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## Pediatric Obesity/Obesity Management

# Effect of changes to the school food environment on eating behaviours and/or body weight in children: a systematic review

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## Summary

Previous school obesity-prevention reviews have included multi-component interventions. Here, we aimed to review the evidence for the effect of isolated food environment interventions on both eating behaviours (including food purchasing) and/or body weight. Five electronic databases were searched (last updated 30 November 2013). Of the 1,002 unique papers identified, 55 reported on school food environment changes, based on a review of titles and abstracts. Thirty-seven further papers were excluded, for not meeting the inclusion criteria. The final selection consisted of 18 papers (14 United States, 4 United Kingdom). Two studies had a body mass index (BMI) outcome, 14 assessed purchasing or eating behaviours and two studies assessed both weight and behaviour. Seventeen of 18 papers reported a positive outcome on either BMI (or change in BMI) or the healthfulness of food sold or consumed. Two studies were rated as strong quality and 11 as weak. Only three studies included a control group. A school environment supportive of healthy eating is essential to combat heavy marketing of unhealthy food. Modification of the school food environment (including high-level policy changes at state or national level) can have a positive impact on eating behaviours. A need exists, however, for further high-quality studies.

**Keywords:** BMI, diet, food environment, school.

**Abbreviation:** BMI, body mass index.

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## Introduction

The prevalence of overweight and obesity among children is high in many developed countries, and increasing in developing countries (1). Between 40 and 50 million school children around the world are now classified as obese, with the prevalence highest in the Americas (2). Obese children are more likely to become obese adults (3), with obesity a significant risk factor for cardiovascular diseases, various types of cancer, type-2 diabetes, lower health-related quality of life, increased disability and premature death (4,5).

Diets characterized by excessive consumption of energy-dense, nutrient-poor foods and drinks are a key cause of weight gain (1). In contrast, the consumption of a high-quality diet with a wide variety of nutritious foods from the five main food groups (vegetables, fruits, grain [cereal] foods, lean meats/poultry/fish/eggs/nuts/seeds/legumes/beans, and milk/yoghurt/cheese) is associated with reduced morbidity and mortality (6). Poor diets become increasingly common throughout childhood (7). Numerous

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factors influence the dietary choices of individuals (8), including social, cultural and physical environments, knowledge and attitudes (9,10) as well as government policies and practices (8). Access and availability to food in the environment may also be an important influence on children's food choices (4,11).

Children have an intensive and prolonged contact with schools throughout childhood, meaning that schools are recognized as one of the best settings for wide-reaching obesity interventions (12). A large proportion of children's energy and fat intake occurs at school (13–15). The food environment in a school setting encompasses all food and drink that is made available to students and provided or supported by the school through policies, interventions and norms (16).

Globally, school food environments differ with a nationally provided school lunch programme provided in some countries (e.g. the United States, United Kingdom, Japan, France and Sweden), but not others (e.g. Australia and Canada) (17–21). The quantity and quality of foods offered, as well as the cost, availability of subsidies and presence of other 'competitive' foods in vending machines, canteens or other outlets also varies between countries. It has been suggested that making changes to the school food environment could be one of the most important ways to improve eating behaviours in children (14,22). Some governments agree, with the US congress voting in 2010 to overhaul school meals with the Healthy, Hunger-Free Kids Act (23).

The ultimate goal of most interventions targeting the school food environment is to prevent unhealthy weight gain and to reduce the prevalence of overweight and obesity. Change in body weight following a school food environment intervention can be extremely powerful evidence for its efficacy, with one previous school food and nutrition review recommending that more studies have body weight as an outcome (24). Indeed the school obesity-prevention review by Brown and Sumerbell only included studies with a weight outcome (25). Because the school food environment is only one influence among many, and because measurable changes in body weight can take considerable time, other more direct outcomes of food environment interventions are also important (e.g. food purchasing and consumption). These outcomes may be able to indicate the effectiveness of an intervention more sensitively than changes in body weight.

Many food environment interventions are implemented as part of multi-component interventions involving additional strategies (e.g. educational, promotional, teacher training) and behaviour targets (e.g. physical activity, sedentary behaviour). The impact of such interventions has been assessed in a number of recent reviews (24–27); however, it is rarely possible to evaluate the specific impact of each of the component parts. To do this requires a review of either isolated interventions (with no additional strategies or target behaviours), or multi-component interventions where it is possible to isolate the effect of specific component parts. No review focusing specifically on isolated food environment interventions has previously been undertaken.

Although a comprehensive school strategy for obesity prevention is preferable, isolated food environment interventions are important strategies in their own right as they are unlikely to be an additional burden for staff and are often both less costly and more easily implemented and scaled-up than multi-component interventions. They are also less likely to be influenced by the personal beliefs, attitudes or teaching style of school staff, and are usually implemented school-wide. With a growing body of literature reporting the effects of school-based food environment interventions, we sought to comprehensively evaluate those that have been implemented in isolation to assess the evidence for their impact on both eating behaviours and/or body weight.

## Methods

The aim of the literature search was to systematically review the evidence relating to interventions that change the school food environment, with outcomes including both food-related behaviours (purchasing, consumption) and body weight.

### Inclusion criteria

Although not their primary focus, three previous school obesity-prevention reviews did include some studies where food environment changes were assessed in isolation (24–26). The most recent of these, however, only included publications up to the end of 2007. For this reason, our literature search included studies published from 2008 onwards plus the reference lists of these three reviews. It is important to note that although the three previous reviews mentioned earlier did include and assess food environment interventions, they were not a specific target, with education interventions, multi-component interventions and interventions targeting physical activity comprising the majority of included studies. Overall, only two studies referenced in these three previous reviews (28,29) met the criteria for inclusion here. In addition, the reference lists of another 11 previous reviews identified as relevant to the school food environment were searched for relevant papers (27,30–39). Only studies reporting the results of interventions targeting the school food environment in isolation, or those that had a mechanism to evaluate the effect of food environment changes separately, were reviewed.

