F

Public Health

A systematic review of the influence of the retail food environment around schools on obesity-related outcomes

J. Williams[1], P. Scarborough[1], A. Matthews[1], G. Cowburn[1], C. Foster[1], N. Roberts[2] and M. Rayner[1]

[1]British Heart Foundation Health Promotion Research Group, Nuffield Department of Population Health, University of Oxford, Oxford, UK; [2]Bodleian Health Care Libraries, University of Oxford, Oxford, UK

Received 25 September 2013; revised 11 December 2013; accepted 11 December 2013

Address for correspondence: Ms J Williams, British Heart Foundation Health Promotion Research Group, Nuffield Department of Population Health, University of Oxford, Old Road Campus, OX3 7LF Oxford, UK.
E-mail: julianne.williams@dph.ox.ac.uk

Summary

The high prevalence of childhood obesity has led to questions about the influence of 'obesogenic' environments on children's health. Public health interventions targeting the retail food environment around schools have been proposed, but it is unclear if they are evidence based. This systematic review investigates associations between food outlets near schools and children's food purchases, consumption and body weight. We conducted a keyword search in 10 databases. Inclusion criteria required papers to be peer reviewed, to measure retailing around schools and to measure obesity-related outcomes among schoolchildren. Thirty papers were included. This review found very little evidence for an effect of the retail food environment surrounding schools on food purchases and consumption, but some evidence of an effect on body weight. Given the general lack of evidence for association with the mediating variables of food purchases and consumption, and the observational nature of the included studies, it is possible that the effect on body weight is a result of residual confounding. Most of the included studies did not consider individual children's journeys through the food environment, suggesting that predominant exposure measures may not account for what individual children actually experience. These findings suggest that future interventions targeting the food environment around schools need careful evaluation.

Keywords: Child obesity, food environment, schools, systematic review.

Abbreviations: AOR, adjusted odds ratio; BMI, body mass index; CS, convenience store; FF, fast food; FFR, fast food restaurant; FO, food outlet; FRI, food retail index; HEI, healthy eating index; HFAI, healthy food availability retail index; HFSS, high in fat, sugar or salt; HFZ, healthy fitness zone; IRR, incidence rate ratio; OR, odds ratio; OW, overweight; SE, standard error; SM, supermarket; TA, takeaway.

obesity reviews (2014) **15**, 359–374

Introduction

The prevalence of childhood obesity in the world has increased dramatically over the past three decades and is considered by the World Health Organization to be one of the most serious public health problems of the 21st century (1,2). Overweight or obese children are likely to remain overweight as adults and have an increased risk of developing chronic conditions such as cardiovascular disease or type 2 diabetes. Swinburn and Egger coined the term the 'obesogenic environment' in 1997, and since then a growing body of research has looked at ways that external factors (such as access to food outlets) may influence dietary behaviours (3).

Despite significant methodological and conceptual limitations in research about the environment and health (4–8), there has been interest in potential environmental interventions to support healthy dietary behaviours (9,10). This has led to regulation of the food environment *within* schools (11) – but these policies aimed at improving the food environment for children do not generally extend beyond school boundaries. Planning or licensing controls to restrict unhealthy food retailing operations around schools have been proposed (and in a few cases implemented) in the UK, United States and Australia (12–20), but it is unclear whether such interventions are effective. Some of this lack of clarity is due to a conflicted and equivocal evidence base.

Existing systematic reviews

Despite a growing body of primary research examining the retail food environment surrounding schools and its potential influence on children, we were unable to find any systematic reviews that focus specifically on food retailing around schools and its associated outcomes among schoolchildren. Existing reviews have considered the broader subject of possible environmental determinants of health (4,5,7,8,21–23), but they have not focused specifically on the retailing around schools. For the first time, our review tackles this knowledge gap by examining associations between these environmental exposures and obesity-related outcomes, as well as how they were defined and measured.

Aim of this review: focusing on school food environment studies

The primary aim of this systematic review was to examine the associations between the retail food environment around schools and dietary intake, weight status or food purchasing behaviour among school-age children. Our hypothesis was that the food environment around schools influences food purchasing behaviour of schoolchildren at three points in the day: (i) on the journey to school; (ii) at lunchtime during 'breaks' from school and (iii) on the journey from school. We also hypothesize that the influence on food purchasing behaviour results in changes in dietary intake and changes in weight status. Our secondary aim was to catalogue and critique the various methods employed within this body of literature.

Methods

We developed a full protocol that is available from the authors on request.

Search strategies

We conducted a search using a combination of free-text terms and subject headings to describe schools and schoolchildren, the retail food environment and our outcomes of interest: food purchasing, food consumption and body weight (please see Supporting Information Appendix S1 for the Medline strategy). The following publication databases were searched from database inception to 24 October 2013: MEDLINE (OvidSP, 1946-), EMBASE (OvidSP, 1974-), Global Health (OvidSP, 1973-), CINAHL (EBSCOHost, 1982-), Education Resources Information Centre (ERIC, Proquest, 1966-), Web of Science (Thomson Reuters, 1945-), the Cochrane Public Health Group Specialized Register, PsychINFO(OvidSP, 1967-), Dissertations & Theses (Proquest, 1637-), LILACS(Virtual Health Library) and Science Direct. Additionally, we hand-searched the reference lists of articles for additional relevant papers with an end search date of October 2013. We did not conduct a Cochrane review because of the small number of intervention studies at present and the observational nature of most of the studies we were considering.

Inclusion/exclusion criteria

Studies were required to include at least one measurement of the school food environment. We defined this as the retailing in the area surrounding schools that schoolchildren encounter either on the journey to or from school, or at a lunchtime break from school. We used this definition because we wanted to consider environmental exposures that children were likely to encounter during the school day. This definition included food stores (e.g. supermarkets, convenience stores, farmers' markets) and catering outlets (e.g. fast food, full-service restaurants) but excluded food provision within the school building (e.g. cafeterias, vending machines, school tuckshops). Additionally, we required studies to include outcome data for schoolchildren 5–18 years old. The outcome data needed to include at least one of the following: (i) food purchases; (ii) dietary intake and (iii) body weight.

