig frukt og grønnsaker. Målet med dette forskningsprosjektet er å finne ut hvordan nordmenn kan få sunnere kosthold.

Vi har fått så mye interessante resultater at vi nå ønsker å følge deltagerne videre. Ved å svare på dette spørreskjemaet samtykker du til at vi også ved senere anledninger kan kontakte deg for nye spørreundersøkelser. Det er imidlertid ikke planlagt ny spørreundersøkelse per dags dato. Alle som jobber med dette prosjektet har taushetsplikt og all informasjon behandles konfidensielt.

Vi vil gjerne at du svarer på alle spørsmålene. Dersom det er spørsmål du ikke kan eller vil svare på så kan du la være. Det er **viktig** at du leser forklaringen for hvordan du fyller ut skjemaet nøye. Det vil ta deg ca. 10 minutter å svare på spørsmålene. Det er frivillig å delta i dette prosjektet. Datamaterialet og kontaktinformasjonen som samles inn vil bli lagret i 10 år fra innsamlingstidspunktet. Dersom du ønsker å trekke deg fra undersøkelsen er det bare å kontakte oss.

Ved å fylle ut denne undersøkelsen er du med i trekningen av 10 gavekort fra Universal Presentkort (www.presentkort.no). Hvert gavekort er på 1000 kroner.

Dersom du har spørsmål kan du kontakte oss på e-post: elling.bere@uia.no ELLER tonje.h.stea@uia.no

TUSEN TAKK FOR HJELPEN!

Elling Bere	Tonje H Stea
Professor	Førsteamanuensis

*FVMM står for Fruits and Vegetables Make the Marks. På norsk heter prosjektet Frukt og grønt i sjette. Universitetet i Agder er prosjektansvarlig.

UNIVERSITETET I AGDER

Institutt for folkehelse, idrett og ernæring

Serviceboks 422

4604 Kristiansand

Telefon: 38 14 23 29

Hva er ditt ID-nummer?

_____

Del A

Hva spiste du i går?

Dagen i går er delt opp i fire perioder: Frokost, mellom frokost og middag, middag og kvelds.

Kryss av for om du spiste de forskjellige matvarene til forskjellige tider eller ikke.

For **frukt, grønnsaker, poteter** og **juice** skal du også skrive HVA du spiste og HVOR MYE.

Under følger en beskrivelse av hvordan du skal gjøre dette.

For å skrive ned hvor mye du spiste og drakk skal du tenke på følgende:

Frukt og **bær** måles i antall (f. eks. ett eple, en banan) eller i porsjon (f. eks. en porsjon fruktsalat)
Grønnsaker måles i antall (f. eks. en gulrot) eller i porsjon (f. eks. en porsjon salat, en porsjon brokkoli)

Hvis du spiste noe som ikke kan måles i stykker, porsjoner eller antall, må du beskrive best mulig hvor mye du spiste (f. eks. 2 never bringebær, 1 1/2 skive kålrot, eller 3 ringer paprika).

Tenk tilbake til i går tidlig

Frokost

1. Spiste du frokost i går tidlig?

Ja	Nei
(1) ❑	(2) ❑

2. Spiste du frukt eller bær i går tidlig?

Ja	Nei
(1) ❑	(2) ❑

Hvis ja, skriv ned hva slags og hvor mye frukt og bær du spiste i går tidlig:

____

____

____

____

____

____

3. Spiste du grønnsaker i går tidlig?

Ja	Nei
(1) ❑	(2) ❑

Hvis ja, skriv ned hva slags og hvor mye grønnsaker du spiste i går tidlig:

____

____

____

____

____

____

Tenk på tiden mellom frokost og middag i går

Formiddag

4. Spiste du lunsj/formiddagsmat i går?

Ja	Nei
(1) ❑	(2) ❑

5. Spiste du frukt eller bær i tiden mellom frokost og middag i går?

Ja	Nei
(1) ❑	(2) ❑

Hvis ja, skriv ned hva slags og hvor mye frukt og bær du spiste i tiden mellom frokost og middag i går:

____

____

____

____

____

____

6. Spiste du grønnsaker i tiden mellom frokost og middag i går?

Ja	Nei
(1) ❑	(2) ❑

Hvis ja, skriv ned hva slags og hvor mye grønnsaker du spiste i tiden mellom frokost og middag i går:

____

____

____

____

____

____

Tilbake til middagstid i går

Middag

7. Spiste du middag i går?

Ja	Nei
(1) ❑	(2) ❑

8. Spiste du grønnsaker til middag i går?

Ja	Nei
(1) ❑	(2) ❑

Hvis ja, skriv ned hva slags og hvor mye grønnsaker du spiste til middag i går:

____

____

____

____

____

____

9. Spiste du frukt eller bær til middag eller som dessert i går?

Ja	Nei
(1) ❑	(2) ❑

Hvis ja, skriv ned hva slags og hvor mye frukt og bær du spiste til middag eller som dessert i går:

____

____

____

____

____

____

Tenk tilbake til tiden etter middag i går

Kvelds

10. Spiste du kveldsmat i går kveld?

Ja	Nei
(1) ❑	(2) ❑

11. Spiste du frukt eller bær etter middag eller til kvelds i går?

Ja	Nei
(1) ❑	(2) ❑

Hvis ja, skriv ned hva slags og hvor mye frukt og bær du spiste etter middag eller til kvelds i går:

____

____

____

____

____

____

12. Spiste du grønnsaker etter middag eller til kvelds i går?

Ja	Nei
(1) ❑	(2) ❑

Hvis ja, skriv ned hva slags og hvor mye grønnsaker du spiste etter middag eller til kvelds i går:

____

____

____

____

____

____

Del B

Dine meninger om frukt og grønnsaker

Nå kommer en rekke utsagn om frukt og grønnsaker. Hvor enig er du i de forskjellige utsagnene? Alternativene er **helt uenig**, **litt uenig**, **litt enig** eller **helt enig**. Hvis du ikke har noen mening, eller du ikke vet hva du skal svare så krysser du av for **verken enig eller uenig**.

Kun ett kryss for hvert spørsmål.

1. Hjemme har jeg/vi vanligvis frukt stående fremme i en skål

(1) ❑ Helt uenig

(2) ❑ Litt uenig

(3) ❑ Verken enig eller uenig

(4) ❑ Litt enig

(5) ❑ Helt enig

2. Frukt og grønnsaker passer veldig godt som snacks/mellommåltid

(1) ❑ Helt uenig

(2) ❑ Litt uenig

(3) ❑ Verken enig eller uenig

(4) ❑ Litt enig

(5) ❑ Helt enig

3. Hjemme har jeg/vi vanligvis alltid frukt og grønnsaker i kjøleskapet

(1) ❑ Helt uenig

(2) ❑ Litt uenig

(3) ❑ Verken enig eller uenig

(4) ❑ Litt enig

(5) ❑ Helt enig

4. Hjemme har jeg/vi som regel grønnsaker til middag hver dag

(1) ❑ Helt uenig

(2) ❑ Litt uenig

(3) ❑ Verken enig eller uenig

(4) ❑ Litt enig

(5) ❑ Helt enig

5. Mer frukt og grønnsaker gjør at måltidene smaker bedre

(1) ❑ Helt uenig

(2) ❑ Litt uenig

(3) ❑ Verken enig eller uenig

(4) ❑ Litt enig

(5) ❑ Helt enig

6. Frukt er noe av det beste jeg vet

(1) ❑ Helt uenig

(2) ❑ Litt uenig

(3) ❑ Verken enig eller uenig

(4) ❑ Litt enig

(5) ❑ Helt enig

7. Det hender at andre personer kutter opp frukt eller grønnsaker til meg som snacks

(1) ❑ Helt uenig

(2) ❑ Litt uenig

(3) ❑ Verken enig eller uenig

(4) ❑ Litt enig

(5) ❑ Helt enig

8. Jeg er glad i rå grønnsaker

(1) ❑ Helt uenig

(2) ❑ Litt uenig

(3) ❑ Verken enig eller uenig

(4) ❑ Litt enig

(5) ❑ Helt enig

9. Hjemme får jeg lov å spise frukt og grønnsaker når jeg vil

(1) ❑ Helt uenig

(2) ❑ Litt uenig

(3) ❑ Verken enig eller uenig

(4) ❑ Litt enig

(5) ❑ Helt enig

10. Hvor mange porsjoner frukt og grønnsaker tror du at du spiser hver dag?

(1) ❑ Ingen

(2) ❑ 1

(3) ❑ 2

(4) ❑ 3

(5) ❑ 4

(6) ❑ 5

(7) ❑ Mer enn 5

Del C

Hva spiser du vanligvis?

Når du fyller ut disse spørsmålene skal du tenke på hva du vanligvis spiser/drikker. Tenk gjerne på hva du har spist/drukket de siste 3 månedene. Tenk både på hva du spiser hjemme, på jobb/skole og i fritiden. Kryss av i den ruten du føler passer best for deg.