The school food environment was defined as all food and drink made available to students and provided or supported by the school through policy interventions or other mechanisms. School settings included primary/elementary or secondary (middle and high) schools only (not pre-school or childcare). Interventions included those in which a material change was made to the school food environment, with or without a relevant school policy directing this. Although by their nature they are able to change eating behaviours, interventions consisting of the provision of free or subsidized food (e.g. free fruit programmes (40–42) or free and subsidized school lunch and breakfast programmes (14,41) ) were excluded because they are reliant on constant financing. We were more interested in exploring the potential impact of low-cost changes that could be introduced at the school level and might have the potential to be sustainable. Studies were considered to be 'isolated' interventions where the school food environment change was the only intervention strategy used and where only eating behaviours and/or body-weight outcomes were targeted. Studies involving educational interventions or promotional strategies were therefore excluded. Outcomes considered were (i) change in weight or other anthropometric measures (body mass index [BMI] or waist circumference) and (ii) eating-related behaviours (includes both the purchasing and consumption of foods). The results are presented separately for these two outcomes. Only studies published in the English language were considered. Studies of any design and including interventions of any duration were considered to fully evaluate the available evidence. While studies were included regardless of their design, a thorough quality assessment of all included studies was undertaken (detailed later). Only studies in the peer-reviewed, published scientific literature were considered.

### Identification of studies

Given the potential for papers on this topic to be published in disciplines including education, public health, medicine, psychology and sports science, a systematic search of five electronic databases (Academic Search Complete, Global Health, Ovid MEDLINE®, PsycINFO®, SPORTDiscus™) was conducted (last updated 30 November 2013). The search strategy included a search for the following terms in either title or abstract: *Food Environment*: ('food environment*' or 'canteen*' or 'tuckshop' or 'cafeteria' or 'vending machine*' or 'lunch*' or 'school meal*'); AND *Eating Behaviour*: ('eating behaviour*' or 'food intake' or 'weight' or 'BMI' or 'body mass index' or 'obesity' or 'overweight' or 'dietary intake' or 'diet'); AND *Location*: ('school' or 'secondary school' or college); AND *Population*: ('child*' or 'teen*' or 'student*' or 'adolescent*'). Reference lists of relevant papers and all previous reviews relating to the school food environment were also searched. The initial search for relevant papers was conducted by one author (CED), with all potentially relevant papers then read in detail by two authors (CED, SKL) to determine eligibility for inclusion. Where doubt existed, all authors were consulted and a group decision was made. Details of each study (sample, design, intervention, outcomes) were extracted by one author (CED) and checked by another author (AJC).

### Analysis

A systematic review was conducted. A formal meta-analysis was not possible because of heterogeneity in the study design, intervention type and outcomes assessed.

### Quality assessment

The quality assessment tool for quantitative studies from the Effective Public Health Practice Project (EPHPP) (43) was used to systematically assess study quality. For each study, ratings of strong (1), moderate (2) or weak (3) were given for each of the following six categories: (i) selection bias; (ii) study design; (iii) confounders; (iv) blinding; (v) data collection methods and (vi) withdrawals and dropouts. As only a single randomized trial was included, the EPHPP tool was modified by the replacement of questions in the study design section asking about randomization with a question asking if a control group was included (see Appendix S1 for precise questions used). A full quality assessment for each study was conducted separately by two authors. The answers of each auditor to the 12 included questions were compared, with the assessors agreeing in 80% of cases. For each of the six categories mentioned earlier, a rating of weak, moderate or strong was assigned by each auditor. These ratings were based on pre-specified criteria from the EPHPP tool (see Appendix S1 for details). Global study quality was assessed in two ways. Firstly, a rating of strong (none of the six categories rated as 'weak'), moderate (one out of six 'weak' ratings) or weak (two or more out of six 'weak' ratings) was calculated for each study. Secondly, a final score out of 18 (the sum of the six categories, where higher scores equals higher quality) was given to each study. Where the auditors disagreed on a categorization, an average of the two scores was taken (i.e. if one auditor scored a category strong [3] and the other moderate [2], the score given was 2.5 [out of 3] ). The final score (out of 18) was converted to a percentage for each study and the mean of all studies calculated. Where sections were not relevant to a particular study type, the percentage was calculated from the relevant scores only – e.g. questions on blinding were not relevant for a repeated cross-sectional study design.

## Results

Based on a search of the title and abstract of the 1,002 unique papers identified from the search (308 from

Academic Search Complete, 380 from Global Health, 193 from Ovid MEDLINE®, 76 from PsycINFO®, 16 from SPORTDiscus™ and 29 from other sources), a total of 55 studies reported on school food environment changes. Following a more detailed investigation of the papers, an additional 37 papers were excluded, as they did not meet the inclusion criteria. A total of 18 papers met the inclusion criteria and were assessed in this review (Figure 1). The details of the study design, intervention type and outcome are presented in Table 1.

Over half (10/18) of the included papers were published since 2010 with the majority ($n = 14$) based on studies conducted in the United States. The remaining four papers reported the results of studies conducted in the United Kingdom. The majority of studies ($n = 14$) reported changes to food or beverage availability in canteens or other food provision/sales areas such as snack bars. Of these, five also made simultaneous changes to vending machine content. It is worth noting that three of these five papers were reporting on the impact of the same intervention. Two papers reported different outcomes (44,45), while a third reported a moderation analysis to detect differences according to the socioeconomic position of the area (46). A further two studies made changes only to vending machine food availability (47,48). The final two studies not involving changes to food availability in existing canteens/snack bars or vending machines included one in which a new fruit only tuckshop was introduced (49), and one in which an analysis of state policy was conducted (with no specific in-school locations specified) (50). Most studies were conducted in middle schools ($n = 11$), with three studies in primary/elementary schools and four in high schools (one being a combined middle/high school). A large number ($n = 11$) of included studies could be described as natural experiments where they are reporting on the effect of state or national policy changes that impact the school food environment.