Study selection

One researcher examined the titles, abstracts and full-text articles. After the first researcher scanned titles and identified exclusions, a second researcher checked a 10% sample of exclusions and identified three papers where there was some disagreement. The title scan was then conducted for a second time, and the second researcher checked a different sample of exclusions and there was complete agreement. The same two researchers reviewed and cross-checked abstracts and full papers.

Classifying and coding the studies

We initially planned to group the studies by exposure and outcome and then, if possible, to perform a meta-analysis of the results. However, because of differences among study research questions, exposure measurements, outcome measurements and methods, formal meta-analysis was not possible, so we followed a semi-quantitative procedure used by Sallis *et al.* (24) and Dunton *et al.* (25). For each study, we identified how the food environment was defined and measured (e.g. type of food outlet, the size of the school neighbourhood) and whether or not it was associated with increased frequency of food purchases, increased consumption of specific foods or increased body weight. We identified whether or not the finding was statistically significant, which we defined as a result that confirmed the hypothesis and had an associated *P* value of less than or equal to 0.05.

The aim of this semi-quantitative method was to allow a rapid assessment of the strength of the evidence of an association between the exposure and the outcomes of interest by reducing a range of results from heterogeneous analytical designs to two binary questions: Did the study show a positive association between the school food environment and the outcome of interest? If so, was this finding statistically significant ($P < 0.05$)?

Quality assessment

We assessed study quality using standard criteria for reviewing primary research papers that are not randomized controlled trials and following the guidelines presented by Zaza *et al.* (26,27). Because of the heterogeneity of study designs and the lack of a robust framework for ranking studies, we adopted a descriptive approach. Quality was assessed according to study methods (e.g. use of random sampling, use of objective or validated outcome measures, controlling for potential confounders) and reporting (e.g. defining exposure and outcome measures, describing the sample) (see Supporting Information Appendix S2).

After the team established the quality assessment criteria, one researcher completed an initial evaluation of the studies. A second researcher independently completed quality assessments for a 10% sample of the papers and the scores were checked for inter-rater reliability. The quality checks were sent to the corresponding authors of the included studies for verification.

Results

The search retrieved 5,789 articles (see Fig. 1). Results come from 30 papers and 29 studies, featuring results from more than 10,000 schools and 1.5 million students (see Table 1).

General characteristics of included studies

The earliest publication was in 2008 and about three quarters of the papers ($n = 23$) were published between 2011 and 2013. The papers were largely cross-sectional, but there were two longitudinal exceptions from Rossen *et al.*

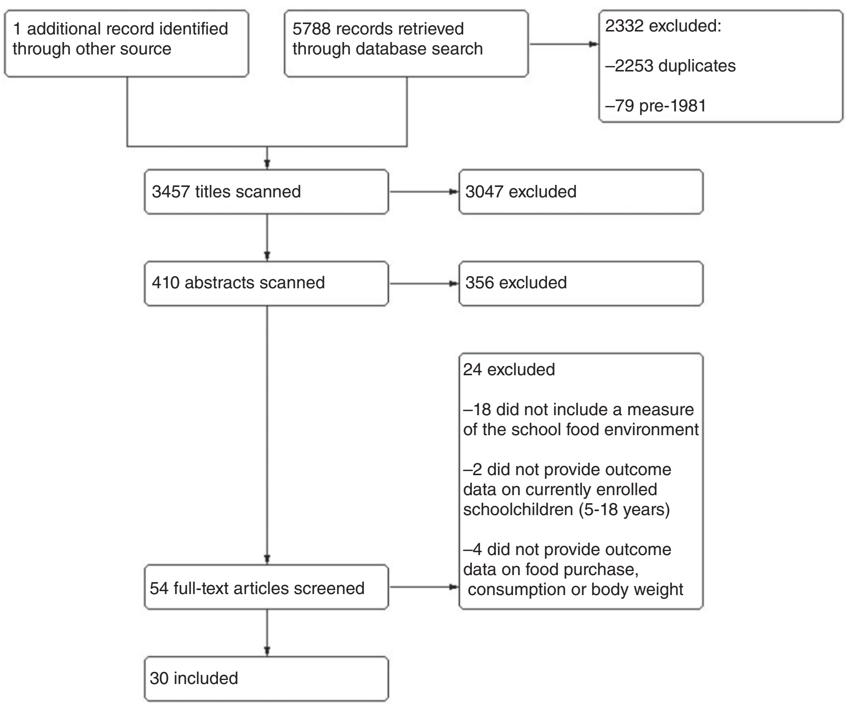

Figure 1 Processing the articles for inclusion in this review.

Table 1 Description of included studies on associations between food outlets around schools and student food purchases, consumption and body weight