1. Hvor ofte spiser du grønnsaker til middag?

(1) ❑ Aldri

(2) ❑ Sjeldnere enn 1 gang i uken

(3) ❑ 1 gang i uken

(4) ❑ 2 ganger i uken

(5) ❑ 3 ganger i uken

(6) ❑ 4 ganger i uken

(7) ❑ 5 ganger i uken

(8) ❑ 6 ganger i uken

(9) ❑ Hver dag

(10) ❑ Flere ganger hver dag

2. Hvor ofte spiser du grønnsaker på brødskivene?

(1) ❑ Aldri

(2) ❑ Sjeldnere enn 1 gang i uken

(3) ❑ 1 gang i uken

(4) ❑ 2 ganger i uken

(5) ❑ 3 ganger i uken

(6) ❑ 4 ganger i uken

(7) ❑ 5 ganger i uken

(8) ❑ 6 ganger i uken

(9) ❑ Hver dag

(10) ❑ Flere ganger hver dag

3. Hvor ofte spiser du andre grønnsaker?

(1) ❑ Aldri

(2) ❑ Sjeldnere enn 1 gang i uken

(3) ❑ 1 gang i uken

(4) ❑ 2 ganger i uken

(5) ❑ 3 ganger i uken

(6) ❑ 4 ganger i uken

(7) ❑ 5 ganger i uken

(8) ❑ 6 ganger i uken

(9) ❑ Hver dag

(10) ❑ Flere ganger hver dag

4. Hvor ofte spiser du eple, appelsin, pære og banan?

(1) ❑ Aldri

(2) ❑ Sjeldnere enn 1 gang i uken

(3) ❑ 1 gang i uken

(4) ❑ 2 ganger i uken

(5) ❑ 3 ganger i uken

(6) ❑ 4 ganger i uken

(7) ❑ 5 ganger i uken

(8) ❑ 6 ganger i uken

(9) ❑ Hver dag

(10) ❑ Flere ganger hver dag

5. Hvor ofte spiser du annen frukt og bær (andre frukter og bær enn eple, appelsin, pære og banan)?

(1) ❑ Aldri
(2) ❑ Sjeldnere enn 1 gang i uken
(3) ❑ 1 gang i uken
(4) ❑ 2 ganger i uken
(5) ❑ 3 ganger i uken
(6) ❑ 4 ganger i uken
(7) ❑ 5 ganger i uken
(8) ❑ 6 ganger i uken
(9) ❑ Hver dag
(10) ❑ Flere ganger hver dag

6. Hvor ofte spiser du potetgull?

(1) ❑ Aldri
(2) ❑ Sjeldnere enn 1 gang i uken
(3) ❑ 1 gang i uken
(4) ❑ 2 ganger i uken
(5) ❑ 3 ganger i uken
(6) ❑ 4 ganger i uken
(7) ❑ 5 ganger i uken
(8) ❑ 6 ganger i uken
(9) ❑ Hver dag
(10) ❑ Flere ganger hver dag

7. Hvor ofte spiser du godterier (sjokolade, blandet godt osv.)?

(1) ❑ Aldri

(2) ❑ Sjeldnere enn 1 gang i uken

(3) ❑ 1 gang i uken

(4) ❑ 2 ganger i uken

(5) ❑ 3 ganger i uken

(6) ❑ 4 ganger i uken

(7) ❑ 5 ganger i uken

(8) ❑ 6 ganger i uken

(9) ❑ Hver dag

(10) ❑ Flere ganger hver dag

8. Hvor ofte drikker du brus MED sukker?

(1) ❑ Aldri

(2) ❑ Sjeldnere enn 1 gang i uken

(3) ❑ 1 gang i uken

(4) ❑ 2 ganger i uken

(5) ❑ 3 ganger i uken

(6) ❑ 4 ganger i uken

(7) ❑ 5 ganger i uken

(8) ❑ 6 ganger i uken

(9) ❑ Hver dag

(10) ❑ Flere ganger hver dag

9. Hvor ofte drikker du brus UTEN sukker?

(1) ❑ Aldri

(2) ❑ Sjeldnere enn 1 gang i uken

(3) ❑ 1 gang i uken

(4) ❑ 2 ganger i uken

(5) ❑ 3 ganger i uken

(6) ❑ 4 ganger i uken

(7) ❑ 5 ganger i uken

(8) ❑ 6 ganger i uken

(9) ❑ Hver dag

(10) ❑ Flere ganger hver dag

10. Hvor ofte har du med deg frukt og grønnsaker hjemmefra på skolen/arbeid?

(1) ❑ 5 ganger i uken eller mer

(2) ❑ 4 ganger i uken

(3) ❑ 3 ganger i uken

(4) ❑ 2 ganger i uken

(6) ❑ 1 gang i uken

(5) ❑ Sjeldnere enn 1 dag i uken

(7) ❑ Aldri

(8) ❑ Vet ikke

11. Hvor ofte spiser du frukt og grønnsaker på skolen/arbeid?

(1) ❑ 5 ganger i uken eller mer

(2) ❑ 4 ganger i uken

(3) ❑ 3 ganger i uken

(4) ❑ 2 ganger i uken

(6) ❑ 1 gang i uken

(5) ❑ Sjeldnere enn 1 dag i uken

(7) ❑ Aldri

(8) ❑ Vet ikke

Del D

Noen spørsmål om deg og ditt

1. Er du?

(1) ❑ Mann

(2) ❑ Kvinne

2. I hvilket år er du født?

______

3. Hva er din sivile status?

(1) ❑ Singel

(2) ❑ Gift

(3) ❑ Samboer

(4) ❑ Annet

4. Har du barn?

(1) ❑ Ja

(2) ❑ Nei

5. I hvilke(t) år er de(t) født?

Barn 1 _____

Barn 2 _____

Barn 3 _____

Barn 4 _____

Hva var barnets fødselsvekt (gram)?