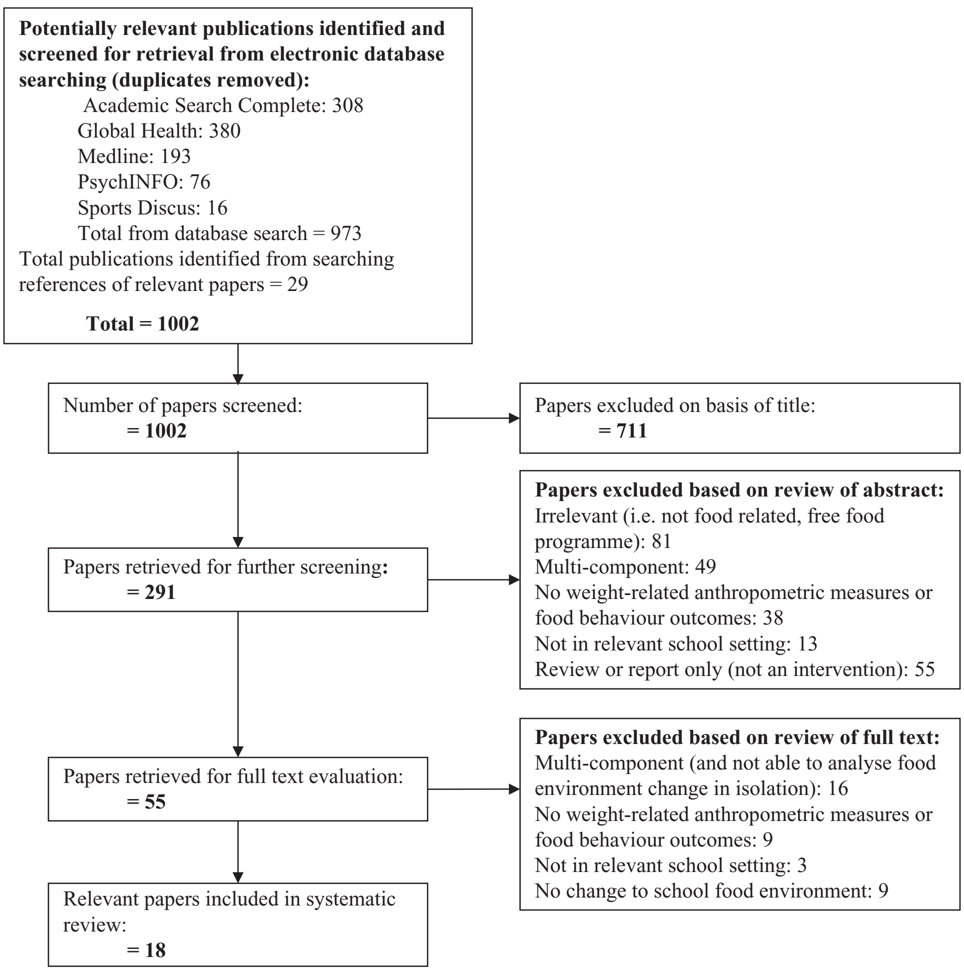


**Figure 1** Flow chart of study selection process.

 

**Table 1** Summary of included studies

| Author (year) | Country | Study design/duration/year | Participants/school | Intervention | Outcome/measurement | Results |
|---|---|---|---|---|---|---|
| Cullen *et al.* (2006) (29) | United States | Cohort followed for 2 years (1 year pre-intervention (2002/2003) and 1 year post). | Three middle schools in Houston, Texas. | Removal of chips, candy, sweetened beverages and desserts from the snack bar of all local schools. Note, vending machine numbers (83% of which were for beverages) doubled post-intervention. | Nutrient and food intake from school lunch programme, vending machines and snack bar. Sales data for specific snack products. | Intake of saturated fat, vitamin A, calcium, sodium and milk were higher and servings of vegetables, sweetened soft drinks were lower post-intervention. Sales of chips decreased, and ice cream increased while no change in sales of sweetened beverages, milk, sweets or fruit and vegetables was seen. |
| Cullen *et al.* (2007) (28) | United States | 2004 uncontrolled trial with data collected for 1 week at baseline and daily during 6 weeks of intervention. | Six middle schools in three states. | Thirteen food service policy changes to the national school lunch programme, the non-reimbursed lunch programme and vending machines. Changes included lower-fat entrees, more fresh fruits/vegetables, bottled water offered and reduced portion size of snack chips and sweetened beverages. | Change in fruits and vegetables served per student per day, and change in daily sales of beverages and chips. | Overall serves of fruits and vegetables increased from 1.1 to 1.4 serves per student per day. Sales of sweetened beverages and chips declined by 28 and 16%, respectively. Sales of water and reduced fat chips increased by 51.0 and 77.5%, respectively. |
| Cullen *et al.* (2008) (44) | United States | Data collected from convenience sample of students on two occasions – 2 years pre policy (2001/2002) and 1 year post policy (2005/2006). (Same data as Mendoza *et al.* 2010) (45). | Three middle schools (students could potentially participate multiple times during data collection, which went over the entire school year – participation was anonymous)/sixth to eighth grade. | State policy – reducing portion sizes and fat content of high-fat/-sugar foods and beverages from all school food sources (National School Lunch Program, vending machines, snack bar). Reduced frequency of serving deep-fried chips. | Student self-report change in dietary behaviours (nutrients and food groups; total and source-specific – National School Lunch Program, snack bar, vending machines, home). | An increase in milk (2.4–6.5 oz), and vegetable (0.3–0.9 serves) consumption and less sweetened beverage (5.4–1.5 oz), soft drink (4.8–0.1 oz), and snack chip (0.2–0.04 serves) consumption observed. Total energy consumed increased from 2,646 to 2,990 kj per day. Protein, fibre, vitamins A and C, calcium, and sodium also increased (all $P < 0.025$). No change in fruit or juice, high-fat vegetables, candy consumption, iron or percentage of kj from fat or saturated fat. |