Author, year	Country	Age in years (grade)*	Number of students (schools)	Exposure	Type of food outlet	Outcome	Covariates/stratification
An 2012 (46)	United States	5–17	13,462	GIS: density within 0.1, 0.5, 1.0 and 1.5 mile circular buffer of school	CS, FFR, grocery stores and SMs , small food stores	Diet^{SR}: F, V, FF, juice, milk, soda, high-sugar foods	Age, gender, household size, education, parent weight, race/ethnicity, survey wave
Buck 2013 (67)	Germany	6–9	610	GIS: clustering around schools, food retail index (kernel density estimates of FOs per km^2)	Bakeries, FFR, kiosks, SMs	BMI^{M}, Diet^{SR}: Junk food (SSB, chocolate, crisps, etc.)	Age, sex, household income, parent education, under and over-reporting
Chiang 2011 (38)	Taiwan	6–13	2,283	GIS: density within 500-m circular buffer of school	CS, FFR, fresh produce markets, street vendors	BMI^{M}	Age, ethnicity, father's education, household income, pocket money, birth weight, time spent watching TV on weekdays, diet quality, region
Currie 2010 (43)	United States	14–15 (9)	8,373	GIS: presence within 0.1, 0.25 and **0.5** mile straight line buffer	FFR	Body fat^{M}	Census demographics of nearest block, ethnicity, free school meals, school characteristics, school test scores, student : teacher ratio
Davis 2009 (39)	United States	12–17 (7–12)	529,367	GIS: presence within 0.25, 0.25–0.5 and 0.5–0.75 mile straight line buffer. Density within 3 miles	FFR, 'other restaurants'	BMI^{SR} and diet: F, V, juice, soda, fried potatoes	Age, gender, grade, physical activity, FSM eligibility, race/ethnicity, school location type, school type
Forsyth 2012 (68)	United States	11–14 (6–9)	2,724 (20)	GIS: Density within 800-m street network buffer	FFR: traditional, pizza, subs/sandwiches, other FF	Diet: FF	Ethnicity/race, grade level, gender, SES
Gebremariam 2012 (30)	Norway	11–12 (6)	1,425 (35)	Survey of school staff: presence 'within walking distance from school'	'Food outlets where food or drinks could be purchased'	Diet^{SR}: F, V, snacks, SSB, fruit drinks	Canteen/food booth at school, food outlets present, gender, parent education, school nutrition committee, school's perceived responsibility for student diet, two parents
Gilliland 2012 (34)	Canada	10–14	1,048 (28)	GIS: presence within 500 and 800-m straight line buffer, street network buffer and school walkshed†	CS, FFR	BMI^{SR}	Age, sex
Grier 2013 (40)	United States	12–17	1,000	GIS: straight line distance to closest outlet	FFR	BMI^{SR} and diet^{SR}: soda	Age, grade, sex, physical activity, race/ethnicity, school time, per cent eligible for FSM, school urbanicity
Harris 2011 (69)	United States	14–17 (9–12)	552 (11)	GIS: density within 2 km (1.24 mile) straight line buffer of school, distance to closest store	Bagel shops, bakeries, coffee shops, FFR (burger/fries or Mexican), fried chicken restaurant, ice cream shops, pizza parlours, sandwich/sub shops, sit-down restaurants, snack bars	BMI^{SR}	Age, birth weight, diet quality, ethnicity, father's education, household income, pocket money, region, time spent watching TV on weekdays
Harrison 2011 (33)	England	9–10	1,995	GIS: density within 800-m pedestrian network buffer weighted sum of the distance to every facility within 6 km of home and school	'Healthy outlets' (SMs and green grocers), 'unhealthy outlets' (CS and takeaway)	Fat mass index^{M}	Age, sex, parent education, mode of travel to school
He 2012 (45)	Canada	11–13 (7–8)	810 (21)	GIS: density within 1-km straight line buffer; shortest network distance to nearest outlet	CS, FFR	Food purchase^{SR}	Mode of transportation, father's education, land use mix
He 2012 (35)	Canada	11–13 (7–8)	810 (21)	GIS: density within 1-km straight line buffer; shortest network distance to nearest outlet	CS, FFR	Diet^{SR}: HEI	Gender, grade level, neighbourhood distress score, annual family income, ethnicity, family structure, parent education
Heroux 2012 (65)	Canada, Scotland, United States	13–15	26,778 (687)	GIS: density within 1-km straight line buffer	CS, chain FFR restaurants and cafés	BMI^{SR}	Family affluence, grade, sex
Howard 2011 (44)	United States	14–15 (9)	(879)	GIS: Presence within 800-m network buffer	CS, FFR	BMI^{M}	Ethnicity, percentage of students receiving free meals, urbanicity

Table 1 *Continued*

Author, year	Country	Age in years (grade)*	Number of students (schools)	Exposure	Type of food outlet	Outcome	Covariates/stratification
Langellier 2012 (70)	United States	10–15 (5–9)	(1,694)	GIS: presence within 800-m network buffer	Corner stores, FFR	BMI^{M}	Eligibility for title 1 funding, race/ethnicity, school type, urbanicity
Laska 2010 (71)	United States	11–18	334	GIS: density within 800, 1,600 and 3,200 m network buffer	Bakeries/doughnut shops, FFR, gas stations, grocery stores, variety stores	BMI^{SR}	Age, parent education, school and area-level SES, sex
Leatherdale 2011 (72)	Canada	9–13 (5–8)	2,429 (30)	GIS: density within 1-km straight line buffer	Any retail facilities, CS, FFR, grocery stores	BMI^{SR}	Ethnicity, gender, grade, physical activity
Li 2011 (36)	China	11–17	1,792 (30)	Survey of school staff: 'presence within 10-min walk of school'	Western FFR	BMI^{M}	Age, household wealth, parent BMI, parent education
Nixon 2011 (41)	United States	14–15 (9)	(41)	GIS: density within 400- and 800-m straight line buffer, closest facility, degree of clustering around schools	FFR	BMI^{SR}	School lunch policy, percentage of students receiving free meals, race/ethnicity, percentage of students in talented education program, parent education level
Park 2013 (37)	South Korea	9–15 (4–9)	1,342	Survey: density within 500-m radius of school	SM, traditional markets, F and V markets, street vendors, snack bars, CS, FFO, doughnuts, ice cream, bakery shops, full-service restaurants	BMI^{M}, HEI	Age, sex, screen time, family affluence, mother's employment, school nutrition environment (composite index), social safety net program participants
Richmond 2013 (73)	United States	11–14 (6–8)	18,281 (47)	GIS: density within a 1,500-m straight line buffer	FFR, CS	$Diet^{SR}$: SSB	Age, sex, race/ethnicity, percentage of students receiving free school meals
Rossen 2013 (28)	United States	8–13	319	GIS: mean healthy food availability index (HFAI), density of outlets within 100 m of shortest street network path between home and school	CS, SM/GS, CS, restaurants (full service or carry-out), gas stations	BMI^{M} , waist circumference (baseline and 1 year)	Age, gender, race/ethnicity, number of siblings, receipt of free or reduced price lunch, walking to school status, distance to school (log km), school violence strata, census-tract deprivation index
Sánchez 2012 (42)	United States	10–15 (5–9)	926,018 (6,362)	GIS: density within 800-m straight line buffer around school	CS, FFR	BMI^{M}	Age, sex, school-level characteristics and interactions with race/ethnicity
Schafft 2009 (74)	United States	10–13 (5, 7)	243 school districts	GIS: absence of 'large grocery store' within 10 mile straight line buffer around 'population based centroid' of the school district	Large grocery store: grocery or retail food store with more than 50 employees	BMI	Median family income, per cent mobile home residence, per cent incomplete kitchen
Seliske 2009 (75)	Canada	11–16	7,281 (178)	GIS: density within **1** and 5 km straight line buffer	CS, doughnut/coffee shops, FFR, full-service restaurants, sub/sandwich shops	$BMI^{SR\ddagger}$	BMI, family affluence scale, physical activity, sex, urbanicity
Smith 2013 (29)	England	11–16	1,382 (29)	GIS: density within 400 and **800-m** road network buffer, median and minimum distance to grocer or TA	TA, grocer/SM/CS	Diet quality: 'Healthy' or 'Unhealthy' (aggregate score)	Age, gender, FSM eligibility, ethnicity, school-level deprivation
Svastisalee 2012 (47)	Denmark	11–15 (5–9)	6,034 (80)	GIS: 'Exposure:' number of FOs divided by total road segments within 300 m of schools	FFR, SMs	$Diet^{SR}$: F, V	Age, family social class, sex
Timperio 2009 (32)	Australia	5–12	816	GIS: density within 50 m buffer along route to school, Presence of FO along route	Cafes, FFR, restaurants, takeaway stores	$Diet^{SR}$: FF or takeaway	Age, SES
van der Horst 2008 (31)	Netherlands	12–15	1,293 (15)	GIS: density within 500-m straight line buffer	Bakery, FFR, fruit/vegetable store, large SM, small food store	$Diet^{SR}$: SSB and snacks	Date of measurement, ethnicity, education