Barn 1 _____

Barn 2 _____

Barn 3 _____

Barn 4 _____

6. Er du gravid nå?

(1) ❑ Ja

(2) ❑ Nei

7. Hvor bor du mesteparten av tiden?

(6) ❑ Eget hus/leilighet

(1) ❑ Hos foreldre/foresatte

(2) ❑ Hybel/internat

(5) ❑ Annet

8. Hva er din hovedaktivitet?

(1) ❑ Student/skoleelev

(2) ❑ Arbeid, heltid

(3) ❑ Arbeid, deltid

(4) ❑ Arbeidsledig

(5) ❑ Sykemeldt

(6) ❑ Uføretrygdet

(7) ❑ Under arbeidsavklaringspenger/rehabilitering

(8) ❑ Permisjon

(9) ❑ Hjemmeværende

(10) ❑ Annet

9. Hva var din årsinntekt for forrige år (brutto)?

______

10. Hvilken utdannelse har du? Marker høyeste fullførte utdannelse

(1) ❑ Mindre enn 10 års grunnskole

(2) ❑ Grunnskole

(3) ❑ Videregående skole (inkl. gymnas/yrkesskole)

(4) ❑ Universitet eller høgskole (inntil 4 år)

(5) ❑ Universitet eller høgskole (mer enn 4 år)

(6) ❑ Annet

11. Hvor mange bøker tror du det er hjemme hos deg/dere? (50 bøker er ca. 1 meter i bokhyllen)

(1) ❑ Ingen bøker

(2) ❑ Mindre enn 20

(3) ❑ 20 - 50

(4) ❑ 50 - 100

(5) ❑ 100 - 500

(6) ❑ 500 - 1000

(7) ❑ Mer enn 1000

12. Har du egen (Kan sette flere kryss)

(1) ❑ Sykkel

(2) ❑ El-sykkel

(3) ❑ Bil

(4) ❑ Motorsykkel, scooter eller moped

13. Hvordan kommer du deg vanligvis til skole/arbeid?

(1) ❑ Går

(2) ❑ Sykler

(3) ❑ El-sykler

(4) ❑ Med buss

(5) ❑ Med bil

(6) ❑ Med motorsykkel, scooter eller moped

14. Utenom skoletid/arbeidstid: Hvor mange timer per dag pleier du å se på TV og/eller PC/nettbrett/telefon?

(1) ❑ Ingen

(2) ❑ Mindre enn 1/2 time om dagen

(3) ❑ 1/2 - 1 time

(4) ❑ 2 - 3 timer

(5) ❑ 4 timer

(6) ❑ Mer enn 4 timer

15. Utenom skoletid/arbeidstid: Hvor mange GANGER i uken driver du idrett, eller mosjonerer du så mye at du blir andpusten og/eller svett?

(1) ❑ Hver dag

(2) ❑ 4 - 6 ganger i uken

(3) ❑ 2 - 3 ganger i uken

(4) ❑ En gang i uken

(5) ❑ En gang i måneden

(6) ❑ Mindre enn en gang i måneden

(7) ❑ Aldri

16. Hva veide du sist du veide deg?

______

17. Hvor høy var du sist du målte deg?

_____

18. Hvordan vil du beskrive din egen helse?

(1) ❑ Meget god

(2) ❑ God

(3) ❑ Verken god eller dårlig

(4) ❑ Dårlig

(5) ❑ Meget dårlig

19. Prøver du å slanke deg?

(1) ❑ Nei, vekten min er passe

(2) ❑ Nei, men jeg trenger å slanke meg

(3) ❑ Ja

20. Hvilken dag er det i dag?

(1) ❑ Mandag

(2) ❑ Tirsdag

(3) ❑ Onsdag

(4) ❑ Torsdag

(5) ❑ Fredag

(6) ❑ Lørdag

(7) ❑ Søndag

21. Hvor ofte drikker du alkohol?

(1) ❑ Aldri

(2) ❑ Sjelden

(3) ❑ Ca. 1 gang/mnd

(4) ❑ Ca. 1 gang/uke

(5) ❑ 2-3 ganger/uke

(6) ❑ 4-6 ganger/uke

(7) ❑ Daglig

22. Røyker du?

(1) ❑ Har aldri røykt

(2) ❑ Har prøvd, men røyker ikke i det hele tatt nå

(3) ❑ Har røykt fast, men har sluttet helt nå

(4) ❑ Røyker, men ikke daglig

(5) ❑ Røyker daglig

Hvis du røyker, hvor mange sigaretter røyker du per dag?

______

23. Snuser du?

(1) ❑ Har aldri snust

(2) ❑ Har prøvd, men snuser ikke i det hele tatt nå

(3) ❑ Har snust fast, men har sluttet helt nå

(4) ❑ Snuser, men ikke daglig

(5) ❑ Snuser daglig

Hvis du snuser, hvor mange poser/priser snuser du per dag?

_____

Du er nå ferdig med undersøkelsen og kan trykke avslutt.

TAKK FOR HJELPEN!