**Table 1** *Continued*

| Author (year) | Country | Study design/duration/year | Participants/school | Intervention | Outcome/measurement | Results |
|---|---|---|---|---|---|---|
| Cullen *et al.* (2009) (46) | United States | Data collected from convenience sample of students on two occasions – 2 years pre policy (2001/2002) and 1 year post policy (2005/2006). | Two middle schools (students could potentially participate multiple times during data collection, which went over the entire school year – participation was anonymous), differing by percentage of students eligible for free or reduced price meals (40 and 80%)/sixth and eighth grade. | State policy – reducing portion sizes and fat content of high-fat/-sugar foods and beverages from all school food sources (National School Lunch Program, vending machines, snack bar). Reduced frequency of serving deep-fried chips. | Student self-report change in dietary behaviours (nutrients and food groups; total and source-specific – National School Lunch Program, snack bar, vending machines, home). | Analysis by school type (low and middle SEP). Increase in protein intake in middle schools only. Increase in milk consumption and decrease in soft drink consumption greater in middle SEP schools (all $P < 0.005$). No other SEP by year interactions for other food groups, nutrients analysed in Cullen *et al.* (2008) (44).. |
| French (2001) (47) | United States | Sales data records over a 12-month intervention in 1997/1998 (no control). | Vending machines in 12 secondary schools (worksites also included in study). | Introduction of low-fat snacks into vending machine with and without price reductions and promotional signage. | Sales of low-fat snacks in vending machines. | Price reduction of 25 and 50% (but not 10%) resulted in increased sales of low-fat snacks by 39 and 93%, respectively. Promotional signage had little effect on sales and average profit per machine was not impacted by the intervention. |
| Hartstein *et al.* (2008) (56) | United States | Cohort followed up in 2004 for 6 weeks, with 1 week of baseline (pre-intervention) data collected. No control schools. | Six middle schools in three states | Pilot study, 2004 intervention to reduce sizes of sweetened beverages and chips, and increasing the availability of water and reduced fat/baked chips. | Sales records of number of calories purchased per day (divided by student n to provide data per student). | Changes observed in energy density ($P = 0.01$) of food sold, but not grams of fat per item. Significant increase in percentage of kilocalories from protein ($P = 0.03$) and amount of water sold per student ($P = 0.01$), and decrease in amount of sweetened beverages ($P = 0.01$) and regular chips sold ($P = 0.03$). |
| Jensen *et al.* (2012) (48) | United States | Repeated cross-sectional, baseline (2006) and 1 year post-intervention. | 444 students/two middle schools/11 years/sixth grade. | State Beverage Policy: changed availability of unhealthy beverages in vending machines (No evidence of change presented.). | Student self-report diet intake measured height and weight. | No change in BMII (–1.19, $P > 0.05$) or unhealthy beverage consumption (–0.08, $P > 0.05$). |
| Madden *et al.* (2013) (57) | United Kingdom | Pre and post 1 week intervention (2005). | Middle school/12–16 years. $n = 180$ and $n = 198$ pre and post-intervention (students may or may not have been sampled on both occasions, but impossible to tell as participation was anonymous). | Canteen menu changes: reducing total and saturated fat and increasing fruit and vegetable consumption. | Micro and macro nutrient intake and fruit and vegetable consumption. Food measuring via observation and weighing of foods. | Fruit and vegetable intake increased from 12 to 30 g ($P < 0.001$). Total energy, fat and saturated fat intake, as well as zinc, calcium and vitamin A lower post-intervention (all $P < 0.01$). |