Buffer size in **bold** indicates the buffer distance that we used in our analysis.
*When papers reported student grade level only, we inferred age in years from the grade described in parentheses.
†The walkshed is the territory within a school's catchment that encompasses only those students living within walking distance.
‡Outcome was percentage of students falling within a 'healthy fitness zone', which includes both fitness measures and BMI.
BMI, body mass index; CS, convenience store; F, fruit; FF, fast food; FFR, fast food restaurant; FO, food outlet; FSM, free school meal; HEI, healthy eating index (a composite variable that reflects overall diet quality); M, measured; SES, socioeconomic status; SM, supermarket; SR, self-report; SSB, sugar-sweetened beverage; V, vegetable.

(28) and Smith *et al.* (29). Most of the studies took place in North America (United States: *n* = 14; Canada: *n* = 5) but there were also studies from Europe (*n* = 6), Asia (*n* = 3) and Australia (*n* = 1). One multi-country study from the United States, Scotland and Canada was also included. Participant age ranged from 5 to 17 years. Sample sizes ranged widely from 334 to 926,018 students and more than three quarters of the studies had more than 1,000 students. Most of the papers did not explicitly identify the theoretical model informing their work, but those that did (30,31) cited social ecological models.

Methods for defining and measuring the school food environment

Studies varied in their methods of constructing exposure measures in terms of the level of the exposure (whether or not it accounted for individual variation) and the source of information (primary vs. secondary sources).

Level of exposure: area-level vs. individual-level exposures

Area-level exposures were based on a static area such as a buffer around the school or the school's census tract. Most of the included studies used area-level measures, defined at the level of the school, which meant that all students attending the same school had a shared exposure value (*n* = 21). The alternative approach of using an individual-level exposure, where quantification of food outlets accounted for individual factors such as a student's home address, was used by nine studies. Three papers (28,32,33) accounted for the student's journey through the food environment by taking the student's school and residential address and calculating the number of outlets falling along the route between the two locations. Gilliland *et al.* (34) used multilevel structural equation modelling techniques to simultaneously test the effects of the school-environment and home-environment predictors on body mass index (BMI) scores and He *et al.* (35) calculated individual participants' 'junk food density' based on the density of stores around both students' home and school address.

Geographical information systems vs. survey-based measures of exposure

The predominant method of characterizing the food environment exposure was by using geographical information systems (GIS) (*n* = 27). Most commonly, this was done through use of a software program to construct a buffer zone (straight line, street or pedestrian network) around the child's school or the route between home and school and then counting the number of food outlets within that area (density). For studies using this density method, the buffer distances ranged from 0.1 to 3.0 miles (about 160–4,800 m) for the area around schools and from 50 to 100 m for the area around routes. For the former category, the most frequently used buffer distance was half a mile (about 800 m). Most of the papers using buffer zones provided rationale for using the buffer distance that they did (*n* = 25) and for about one-third of them (*n* = 12), at least one of the cited reasons was to be consistent with earlier studies. Another GIS method calculated the distance from the school to the nearest outlet (proximity). For these GIS-based studies, information about the locations, names and types of food outlets came predominantly from large secondary data sources including private companies and local business directories (*n* = 18) or public records such as census data, tax registry documents or government food premise databases (*n* = 8). Harris *et al.* collected store data using a global positioning system (GPS) unit and adding these geo-referenced points to a digital map.

Subjective measures of the retail food environment included the use of questionnaires. Two studies identified food outlets via a questionnaire in which school administrators identified the presence of food outlets 'within walking distance' (30) or within 'ten minutes' walk' (36) of the school. Park *et al.* (37) used an audit tool to record observations of the various types of food outlets found within a 500-m radius of the school.

Defining types of food outlets

Food outlet definitions and categories varied between papers and, in the instances when they were explicitly defined, often depended on the definitions provided by the original data source. A range of food outlets were included, but most of the studies narrowed their measures to a few specific types. The most common types of outlets to be included were fast food restaurants (*n* = 23), convenience stores (*n* = 10), supermarkets (*n* = 6) and grocery stores (*n* = 7).

Types of outcomes: food purchasing behaviour, consumption and body weight

Of the three outcomes we considered in this review, the most common was body weight, with 20 papers evaluating environmental associations with BMI (*n* = 18) and fat mass (*n* = 2). The second most common outcome was food consumption, with 14 papers evaluating associations between the environment and diet. Food consumption was predominantly assessed as daily or habitual consumption (rather than food consumption at school). A range of specific foods were measured, but the most frequently evaluated were fruit and vegetables (*n* = 4), soda or sugar-sweetened beverages (*n* = 7), or fast food (*n* = 4). Three papers used a composite variable such as a Healthy Eating Index (HEI; *n* = 2) or a healthy diet score ($n = 1$). Of the three types of outcomes we considered, food purchases were measured least frequently, with only one paper including it as an outcome. This measure was based on participant's self-report of purchasing fast food at least once in the previous week.