Appendix 3

Pupil form including consent from the Norwegian Childhood Growth Study 2012
(identical to forms in 2010 and 2015)

[in Norwegian]

folkehelseinstituttet

2012
Barns vekst i Norge

ELEVskjema - 2012

(Fylles ut av helsesøster)

1. Elevkode (Preutfylt barkode som inneholder; 3 siffer skolenummer, 2 siffer fylkesnummer, 4 siffer elevnummer)

2. Skole: (Preutfylt)

3. Fylke: (Preutfylt)

4. Elevens fødselsnummer: Dag / Måned / År / Personnummer

☐☐/☐☐/☐☐/☐☐☐☐☐

5. Elevens kjønn:

☐ Gutt

☐ Jente

6. Elevens for- og mellomnavn:..

Elevens etternavn:...

7. Hvordan kom eleven seg til skolen <u>i dag</u>?
(kryss av for det/de alternativet/ene eleven oppgir)

☐ Gikk eller syklet

☐ Ble kjørt i privat bil

☐ Buss/trikk eller annen off. kommunikasjon

☐ Annet som:............................

folkehelseinstituttet

Mål

Noter mål i angitt enhet med <u>en</u> desimal:

8. Vekt (kg) ☐☐,☐

9. Høyde (cm) ☐☐☐,☐

10. Livvidde (cm) ☐☐,☐

11. Beskriv klærne barnet har på under målingene:
(velg kun <u>ett</u> alternativ)

☐ Lett tøy som t-skjorte og strømpebukse/stillongs eller lignende
☐ Tykkere tøy som genser og olabukse eller lignende
☐ Annet (spesifiser) ....

12. Tidspunkt for måling:
(velg <u>ett</u> passende alternativ)

☐ kl. 08-10
☐ kl. 10-12
☐ kl. 12-14
☐ kl. 14-16

Utskrift fra barnets helsekort
☐ Ja
☐ Nei.

13. Dato for måling: Dag / Måned / År

☐☐/☐☐/☐☐

Signer for at samtykkeerklæringen fra foreldre/foresatte er mottatt.

Helsesøsters signatur:..

Appendix 4

Pupil web form from the Norwegian Youth Growth Study 2017

[in Norwegian]

UngVekst_Ungdom

Side 1

UngVekst-studien

UngVekst-studien starter i 2017. Den gjennomføres av Folkehelseinstituttet, og er basert på støtte fra Helse- og omsorgsdepartementet og Norges forskningsråd. For å få et bilde av ungdommers vekst skal vi måle høyde og vekt hos 13-åringer i oktober 2017.

Fødselsnummer *

Skriv fødselsnummer 11 sifre.

Skolenummer: *

FFxxx (FF=fylkesnummer xxx=nummer for den enkelte skole i aktuelt fylke)

Side 2

Sideskift

Vennligst registrer høyde- og vektmålinger under, samt dato for målingene.

.

13 år (8.klasse)

Dato

dd.mm.åååå

Høyde (cm)

Vekt (kg)

8 år (3.klasse)

Dato

dd.mm.åååå

Høyde (cm)

Vekt (kg)

6 år (skolestart)

Dato

dd.mm.åååå

Høyde (cm)

Vekt (kg)

4 år (4-årskontroll)

Dato

dd.mm.åååå

Høyde (cm)

Vekt (kg)

Ca. 2 år

Dato

dd.mm.åååå

Høyde (cm)

Vekt (kg)

Ca. 15 måneder

Dato

dd.mm.åååå

Høyde/lengde (cm)

Vekt (kg)

Ca. 12 måneder

Dato

dd.mm.åååå

Høyde/lengde (cm)

Vekt (kg)

Ca. 5 måneder

Dato

dd.mm.åååå

Lengde (cm)

Vekt (kg)

Ca. 3 måneder

Dato

dd.mm.åååå

Lengde (cm)

Vekt (kg)

Ca. 6 uker

Dato

dd.mm.åååå

Lengde (cm)

Vekt (kg)

Nyfødt

Dato

dd.mm.åååå

Lengde (cm)

Vekt (kg)

Takk for hjelpen!

Nettskjema v149.0

Appendix 5

School form from the Norwegian Childhood Growth Study 2012
(identical to forms in 2010 and 2015)

[in Norwegian]

2012
Barns vekst i Norge

folkehelseinstituttet

SKOLEskjema - 2012

FØRSTE SIDEN AV SKOLESKJEMA FYLLES UT AV HELSESØSTER **FØR** MÅLINGEN AV ELEVENE BEGYNNER

1. Skolekode: (skolenummer – fylkesnummer)
2. Skole:
3. Fylke:

KONTROLL AV MÅLEINSTRUMENTER – se i Metodebok

4. Noter nummeret på tilsendt plastbeholder: ☐☐☐

5. Les av hvor mye plastbeholderen fylt med vann veier på skolehelsetjenestens vekt:
(noter måleresultat i kilo med en desimal)

Vekt (kg) ☐☐ , ☐

6. Les av hvor mye **120 cm** på tilsendt målestokk (gul på bildet) **tilsvarer** på skolens høydemåler. (noter måleresultat i centimeter med en desimal)