**Table 1** *Continued*

| Author (year) | Country | Study design/duration/year | Participants/school | Intervention | Outcome/measurement | Results |
|---|---|---|---|---|---|---|
| Mendoza *et al*, (2010) (45) | United States | Data collected from convenience sample of students on two occasions – 2 years pre policy (2001/2002) and 1 year post policy (2005/2006). (Same data as Cullen *et al.* 2008) (44). | Three middle schools (students could potentially participate multiple times during data collection, which went over the entire school year – participation was anonymous)/sixth and eighth grade. Total of 12,788 lunch records collected. | State policy – reducing portion sizes and fat content of high-fat/sugar foods and beverages from all school food sources (National School Lunch Program, vending machines, snack bar). Reduced frequency of serving deep-fried chips. | Student self-report change in dietary behaviours (nutrients and food groups; total and source-specific – National School Lunch Program, snack bar, vending machines, home). | Energy density of foods consumed decreased from 2.80 to 2.17 kcal $g^{-1}$ ($P < 0.0001$). Significant differences observed for schools regardless of socioeconomic position. |
| Moore and Tapper (2008) (49) | United Kingdom | Cluster randomized effectiveness trial with schools as the unit of randomization. Measurement at baseline (1999) and one year. | 43 primary schools (measurement only in 9–11-year-olds). | Introduction of fruit tuck shops for one academic year. | Consumption of fruits and other snacks at school. | No significant change in consumption of fruit or other snacks, although in intervention schools that also had a policy of bringing fruit as snacks the intervention increased fruit consumption (i.e. children used the tuck shop where fruit but not other snacks were permitted in school). |
| Nicholas *et al.* (2013) (53) | United Kingdom | Repeated national, cross-sectional surveys 5 years prior to and 2 years after a 2009 intervention. | 80 secondary schools (schools responding = 38%) at follow-up. 15 students per day selected to participate, with 5 days of sampling per school (meaning students could potentially participate more than once). 5,969 students participated in total/10–19 years. | National food and nutrient-based standards revised in 2009 to increase access to healthier food and limit availability of less healthy foods and drinks and to ensure appropriate energy density and amounts of vitamins, minerals, fat, sugar and salt. | Nutrient content of school lunches, food choices by students. Observation and measuring of foods not consumed by students. Survey of the provision of foods in canteens. | Improvement in healthfulness of foods being provided in secondary schools since 2004 (less high-fat foods, confectionery, desserts, cakes and biscuits, non-permitted snacks, non-permitted drinks and condiments [all $P < 0.005$] ). Average student meals had lower energy, carbohydrate, sugar, fat, saturated fat, sodium, vitamin C and folate and more protein, fibre, vitamin A and calcium (all $P < 0.001$) compared with 2004. |
| Quann & Adams (2013) (58) | United States | Repeated cross-sectional design (average of 12 days observations per school) with measurement according to day of the week when flavoured milk available or not. 2009/2010. | 51 schools/elementary. | Removal of flavoured milk from canteen on all or some days, and offering only plain milk. | Observation of milk sold and milk discarded. | 26% less milk ($P < 0.01$) was sold on plain milk only days and consumption was 37.4% lower ($P < 0.001$). |

**Table 1** *Continued*

| Author (year) | Country | Study design/duration/year | Participants/school | Intervention | Outcome/measurement | Results |
|---|---|---|---|---|---|---|
| Sanchez-Vaznaugh *et al.* (2010) (51) | United States | Repeated cross-sectional/annual assessment 4 years pre and 4 years post-2004 intervention. | Middle school (fifth, seventh grades). Students from Los Angeles and the rest of California analysed separately. A total of 5,389,819 observations (average of 673,727 per year over the 8 years 2001–2008) were included in the analysis, with 763,181 from the Los Angeles school district. | Different state and Los Angeles (LA) beverage and nutrition policies: State-wide prohibition on sale of sugar beverages. Nutrition and portion size standards for beverages and foods (LA, 2004; State, 2007 – some differences). LA rules apply to all food at all schools; state rules apply to snacks and entrees in middle school and snacks in elementary school. | Measured height and weight. Weight status defined as normal or overweight/obese. z-BMI calculated. Assessment of rate of increase over time pre and post-intervention. | A statistically significant decline in the rate of increase of over weight prevalence: Mean z-BMI increased by 0.05 in both LA and California between 2001–2004. Mean z-BMI decreased by 0.02 and 0.01 between 2005–2008 in LA and California, respectively. The change in the odds of overweight/year pre and post-intervention was significantly different in fifth graders, but not seventh graders in LA, and in fifth-grade boys (but not girls) and all seventh graders in California. |
| Snelling and Kennard (2009) (54) | United States | Repeated cross-sectional study 1 year pre and one year post-2006 intervention. | Three high schools (with 4,579 students enrolled at follow-up). Note, as data collection occurred over a 4-week period – students could contribute data on multiple occasions. | National wellness policy regarding nutrition standards of foods offered, implemented in 2006. | Food availability and purchased (using sales records) according to traffic light colour (red, orange, green based on nutrient and fat/sugar content). The traffic light labelling system for all school cafeteria competitive food was in place both pre (2005) and post (2007) intervention. | Change in the proportion of food available by colour between 2005 and 2007: (green, 25–22%; yellow, 18–47%; red, 57–30%;). Change in proportion of food purchased by colour between 2005 and 2007 (green, 11–20%; yellow 6–34%; red 83–46%). |
| Spence (2013) (77) | United Kingdom | Pre and post national school lunch intervention (cross-sectional surveys in 2003/2004 and 2008200/9). | Children aged 4–7 from 12 primary schools ($n = 385$ in 2003/2004, $n = 632$ in 2008/2009). | Legislated introduction of food standards (what type of foods can and cannot be served) and nutrient standards (minimum and maximal levels) for primary school lunches in the United Kingdom. | The main outcome measures were change in mean daily intake of macro- and micronutrients in school lunches, packed lunches from home and total diet. | Post-implementation, children eating school lunches consumed a lower percentage energy from fat (mean difference between intervention effects = –1.8%, 95% CI –2.8 to –0.9) and saturated fat (–1.0%; –1.6 to –0.5) than children eating packed lunches. Children eating school lunches post-implementation consumed significantly more carbohydrate (16.4 g, 5.3–27.6), protein (3.6 g, 1.1–6.0), non-starch polysaccharides (1.5 g, 0.5–1.9), vitamin C (0.7 μg, 0.6–0.8) and folate (12.3 μg, 9.7–20.4) in their total diet than children eating packed lunches. |