Quality assessment

We assessed the quality of studies using 13 criteria that included whether or not studies randomly selected participants, provided clear definitions of the study area, validated their exposure and outcome measurements, or attempted to control for potential confounders. When it was applicable, most papers randomly selected schools ($n = 18$) and students ($n = 19$), and defined the area of measurement (i.e. the 'school neighbourhood') in terms of a defined spatial size ($n = 27$). Nine studies validated their exposure measures via ground-truthing and three via Google Maps. Nine of the 14 studies measuring diet used a validated instrument. Twelve of the 20 studies with BMI or weight as an outcome used objective measures and eight relied on self-report. Almost all of the studies adjusted for potential confounders in their final analysis with the most common adjustments for socioeconomic status ($n = 26$), race/ethnicity ($n = 20$) and urbanicity/population density ($n = 8$).

Results from the included studies

The results below are organized according to their outcome measures. Because of the heterogeneity in study design, we report the following results in terms of increased food purchases, increased consumption or increased body weight. We chose an arbitrary level of significance ($P = 0.05$).

Because of a diverse range of exposures, outcomes, levels of adjustments and the number of analyses reported by individual studies, and to avoid over-representing results from papers that reported many results, we used the following criteria to determine which results to feature in Tables 2–4. When papers presented results using multiple levels of adjustment, we took the most adjusted. When results were stratified using categorical variables (e.g. ethnicity), we included all results, but when they were stratified using ordered variables (e.g. grade or social class) we took the result from the highest and lowest levels only. When papers presented results using multiple exposure measures (varying buffer sizes and types, GIS methods, and means of quantifying food outlets), we included the network buffer size closest to 800 m and the 'density' variable that accounted for the most individual-level variation. When papers presented results of multiple outcomes related to weight (BMI, waist circumference, triceps skinfold thickness), we used the outcome closest to our primary outcome of interest (BMI). All of the results (both included and excluded) have been provided (Supporting Information Appendixes S3–S5).

Food outlets and body weight

Twenty papers looked at the relationship between food outlets and body weight. Of the 72 associations (reported in Table 2), 43 showed a positive relationship between body weight and exposure to food outlets. Nineteen of these positive relationships were significant, with most in the expected direction after adjustments. These included positive associations between exposure to fast food outlets and BMI (34,36,38–40), obesity (37) and the proportion of overweight (41,42) or obese (43) students. Positive associations were also observed between the presence of 'unhealthy outlets' (convenience stores and takeaways) and adiposity among girls who walk or cycle to school (33) or convenience stores and proportion of overweight students (42,44).

Food outlets and food purchases

Although three studies reported measuring food purchases, only one paper provided results. He *et al.* found that high fast food outlet density was positively correlated with student report of fast food purchases in the past week and this was significant ($P < 0.05$) (45) (see Table 3).

Food outlets and consumption of foods high in fat, sugar or salt

Ten papers measured associations between food outlets and consumption of foods high in fat, sugar or salt, the most common of which were sugar-sweetened beverages ($n = 6$) and 'fast-food' (including fried potatoes) ($n = 4$) or an aggregate variable that took these foods into account) (see Table 3). In total, 54 associations between these foods and retail outlets were reported and in about half ($n = 28$), food outlets were associated with increased consumption. However, only two of these results were significant ($P < 0.05$); Smith *et al.* found that unhealthy diet scores (reflecting frequency of consuming crisps, sweets, biscuits, fried food, fizzy drinks) were negatively correlated with the minimum distance to grocery stores and takeaways within 800 m (29).

Food outlets and consumption of fruits, vegetables or overall diet quality

Four papers considered associations between food outlets and fruit and vegetable consumption (see Table 4) (30, 39,46,47). A total of 32 associations were reported and in about half ($n = 18$), exposure to food outlets was associated with increased consumption of fruit and vegetables. Three of these associations were significant ($P < 0.05$) and they all related to fast food outlets. An (46) observed positive association between the presence of fast food outlets and vegetable consumption among adolescents and Davis