Høyde (cm) ☐☐☐ , ☐

DENNE DELEN AV REGISTRERINGSSKJEMAET FYLLES UT AV HELSESØSTER OG EVT. REKTOR ETTER AT MÅLINGENE AV ELEVENE ER AVSLUTTET

INFORMASJON OM 3. KLASSETRINNET PÅ DIN SKOLE

7. Hvor mange elever er det i 3. klasse totalt? Gutter ☐☐ Jenter ☐☐

8. Hvor mange foresatte ga **ikke** samtykke til sitt/sine barns deltakelse? ☐☐

Er ditt inntrykk at noen av disse var aktivt imot å la sitt/sine barn delta?

Ja ☐

Nei ☐

Vet ikke ☐

Hvis ja, hvor mange? ☐☐

Eventuelle kommentarer:...

9. Hvor mange minutter per uke har elevene på **3. klassetrinnet** kroppsøving/ fysisk aktivitet dette skoleåret?

Minutter/uke ☐☐☐

10. Er det organisert helsefremmende prosjekt/er eller aktivitet/er som omfatter 3.klassetrinnet dette skoleåret (f.eks. for å fremme sunne kostvaner eller fysisk aktivitet)

Ja ☐

Nei ☐

11. Hvis "ja" - sett kryss for passende alternativ(er) samt beskriv prosjekt/aktivitet kort:

PROSJEKT / AKTIVITET:		**HVA? (beskriv kort)**
Fysisk aktivitet	☐	
Kosthold	☐	
Annet	☐	

Eventuelle kommentarer:...

12. Hvordan vurderer du/dere at skoleveien er for de fleste av elevene i **3. klasse** med tanke på å gå og/eller evt sykle til skolen? (sett kryss for passende alternativ)

☐ svært trygg

☐ trygg

☐ utrygg

☐ svært utrygg

Eventuelle kommentarer:...

....

INFORMASJON OM SKOLEMILJØET VED SKOLEN SOM HELHET

Spørsmålene som følger gjelder alle elevene ved skolen.

13. Hvordan vurderer du/dere at skolens områder er tilrettelagt for lek og fysisk aktivitet?

(sett kryss for passende alternativ)

☐ svært godt

☐ godt

☐ dårlig

☐ svært dårlig

Eventuelle kommentarer:...

....

14. Hvilke av følgende mat- og drikkevarer får elevene på skolen?
Kryss av for om elevene får det gratis eller om det kreves foreldrebetaling.

	Gratis	Foreldrebetaling
Frukt	☐	☐
Grønnsaker	☐	☐
Melk	☐	☐
Smaksatt melk	☐	☐
Yoghurt	☐	☐
Frukt-jus	☐	☐

Eventuelle kommentarer:

....

....

15. Har elevene tilgang på andre drikker i automat eller lignende, som for eksempel brus, iste, varme drikker som te, kakao eller lignende?

☐ ja

☐ nei

Eventuelle kommentarer:

....

....

16. Er det tilrettelagt for kaldt drikkevann fra drikkevannsfontener, vannbeholdere eller lignende på skolen?

☐ ja

☐ nei

Eventuelle kommentarer:

....

....

17. Serveres elevene frokost på skolen regelmessig?

☐ ja

☐ nei

18. Hvis "ja", hvor ofte? ....dager/uke

Eventuelle
kommentarer:..

....

19. Hvis "ja", er frokostservering på skolen gratis eller basert på foreldrebetaling?

☐ gratis

☐ foreldrebetaling

20. Serveres elevene lunsj på skolen regelmessig?

☐ ja

☐ nei

21. Hvis "ja", hvor ofte? ....dager/uke

Eventuelle
kommentarer:..

....

22. Hvis "ja", er lunsjservering på skolen gratis eller basert på foreldrebetaling?

☐ gratis

☐ foreldrebetaling

23. Dato for utfylling av skjemaet dag / måned / år

☐☐/☐☐/☐☐

Helsesøsters eller rektors signatur: ....

Appendix 6

School web form from the Norwegian Youth Growth Study 2017

[in Norwegian]

UngVekst_Generelt

Side 1

UngVekst-studien

Fylles kun ut én gang på vegne av klasse 8A.

Skolenummer: *

FFxxx (FF=fylkesnummer xxx=nummer for den enkelte skole i aktuelt fylke)

Hvor mange jenter er det totalt i klasse 8A?

Hvor mange gutter er det totalt i klasse 8A?

Hvor mange har samtykket i klasse 8A?

Takk for hjelpen!

Nettskjema v149.0

Appendix 7

Norwegian Youth Growth Study 2017 consent form

[in Norwegian]

SAMTYKKE TIL DELTAKELSE I UNGVEKST-STUDIEN

Jeg har lest invitasjonen og er villig til å delta i prosjektet

Som foresatt til …………………………………………………………………………………… (fullt navn)

samtykker jeg til at hun/han deltar i prosjektet.