**Table 1** *Continued*

| Author (year) | Country | Study design/duration/year | Participants/school | Intervention | Outcome/measurement | Results |
|---|---|---|---|---|---|---|
| Taber *et al*. (2011) (52) | United States | Cross-sectional survey in 2007, stratified by policy status between 2000 and 2006. | 90,730/14–18 years (ninth to 12th grade)/high school. | Change in state policy between 2000 and 2006 regarding prohibition of 'junk food' in different school settings (vending machines, snack bars, concession stands, parties). | Self-reported consumption of soda (not restricted to while at school) and self-reported BMII in 2007 (post-intervention only). | Reduction in soda consumption when policy directed at concession stands (0.09 fewer servings per day, 95% CI = –0.17–0.01) and parties (0.07 fewer servings per day, 95% CI = –0.13–0.00), but not vending machines, snack bars. No change in BMI associated with policy change directed at any setting. |
| Taber *et al*. (2012) (50) | United States | Cohort study, follow-up over 4 years (2003–6). | 6,300 public school students in the fifth and eighth grades. | Change in state policy on competitive foods – rated as none, weak or strong between 2003 and 2006. | Change in measured height and weight (BMI calculated), stratified according to change in policy. | Students in states with new laws had lower increases in BMII than students in states with no laws at baseline or follow-up (probability of being overweight decreased by 4.5% where new laws were 'strong', and by 2.8% where new laws were 'weak'. BMII change between 2003–6 was lower (–0.25 kg $m^{-2}$ (95% CI –0.54–0.03) in states with strong laws at baseline compared with states with no laws at baseline. |
| Wordell *et al*. (2012) (55) | United States | Cross-sectional study in 2009/10 stratified by intervention and control schools 3 years post-2007 intervention. | 2000/grades 7 and 8. | Individual school beverage and competitive foods policy. Differences between intervention and control: Intervention removed all juices and flavoured water, only milk and fruit available à la carte. Seasonal fruit and vegetable bar available. | Self-report dietary intake (food frequency questionnaire) at follow-up (3 years post-intervention). | Students from intervention schools less likely to consume pastries (OR = 0.44, $P < 0.001$) and juice (OR = 0.73, $P = 0.02$) at school and more likely to consume milk (OR = 1.24, $P = 0.04$) at home. No difference in consumption at school of milk, fruit, vegetables, sweet drinks (not defined further), chips, candy or energy drinks. |

BMI, body mass index; CI, confidence interval; OR, odds ratio; SEP, socio-economic position.

## Intervention effect

A simple analysis of the 18 papers (noting that three papers were reports of the same study) found 17 studies reporting a positive outcome on either BMI (or change in BMI) or the healthfulness of food sold or consumed. The single study that reported no positive outcome was a repeated cross-sectional study (in sixth graders at baseline and in seventh graders at follow-up) looking at consumption of sweetened beverages and BMI change in a small number of students ($n = 444$) before and after a state vending machine beverage policy was introduced (48). Major limitations of this study include not taking into account age-related change in dietary habits, the comparatively small sample size, the absence of any data on the degree of change to the food environment post policy, that change was at the group rather than individual level and that there was no control group.

## Body-weight outcomes

Two studies reported BMI as their primary outcome measure. Sanchez-Vaznaugh reported the change in z-BMI and the prevalence of overweight 4 years prior and 4 years post the implementation of state beverage and nutrition policies (51). They demonstrated a significant decline in the rate of increase in overweight prevalence in the post-intervention period. Interpretation of these findings is difficult; however, given that this is an uncontrolled study and that the changes in body weight may potentially have resulted from other changes in behaviour or the environment over this time. Taber *et al.* followed a cohort of students from fifth to eighth grade and examined the change in state policy on competitive foods (foods outside the provided lunch programme) over this period, rating the policies as none, weak or strong (50). Their findings were that students from states with new laws, as well as states where laws were strong at baseline, had lower increases in BMI compared with students where no food policy was present at baseline or follow-up. Again, with this study design, it is difficult to tell if changes in BMI were a result of these laws or other changes occurring at that time. The two studies that reported both body weight and dietary or purchasing outcomes include the paper by Jensen *et al.* (discussed earlier), which found no effect of a state vending machine policy on either outcome (48), and a paper by Taber *et al.* looking at the effect of state policy change related to 'junk food' in different settings (50). That study also failed to detect any intervention effect on BMI.

## Food purchasing/consumption outcomes

All but one of the 16 papers with purchasing or dietary outcomes reported a significant intervention effect (the paper by Jensen *et al.* being the exception (48) ). Almost all of these studies involved changes to the availability of foods offered in school canteens. The only exception was a study where promotion of foods in vending machines was altered (47). This study found that signage had no effect on sales, while price discounting of healthy products by 25 and 50% increased sales by 39 and 93%, respectively. Importantly for translation of this intervention, overall profits per vending machine were not impacted by this policy.

The changes to canteen or snack bar food availability in the remaining studies were a result of changes in national, state or local policy (29,44–46,52–54), or were implemented as a scientific study (28,49,55–58). In three cases, simultaneous changes were made to food availability in both canteens/snack bars and vending machines (28,44–46,52). The majority of studies where canteen or snack bar food availability was altered produced clear changes in either diet or purchases in the expected direction (28,44,45,53,54,56–58), with four studies providing less conclusive evidence. Taber *et al.* reported changes in soda consumption, but only where state policies were directed at 'concession stands (not defined)' and 'parties (not defined)', and not vending machines or snack bars (50). Wordell *et al.* found that a school competitive food policy resulted in a reduction in consumption at school of pastries and juice, but not sweet drinks (not defined further), chips, candy or energy drinks (55). Cullen *et al.* reported the effects of a policy to remove chips, candy, sweetened beverages and desserts from snack bars (29). According to self-reported food frequency questionnaires, less soft drinks and more milk were consumed at school while consumption of chips and candy as part of the national school lunch programme declined. Compensatory increases in consumption of these products from vending machines meant that overall consumption did not change (during the intervention, the number of vending machines [83% for sweetened beverages] doubled). Sales data and self-reported consumption data are incongruent; however, with sales data showing no difference in purchases of soft drinks or milk. Finally, Moore and Taper reported on a U.K. study in which a fruit tuck shop was introduced for one academic year (49). While no overall change in consumption of fruit or other snacks was seen, a moderation analysis revealed an increase in fruit consumption in schools that also had an enabling policy where either only fruit or no foods at all could be brought to school as a snack by students.