Table 2 Summary of findings: food outlets around schools and student body weight

Author	Type of food outlet	Outcome			Increases weight?	$P < 0.05$
Buck 2013 (67)			β	*P* value		
	FRI	BMI *z* score	0.110	0.17	Yes	No
Chiang 2011 (38)	# within 500 m	BMI *z* score	β			
	CS	Boys	0.010		Yes	No
	FF		0.080		Yes	Yes
	CS	Girls	0.020		Yes	No
	FF		0.030		Yes	No
Currie 2009 (76)	FO within 800 m*	% obese	β	SE		
	FFR	Ninth graders	–0.0391	0.4475	No	No
	Other		0.4638	0.4881	Yes	No
	FFR	Fifth graders	0.4341	0.1844	Yes	Yes
	Other FO		0.2879	0.2312	Yes	No
Davis 2009 (39)	FO within 800 m*	BMI	*b*	95% CI		
	FF		0.10	0.03, 0.16	Yes	Yes
	Other FO		0.08	0.01, 0.14	Yes	Yes
Gilliland 2012 (34)	FO within school walkshed	BMI *z* score	Estimate	SE		
	FFR		0.073	0.034	Yes	Yes
	Presence of CS (school walkshed)		0.020	0.021	Yes	No
Grier 2013 (77)	Distance	Β	95% CI			
	FFR	BMI	–0.050	–.10, .00	Yes[†]	Yes
Harris 2011 (69)	# within 2 km	BMI	β	*P*		
	Restaurants		0.010	0.31	Yes	No
	Pre-packed food stores		3×10^{-4}	0.96	Yes	No
	Grocery stores		0.046	0.53	Yes	No
	Other stores		0.020	0.78	Yes	No
	Stores overall		0.000	0.66	Yes	No
Harrison 2011 (33)	School access (high vs. low)	FMI for girls	*B*	95% CI		
	Healthy FOs	Car, bus or train	0.020	–0.068, 0.110	Yes	No
	Unhealthy FOs		0.010	–0.107, 0.130	Yes	No
	Healthy FOs	Walk or cycle	–0.090	–0.183, –0.006	No	No
	Unhealthy FOs		0.140	0.009, 0.280	Yes	Yes
	Route to school access (present vs. not)					
	Healthy FOs present	Car, bus or train	–0.021	–0.104, 0.062	No	No
	Unhealthy FOs present		0.041	–0.029, 0.110	Yes	No
	Healthy FOs present	Walk or cycle	–0.032	0.143, 0.078	No	No
	Unhealthy FOs present		0.007	–0.068, –0.082	Yes	No
Heroux 2012 (65)	# within 1 km (ref: 0)	OW/obesity	OR	95% CI		
	All FOs (5+)	Canada	0.97	0.80, 1.18	No	No
	CS (5+)		1.00	0.79, 1.26	No	No
	FFR (5+)		0.81	0.63, 1.06	No	No
	Cafes (3+)		0.79	0.53, 1.21	No	No
	All FOs (5+)	Scotland	0.89	0.61, 1.29	No	No
	CS (5+)		1.05	0.61, 1.80	Yes	No
	FFR (5+)		0.60	0.32, 1.15	No	No
	Cafes (3+)		0.66	0.42, 1.03	No	No
	All FOs (5+)	United States	1.01	0.84, 1.23	Yes	No
	CS (5+)		1.11	0.87, 1.40	Yes	No
	FFR (5+)		0.99	0.81, 1.22	No	No
	Cafes (3+)		0.98	0.66, 1.41	No	No
Howard 2011 (44)	FO within 800 m	% OW	β	SE		
	FFR		–0.010	0.58	No	No
	CS		0.050	0.59	Yes	Yes
	SM		–0.010	0.65	No	No

Table 2 *Continued*

Author	Type of food outlet	Outcome			Increases weight?	P < 0.05
Langellier 2012 (70)	FO within 800 m*	% OW	β	SE		
	Corner store or liquor store		1.63	0.61	Yes	Yes
	FFR		0.35	0.52	Yes	No
Laska 2010 (71)	Presence within 800 m		β	95% CI		
	Any restaurant	BMI *z* score	–0.28	–0.50, –0.07	No	Yes
Leatherdale 2011 (78)	# within 1 km	OW (vs. normal weight)	AOR	95% CI		
	Gas stations		1.46	0.79, 2.68	Yes	No
	FFO		0.96	0.82, 1.13	No	No
	Bakeries/doughnut shops		0.89	0.68, 1.15	No	No
	Variety stores		0.82	0.59, 1.13	No	No
	Grocery stores		1.10	0.86, 1.42	Yes	No
Li 2011 (36)	# within 10 min walk (ref: 0)	BMI	β	95% CI		
	FFR (1)		0.60	–0.02, 1.1	Yes	No
	FFR (≥2)		0.80	0.1, 1.4	Yes	Yes
Nixon 2011 (41)	FFR clustering	% not within HFZ*	Moran's I index*	*P* value		
	400 m		1.24	*P* < 0.01	Yes	Yes
	800 m		0.37	*P* < 0.05	Yes	Yes
Park 2013 (37)	FO density (low: ref)	Obese	OR	95% CI		
	Markets (SM, traditional, FV)		1.04	.99, 1.11	Yes	No
	Street vendors, snack bars, CS		0.98	.95,1.01	No	No
	FFR, doughnuts, ice cream, bakery shops		1.02	1.00,1.04	Yes	Yes
	Full-service restaurants		0.99	.98, 1.01	No	No
Rossen 2013 (79)	FO within 100-m path to school	1 year change	*b*	95% CI		
	HFAI*	BMI	–0.15	–0.26, –0.13	No	Yes
Sánchez 2012 (42)	Presence within 800 m	% OW	APR	95% CI		
	FFR (≥1 vs. 0)		1.02	1.01, 1.03	Yes	Yes
		White	1.02	1.00, 1.04	Yes	Yes
		Hispanic	1.02	1.01, 1.03	Yes	Yes
		Black	1.03	1.00, 1.06	Yes	Yes
		Asian	0.94	0.91, 0.97	No	Yes
	CS (per additional FO)		1.01	1.00, 1.01	Yes	Yes
		Fifth grade	1.01	1.00, 1.02	Yes	Yes
		Ninth grade	1.00	0.99, 1.01	No	No
Schafft 2009 (74)	Absence within 10 miles	% OW/at risk	*b*	SE		
	Large grocery or SM		0.044	0.020	No†	Yes
Seliske 2009 (75)	Presence within 1 km (ref: 0 vs. high)	OW vs. normal	OR	95% CI		
	FFR		0.83	0.70, 0.98	No	Yes
	Sub/sandwich shops		0.78	0.64, 0.93	No	Yes
	Doughnut/coffee shops		0.81	0.68, 0.96	No	Yes
	Total FRI		0.70	0.61, 0.81	No	Yes

*Approximate: rounded from ½ mile (804.7 m).
†Measure is the distance from food outlet and weight outcome or the absence of food outlet and weight outcome.
AOR, adjusted odds ratio; APR, adjusted prevalence ratio; BMI, body mass index; CS, convenience store; FFR, fast food restaurant; FO, food outlet; FRI, food retail index (# of FOs per 1,000 residents); HFAI, healthy food availability index (based on the availability of foods from eight food groups within each outlet); HFZ, healthy fitness zone (accounts for school fitness levels and student BMI); IRR, incidence rate ratio; OR, odds ratio; OW, overweight; SE, standard error.

(39) observed a negative association between proximity to fast food and fruit or vegetable consumption.