…………………………………….. ……………………………………………………………………….

Sted og dato Foresattes signatur

……………………………………………………………………….

Foresattes navn med trykte bokstaver

…………………………………….. ……………………………………………………………………….

Sted og dato Foresattes signatur

……………………………………………………………………….

Foresattes navn med trykte bokstaver

☐ Kryss av dersom du er alene om foreldreansvaret

Navn på elevens tidligere **barneskole(r)** ……………………………………………………………………

……

Samtykket returneres til skolen i vedlagt returkonvolutt ***innen 1 uke****. Tusen takk for deltakelsen!*

folkehelseinstituttet

Appendix 8

Pre-registered analysis of Paper III

The effects of an abrupt increase in taxes on sugary products: A difference-in-discontinuity analysis of retail data. Analysis plan 28.06.19.

Øvrebø, B., Halkjelsvik, T., Bere, E., Meisfjord, J. R., & Hart, R. (2019, June 28). The effects of an abrupt increase in taxes on sugary products: A difference-in-discontinuity design. Analysis plan. Retrieved from osf.io/pz4eg

The effects of an abrupt increase in taxes on sugary products:

A difference-in-discontinuity analysis of retail data

Analysis plan 28.06.19

Bente Øvrebø[1], Elling Bere, Torleif Halkjelsvik, Jørgen Rajan Meisfjord and Rannveig K. Hart[2]

Norwegian Institute of Public Health

Introduction

The primary aim of this analysis is to identify the effect of an increase in the Norwegian taxes on chocolate and sugar products and non-alcoholic beverages on sales of taxed products. A secondary aim is to evaluate sales of potential substitutes to the taxed products, as a shift to unhealthy substitutes has been reported as a concern when implementing taxes on unhealthy food and sugar sweetened beverages. While minuscule adjustments in these taxes happens January 1st yearly, our interest lies in a large jump January 1st 2018. From January 1st 2018 there was an increase of 80 and 40% in the taxes on (1) chocolate and sugar products and (2) non-alcoholic beverages, respectively. Our analysis is based on retail data from the Nielsen company, and consists of grocery stores sales data (value, volume and number of items) as registered at the cash register and aggregated by product category, shop and week.

We aim to estimate the causal effect of the change in these taxes on sales using quasi experimental methods. The preparation of the analysis plan has been guided by preliminary analysis of a data set for the pre-reform period 2012-2016. Our preliminary models hence pertain to "placebo tests". If placebo models yield significant results, the result is biased by differences in trends or levels other than the reform we are interested in. Hence, we have constructed a model that does not yield systematically significant placebo effects, yet also retains as much precision as possible (as indicated by narrower confidence intervals).

Our methodological approach is a difference-in-discontinuity design (see e.g. Grembi et al 2016), which combines elements from the better-known difference-in-difference and regression discontinuity designs (see e.g. Angrist & Pischke 2014). In essence, this approach compares the jump

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in sales around January 1st in a "treatment year" (with a substantial tax change) to a "control year" (with a minuscule or no change).

Data preparation

Our starting point is a data set on the weekly sale on a food and drinks in detailed categories at the shop level. Shops are located in municipalities. Our unit of analysis is shop-weeks.

We construct seasons using data from two calendar years. Each season consist of week 30-52(53) in year 1 and week 1-22 in year 2. A treatment (or placebo) season is then compared to the (immediately preceding) control season. E.g., if the placebo treatment season consists of week 30-52 in 2015 and week 1-22 in 2016, the appropriate control season will be week 30-52 in 2014 and week 1-22 in 2015. Note that while weeks from the same year is included in different seasons, two weeks are never included in the same model as both treatment and control.

We construct a variable for duration in weeks, where week 1 in (the second year of) the treatment season is set to 0. The variable captures distance to 0 (i.e., the week with January 1st) for all other weeks, giving positive numbers for year 2 and negative numbers for year 1. We also construct an interaction variable between treatment season and duration to allow the effect of duration to differ between the treatment and control seasons.

Descriptive analysis show strong and unsystematic seasonal variation just around January 1st. This is plausibly linked to different food consumption around Christmas holidays, which again impact shopping patterns early in January. To avoid bias from these changes, we exclude four weeks on each side of the cutoff (week 1) in each season. This gives a "donut" of eight weeks in total, and means that week 4 (year 2) pertains to duration 0, while week 49 (48 if the year has 52 weeks) pertains to duration -1. In essence, we then compare the difference between the sales in late November and the sales in early February at the cutoff.

Food categories are coded at a very detailed level in our data set, and performing tests from each and every product would rise challenges with multiple testing. For this reason, we have formed two groups of products with tax, which serve as our primary outcomes:

1) Drinks (can be split into light drinks and sugary drinks for exploratory analysis)
2) Chocolate and edible sugar products (can be split into chocolate and other candy for exploratory analysis)

In addition, we assess effects on four substitutes (secondary outcomes):

3) Salty snacks

4) Fruit/berries
5) Water
6) Juice

Exclusion of any specific product should be motivated in significant placebo tests for this particular category. For each group, we sum the weight of (alternatively number of) items, and then take the natural log of the sum. Separate models will be estimated for each of the food groups.