The study by Quann and Adams warrants further mention (58), with the study having both positive and negative nutritional outcomes. The state policy of reducing the availability of flavoured milk did indeed reduce consumption; however, the benefits of the reduction in added sugars consumed was offset by the simultaneous reduction in important nutrients such as calcium, potassium and vitamin D. No parallel increase in consumption of unflavoured milk was seen.

## Study quality

The mean total quality score for all included studies was 56.6% (range 38.9–86.1). Studies were also given an overall rank of weak (two or more of the six categories rates as weak), moderate (one weak rating) or strong (no weak ratings). Eleven percent ($n = 2$) of all studies were rated strong, 28% ($n = 5$) were moderate and 61% ($n = 11$) were weaker. Only one study was rated strong in the category of study design (49) with only three studies having any kind of control group (49,50,55) (Appendix S1).

# Discussion

With 17 of the 18 included papers (from 16 separate studies) reporting a statistically significant increase in healthy eating behaviours or decrease in BMI of children, it is clear from this review that improving the school food environment has the potential to be an important strategy for obesity prevention in children. The methodological limitations of the included studies and the lack of high-quality study designs does, however, temper the strength of these findings. The intervention effects observed can be attributed to changes to the food environment as all included studies were conducted in the absence of any other education, physical activity or other obesity-prevention interventions. We believe this is the first attempt to examine the specific effect of changing the food environment in isolation. The finding that changes to school food environments appear to be effective in improving student eating behaviour even without simultaneous education or promotion activities is important, as environmental interventions are often relatively simple to implement. With many of the interventions involving policy at the regional, state or national level, the ability to scale-up such initiatives is obvious.

## Comprehensiveness of change

In two previous reviews of school-based nutrition interventions, a link has been observed between the comprehensiveness of the change and the likelihood of a significant positive outcome (24,26). Jaime and Lock, for instance, found that focusing on only one aspect of the food environment (such as vending machines) was less likely to be effective compared with interventions focusing on multiple aspects of the food environment (canteen menus, snack bars, vending machines etc.) (24). One reason why more comprehensive interventions may be preferable is the lower likelihood of unintended compensatory behaviour. Where an intervention targets only one of multiple food sources, increases in the consumption of unhealthy foods from other sources is highly likely (44). As an example, Cullen *et al.* reported on the effect of the removal of chips, candy and sweetened beverages from school snack bars and reported that sales of each product from the snack bar declined over the course of the study (29). Unfortunately, a corresponding increase in the purchase of both chips and candy from vending machines was observed, with ice cream sales also increasing. A further unfortunate observation in this study was that the number of vending machines more than doubled over the study period. From this example, it is clear that food environment interventions that limit the possibility for compensatory behaviour (i.e. the same products not still available elsewhere) should be a priority.

Encouragingly in this review, several studies reporting relatively modest changes to the school food environment have influenced on-site eating behaviours (47,56,57). It is difficult to uniformly assess the comprehensiveness of change in the studies included in this review, with changes made in multiple settings (snack bars, canteens, vending machines), across multiple levels of influence (national and state policy, school policy and as part of a scientific study), with different intervention types (addressing availability of healthy food/drinks, unhealthy food/drinks or both) and with differences in the scope of change (reductions vs. complete bans of unhealthy foods, for example).

## Compensating for school foods elsewhere?

Some previous research has found that students may compensate for reduced intake of unhealthy foods at school by increasing consumption at home (44). A review completed by Chriqui *et al.* found, however, that most research finds that students who reduce consumption of unhealthy foods at school do not increase consumption at home (59). Within the current review, both Jensen *et al.* and Wordell *et al.* examined changes to consumption at home in addition to school-based consumption (48,55). The only statistically significant change following the school-based intervention was an increase in milk consumption at home in the study by Wordell *et al.* (odds ratio [OR] 1.24, $P = 0.04$). In that study, pastry consumption (which was lower in school [OR 0.44, $P < 0.001$] ) was also borderline significantly higher at home (OR 1.4, $P = 0.06$).

In addition to consumption at home, alternative retail food stores outside of schools present an additional opportunity for children (particularly older children) to compensate for the lower consumption of unhealthy food at school. Unfortunately among the included studies, there is presently no evidence for this potential confounding influence on total child diets. The availability of unhealthy food venues (fast food restaurants) near schools has previously been found to be associated with adolescent overweight (60). A recent review, however, found the retail food environment around schools had little effect on food purchasing and consumption. An association with body weight was observed; however, the authors concluded that the observational nature of the studies and the fact that no associations were seen with the mediating variables of purchasing and consumption meant that residual confounding was a likely explanation for this finding (61). Clearly, it is important for intervention studies targeting the school food environment to also examine potential compensatory effects at home and/or via external retail outlets.

### Economic analyses

There is currently little evidence that changes to the school food environment may result in a reduction in school revenue from competitive foods and beverages (22,40,62). Two studies in this review investigated the effect of the interventions on school income (47,55). In their study of a comprehensive food environment intervention in two schools, Wordell *et al*. reported that intervention schools spent 49% more on produce per student compared with control schools, and lost on average USD$16,500 each per year from reduced sales of competitive school meals and vending machine purchases (55). French *et al*. on the other hand demonstrated that increasing the availability of healthy food in vending machines, and even discounting its price, can be both effective and cost-effective, with no impact on overall sales per machine (47). The impact on school budgets clearly needs to be assessed in any school food environment intervention. Given the obesity prevalence in most countries, it could nevertheless be argued that relying on the sales of obesogenic foods is not an appropriate strategy to support school budgets. Creative alternative fund-raising solutions are perhaps a more appropriate way of ensuring budget sustainability.