Food outlets and healthy eating indexes

Three papers included composite variables that reflected overall diet quality (29,37,45) (see Table 4). Of seven associations, four were positively correlated with increased healthy eating scores. Among these, there were two significant ($P < 0.05$) findings. He *et al.* (35) looked at associations between food outlets around schools and the HEI score, which reflects overall diet quality, and found that students attending schools with a convenience store or fast

Table 3 Summary of findings: food outlets around schools and student consumption or purchase of foods high in fat, sugar or salt (HFSS)

Author	Type of food outlet	Outcome			Increases consumption	$P < 0.05$
An 2012 (46)	# within 500 m		Child			
			IRR	SE		
	FFR	Soda	1.006	0.011	Yes	No
		High-sugar food	0.998	0.008	No	No
		Fast food	0.991	0.01	No	No
	CS	Soda	0.984	0.036	No	No
		High-sugar food	0.986	0.027	No	No
		Fast food	0.987	0.033	No	No
	Small FO	Soda	1.002	0.011	Yes	No
		High-sugar food	0.999	0.007	No	No
		Fast food	1.006	0.009	Yes	No
	Grocery	Soda	1.013	0.039	Yes	No
		High-sugar food	1.022	0.025	Yes	No
		Fast food	1.029	0.035	Yes	No
	Large SM	Soda	0.995	0.035	No	No
		High-sugar food	0.955	0.024	No	No
		Fast food	1.008	0.031	Yes	No
			Adolescent			
	FFR	Soda	0.989	0.011	No	No
		High-sugar food	1.029	0.016	Yes	No
		Fast food	0.993	0.012	No	No
	CS	Soda	0.984	0.039	No	No
		High-sugar food	1.051	0.055	Yes	No
		Fast food	1.005	0.032	Yes	No
	Small FO	Soda	1.002	0.009	Yes	No
		High-sugar food	1.013	0.015	Yes	No
		Fast food	1.01	0.009	Yes	No
	Grocery	Soda	1.023	0.036	Yes	No
		High-sugar food	0.96	0.047	No	No
		Fast food	1.042	0.043	Yes	No
	Large SM	Soda	1.038	0.039	Yes	No
		High-sugar food	1.033	0.04	Yes	No
		Fast food	1.06	0.036	Yes	No
Buck 2013 (67)	# per 1,000 people		Exp β	*P* value		
	FRI	Junk food*	1.04	0.57	Yes	No
		Simple sugar food†	0.99	0.87	Yes	No
Davis 2009 (39)	Proximity	# of servings	b	95% CI		
	FFR	Soda	0.02	–0.01, 0.04	Yes	No
		Fried potatoes	0	0.02, 0.02	No	No
Forsyth 2013 (80)	# within 800 m	Adjusted weekly frequency		Dif *P* value‡		
	FFR type		Boys			
	Traditional§	0	1.0			
		1+	0.7	0.066	No	No
	Pizza	0	0.9			
		1+	0.9	0.998	No	No
	Sandwiches	0	0.8			
		1+	0.9	0.341	Yes	No
	Other	0	1.2			
		1+	1.2	0.832	No	No
	All types	0	3.6			
		1–2	4			
		3+	4.4		Yes	No
		Trend *P* value**	0.644			
			Girls			
	Traditional	0	1.0			
		1+	0.9	0.673	No	No
	Pizza	0	0.9			
		1+	0.9	0.822	No	No
	Sandwiches	0	0.8			
		1+	0.8	0.949	No	No
	Other	0	1.2			
		1+	1.2	0.927	No	No
	All types					
		0	3.6			
		1–2	4.3			
		3+	3.2		No	No
		Trend *P* value**	0.299			
Gebremariam 2012 (30)	# within walking distance		β	SE		
	FOs	Snacks	–0.193	0.494	No	No
		SSB	–0.002	0.153	No	No

Table 3 *Continued*

Author	Type of food outlet	Outcome			Increases consumption	$P < 0.05$
Grier 2013 (81)	Distance from school		β	95% CI		
	FFR	Soda	–0.01	–.03,.04	Yes**	No
Richmond 2013 (73)	# within 1,500 m	Mediational effect¶	β	SE		
	FFR and CS	SSB (servings per day)	0.0001	0.001	Yes	No
Smith 2013 (29)	Distance to school (min)	Unhealthy diet	β	95% CI		
	Grocer (800 m)		–0.001	–0.003, 0.000	Yes**	Yes
	Takeaway (800 m)		–0.002	–0.004, 0.000	Yes**	Yes
Timperio 2009 (32)	Access along route to school		AOR	95% CI		
	# of FF or TA	Consumed ≥1/wk	1	1.0, 1.0	No	No
van der Horst 2008 (31)	# within 500 m	Litres per day	β			
	SM	Soft drinks	0.077		Yes	No
	FFR		–0.055		No	No
	Small food stores		–0.259		No	Yes
Food outlets and purchases of HFSS foods						
He, 2012 (35)	# within 1 km	Previous week	OR	95% CI		
	FFR	FF purchase	1.4	1.1, 1.7	Yes	Yes

*SSB, chocolate, nut-based spreads, crisps, chocolate bars, candies.
†Fruit juice, SSB, sugar-added cereals, chocolate, candy, etc.
‡Dif *P* value: difference between those with 0 and those with 1 at $P < 0.05$; *t*-test.
§Traditional FF: burgers and fries.
¶Mediational effect of FO density on association of race/ethnicity and SSB consumption.
**Exposure is expressed as *distance* to food outlet.
AOR, adjusted odds ratio; CS, convenience store; FF, fast food; FFR, fast food restaurant; FO, food outlet; FRI, food retail index (# of FOs per 1,000 residents); HFAI, healthy food availability index (based on the availability of foods from eight food groups within each outlet); OR, odds ratio; OW, overweight; SM, supermarket.

food outlet farther than 1 km away had a significantly higher HEI score than students with an outlet within 1 km (35). Smith *et al.* found a positive correlation between distance to grocers and healthy diet scores.