We prefer to do analysis with the volume of sales as the outcome. We will then only include measures for which volume is measured precisely in the retail data. If standardization of volume is not possible for a group of products, we will use the number of items sold. Each aggregated outcome will be either measured entirely in volume or entirely in item for group aggregation to be consistent and meaningful. As a non-endogenous proxy for total sales, we will control for the value of sales of non-edible products.

It is likely that the effect of the taxes varies with cross-border shopping. We will run (subsidiary) subsample analysis separately by such access. Our starting point is a list of municipalities close to the main Swedish cross-border shopping towns based on reports from Statistics Norway (https://www.ssb.no/varehandel-og-tjenesteyting/statistikker/grensehandel/). We will also identify municipalities that has, or borders a municipality with, a busy international ferry connection. As we know meat is the most popular product for border shopping (Steen, Friberg and Ulsaker, 2018), we will also identify the quartile of municipalities that have the lowest sales of meat in NOK (adjusted by total sales of groceries in NOK). Municipalities that both have easy access to cross-border shopping (by ferry or car) and have meat sales in the lowest quartile are defined as high border shopping areas. Meat sale is measured before the change in the sugar tax.

Statistical model

Due to strong seasonal variations in consumption, and a yearly fall in sugary products after Christmas, a traditional RD would likely have identified an «effect» in placebo years. The simple RD is in other words biased by seasonal trends. Hence, we implement a difference-in-discontinuity design.

Our starting point is a log-linear OLS model with of sales as outcome:

$$\ln(y)_{i,t} = a_{shop} + \beta_1 \left(X_{season,\,i,t} * X_{dur\geq 0\; i,t}\right) + \beta_2 \left(X_{season,\,i,t}\right) + \beta_3 \left(X_{dur\geq 0\; i,t}\right) + \gamma f\left(X_{dur,\,i,t}\right) + \delta f\left(X_{dur,\,i,t} * X_{season,i,t}\right) + e_{i,t}$$

$\beta_1$is the parameter of interest (reform effect), and captures the difference between the discontinuity in the treatment and control season. Exponentiating the estimate gives the change on relative scale.

β_2 captures differences in level between treatment and control season, β_3 captures the shared jump at dur 0 across the treatment and control season. a_{shop} captures fixed effects at the shop level.

Modeling seasonal trends efficiently is crucial for both identification and precision. In the above equation, we model trends by cubic penalized splines.[3] γ captures shared time trends, and δ captures how the treatment season deviates from this trend. For further precision, we include dummy variables for events that impact purchase of sugar produce across seasons, such as Halloween and Easter. If trends for chocolate and other candy differ significantly and substantially, we will attempt to model them separately in a joint model.

An alternative specification would be a week fixed effects model:

$$\ln(y)_{i,t} = a_{week} + a_{shop} + \beta_1 \left(X_{season,\, i,t} * X_{dur\geq 0\ i,t}\right) + \beta_2 \left(X_{season,\, i,t}\right) + \beta_3 \left(X_{dur\geq 0\ i,t}\right) + e_{i,t}$$

Where fixed effects at the week level (α_{week}) replaces joint and separate trend modelling.

The decision between the fixed effects and regional trend specification will be based on the following criteria:

- Significant trend deviations (δ) (at the 5 per cent level) indicate that a season-specific trend model is to be preferred
- A trend model must further fit data well to be preferred. A simple inspection of this is to compare predicted values from the trend models to (average) observed values. A fixed effects model will be compared to a poorly fitting trend model, even if trend deviations are significant
- If the trend modelling and time fixed effects give comparable point estimates, we will prefer the specification with highest precision

Observations are clustered across time and space. We estimate robust standard errors with two way clustering at the week and municipality level using Correira's (2017) estimator.

Our starting point is the conventional significance threshold at 5 percent. If effects both primary outcomes are statistically insignificant at this level, we will consider our study to be a null finding. (This holds also in combination with statistically significant effects on secondary outcome(s).) Our hypotheses are one sided: We expect, if anything, the sales of taxed products to fall and the sales

[3] Splines are constructed using the **mkspline (…), cubic** command in Stata.

of substitutes to increase. Hence, we will perform one-sided hypothesis tests. We note that we are testing effects on two primary outcomes, and that the probability of at least one significant result at the 5 per cent level exceeds 0.05 under the null. Hence, we will make a contextual interpretation of the analyses, based on the strength of evidence against the null (i.e., the p-values), the consistency of results across product groups, and the tests of robustness.

Robustness tests

We will perform robustness tests of our final results, also in case of a null finding. We will perform placebo tests as indicated above. We will also test whether extending the number of weeks excluded around the cutoff ("donut") changes our results (we do not expect results to be robust to no exclusion around the cutoff). We will also test if results are different in municipalities with and without easy access to cross-border commerce (see above for operationalization).

Literature

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