### Strengths

The main strength of this review was the focus on studies with interventions targeting the food environment in isolation. Without a targeted review such as this, schools and policy-makers cannot easily draw upon the evidence base for this type of intervention. In comparison with interventions that involve an educational component and/or promotion or changes to the built environment, food environment interventions are potentially simpler and more achievable. With limited literature available in this area, a range of intervention outcomes related to food behaviours and weight were included to ensure all available evidence was incorporated. This inclusion of numerous outcomes precluded the use of meta-analytic techniques, which could be seen as a limitation. A persuasive argument can be made, however, that it is more important from a policy relevance perspective to organize a systematic review according to 'like interventions' (as we have here) rather than 'like outcomes'. For this reason, we included any outcome relevant to school food environment change.

### Generalizability of studies

The majority of studies were conducted in the United States, where a highly privatized food service exists alongside a government funded lunch programme. U.S. schools provide the federally funded National School Lunch Program and School Breakfast Program (14) in which all students have access to these meals either free or subsidized based on their socio-economic status (63). These federally reimbursable school meals are subject to minimal nutritional standards (64), which were recently strengthened following a bill passed in the U.S. Congress (65). All other foods available outside of these school meals are termed 'competitive foods' as they compete with the nutritionally regulated school meal programmes (64). Nine out of 10 U.S. schools sell competitive foods, with such food being accessed through different venues such as *a la carte* lines, vending machines, snack bars and student stores (64). Competitive foods are typically considered 'junk foods' as they are usually low in nutritional value and high in sugars and fats (66). New U.S. guidelines announced by the First Lady, Michelle Obama, will prohibit the marketing of junk food and sugary drinks in American schools (65).

As the majority of school food environment research has been conducted in the U.S. context, the findings may not translate easily to settings with no government lunch programme (e.g. Australia, Canada), or where government lunch programmes exist, but are not privatized (e.g. France). Although only three of the included studies were conducted in primary schools, it is possible that focusing on changes in the earlier years may be particularly important in order to establish eating behaviours before middle school and high school (63).

The scope for modification of the school food environment is considerable. The cornerstone of food environment change is clearly improving the nutrient profile of the foods offered. Recent work by Wansink and colleagues, however, has demonstrated a diverse range of additional strategies that have also been found to improve the nutritional profile of foods chosen by students. Among these are: manipulating the presentation order to offer healthier foods first, the use of nutrition report cards, pre-slicing fruits, increasing the convenience and attractiveness of healthy food and naming healthy foods with catchy and appealing names (67–75). Further research to confirm these findings and more fully evaluate the impact of such strategies in different settings should be a research priority.

### Compliance

The degree to which the interventions were implemented as intended varied among studies. Compliance would be expected to differ depending on the study type. More intensive experimental studies are likely to have greater compliance from the schools that participate compared with studies of state- or national-level policy initiatives. Because of the variability in study design, it is difficult to determine the impact that the level of school compliance has had on the findings. Some studies mentioned compliance, including the state-level study of Sanchez-Vaznaugh *et al.*, which found compliance with school nutrition policies to be 'inadequate overall' (51). Cullen *et al.* reported schools in the district to be 'very compliant' with state policy (46), Jensen *et al.* reported school beverages were 70% compliant with state policy (48) and Nicholas *et al.* reported differing compliance rates in U.K. schools depending on the regulation (varying from 23 to 91%, with lower compliance for provision of fruits and vegetables and greater compliance for restricting salt, condiments, confectionery and snacks) (53).

## Conclusions

With virtually all children exposed to the school food environment for much of their childhood, schools can play an important role in obesity prevention and public health. With unhealthy food choices marketed heavily to children in the advertising environment and the retail food environment in most countries, a school environment that supports healthy eating behaviours is essential for children to learn to make healthy food choices (76). The steady decrease in the consumption of healthy foods throughout childhood and the simultaneous increases in the consumption of energy-dense snack foods and sugar-sweetened beverages (7) further demonstrate the importance of the school food environment. In addition to improving eating behaviours directly, a healthy food environment at school can help reinforce nutrition messages received as part of the school curriculum and outside the school from parents and others (17).

Here we have demonstrated that schools, and the policymakers who influence them, can have a positive impact on the eating behaviours of students by improving the food environment. With a large number of natural experiments and an almost complete absence of controlled trials, there is, however, a clear need for high-quality intervention studies to provide more conclusive evidence. Including body weight as an outcome is an important priority, but should only be done in those studies that assess changes to the school food environment large enough and with long enough follow-up to be likely to effect this outcome. The few studies reporting change in BMI in this review were natural experiments involving state policy changes. The association between interventions and BMI change may therefore be confounded by other changes occurring over the same time period.

Even though the design of the included studies may not be optimal, numerous studies reported the effect of state-, district- or national-level policy changes in this review. This provides important evidence suggesting that high-level policy changes impacting the school food environment are possible and can simultaneously impact a large number of children. While American and British researchers should be highly commended for their efforts in this area, the school food environment clearly differs in other contexts based on cultural, policy and structural differences. The absence of studies from other countries and settings (including students from a wider age range) is therefore a serious evidence gap.

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## Conflict of interest statement

No conflict of interest statement.

## Supporting information

Additional Supporting Information may be found in the online version of this article, http://dx.doi.org/10.1111/obr.12224

**Appendix S1.** (i) Study quality summary table (scores out of 3 for each category); (ii) list of questions used for study quality assessment (based on the Effective Public Health Practice Project [EPHPP] ) and (iii) guide for final assessment of study quality.

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