Discussion

Principal findings

This review examined associations between the food environment around schools and children's food purchases, consumption or body weight. The methods for defining and measuring the food environment varied widely between studies and few consistent findings emerged. We found little reported evidence for an effect of the school food environment on food consumption patterns and limited evidence of an effect on food purchases, but some evidence of an effect on body weight. However, these results should be interpreted cautiously. These studies were observational and therefore susceptible to confounding. With only two exceptions (from the longitudinal studies of Smith *et al.* and Rossen *et al.*), the evidence base is composed almost entirely of cross-sectional data. Measurement bias is likely, particularly with the diet-related outcomes, where misreports have been shown to vary children's characteristics (age, sex, weight) and social factors (48). Reporting bias is possible, which is suggested by the fact that several papers reported significant results only.

Strengths and weaknesses

We were unable to assess pooled effects as there were many definitions and measures of the food environment surrounding schools (6). One strength of this review was that it provided some focus by honing in on one specific element of the food environment – the presence of retail food outlets in the area surrounding schools. However, this strength was also a weakness; this definition does not account for all of the other relevant obesogenic environments that a child will encounter over the course of a day (49,50) and it prevented us from considering research about the other elements of food access, such as availability, accessibility, affordability and accommodation (5,7,51). The recent review by Caspi *et al.* provides a helpful overview of these other influences (5). Additionally, the focused nature of this review kept us from considering the environment within retail outlets (e.g. product availability or placement within stores), but another recent review by Ni Mhurchu *et al.* suggests that this aspect of the food environment is not consistently associated with dietary outcomes (52). As here, methodological heterogeneity makes it difficult to draw firm conclusions.

As noted earlier, given the heterogeneity of the studies and the wide range in the number of exposures, outcomes and analyses that individual papers reported, we did not include every single result that every paper provided in our overall assessment. We used a consistent and transparent

Table 4 Summary of findings: food outlets around schools and student consumption of fruit and vegetables or healthy eating indexes

Author	Type of food outlet	Outcome			Increases consumption?	$P < 0.05$
An 2012 (46)	FO within 800 m*		Child			
			IRR	SE		
	FFR	Fruits	1.003	0.005	Yes	No
		Vegetables	0.997	0.006	No	No
	CS	Fruits	0.986	0.015	No	No
		Vegetables	1.003	0.019	Yes	No
	Small FO	Fruits	1.002	0.005	Yes	No
		Vegetables	1.004	0.005	Yes	No
	Grocery	Fruits	1.015	0.015	Yes	No
		Vegetables	1.015	0.018	Yes	No
	Large SM	Fruits	1.009	0.016	Yes	No
		Vegetables	0.996	0.019	No	No
			Adolescent			
	FFR	Fruits	1.007	0.006	Yes	No
		Vegetables	1.017	0.008	Yes	Yes
	CS	Fruits	1.000	0.021	No	No
		Vegetables	0.987	0.026	No	No
	Small FO	Fruits	0.996	0.007	No	No
		Vegetables	1.002	0.010	Yes	No
	Grocery	Fruits	0.962	0.028	No	No
		Vegetables	0.995	0.029	No	No
	Large SM	Fruits	1.020	0.021	Yes	No
		Vegetables	1.001	0.026	Yes	No
Davis 2009 (39)	*P*	*# of servings*	*b*	95% CI		
	FFR	Fruit	–0.02	–0.04, 0.00	No	Yes
		Vegetables	–0.02	–0.03, 0.00	No	Yes
Gebremariam 2012 (30)	FO within walking distance		β	SE		
	FOs	Fruits	–0.016	0.096	No	No
		Vegetables	–0.087	0.122	No	No
Svastisalee 2012 (47)			Low family social class			
	SMs (low vs. high)	Infrequent consumption	AOR	95% CI		
		Fruit	1.17	0.89, 1.54	Yes§	No
		Vegetables	1.33	0.92, 1.90	Yes§	No
	FFR (high vs. low)	Fruit	1.32	0.98, 1.76	No§	No
		Vegetables	1.17	0.80, 1.71	No§	No
			High family social class			
	SMs (low vs. high)	Infrequent consumption	AOR	95% CI		
		Fruit	1.08	0.80, 1.45	Yes§	No
		Vegetables	1.04	0.80, 1.35	Yes§	No
	FFR (high vs. low)	Fruit	1.23	0.89, 1.69	No§	No
		Vegetables	1.26	0.95, 1.66	No§	No
Food outlets and composite variables						
He 2012 (45)	# within 1 km	HEI‡ score	Daff	SE		
	FFR (0) (ref: ≥3)		2.75	1.06	Yes	Yes
	FFR (1–2) (ref: ≥3)		0.66	1.14	Yes	No
Park 2013 (37)	# within 500 m	HEI‡	β	SE		
	Markets (SM, traditional, FV)		–0.02	0.06	No	No
	Street vendors, snack bars, CS		0.04	0.08	Yes	No
	FFR, donuts, ice cream, bakery		–0.13	0.07	No	No
	Full-service restaurants		0.03	0.07	Yes	No
Smith 2013 (29)	Minimum distance	Healthy diet	β	95% CI		
	Grocer (800 m)		0.002	0.000, 0.003	No‡	Yes

*Approximate: rounded from ½ mile (804.7 m).
†Difference in HEI score compares the difference in scores between schools where nearest outlet was <1 km away and schools where nearest outlet was ≥1 km away.
‡Exposure is expressed as *distance* to food outlet.
§Outcome is *infrequent* consumption.
AOR, adjusted odds ratio; CS, convenience store; FF, fast food; FFR, fast food restaurant; FO, food outlet; FRI, food retail index (# of FO's per 1000 resident); HE, healthy eating index, a composite variable based on habitual meal habits (e.g. skipping breakfast) or consumption (fruit, vegetables, milk, soda, FF, Ramen noodles, chips, fried food, etc.); HFAI, healthy food availability index (based on the availability of foods from eight food groups within each outlet); IRR, incidence rate ratio; OR, odds ratio; OW, overweight; SE, standard error; SM, supermarket; TA, takeaway.

approach to select results from studies so as to avoid conclusions being overweighted by studies that reported multiple findings from the same dataset. For example, for the BMI outcome, we reported 72 associations, with 43 showing a positive correlation with food outlets (28 of those being significant). Comparing these figures to all results reported (and featured in the Supporting Information Appendix S3), there were 142 associations, with 89 showing a positive correlation of weight with food outlets and 53 being significant. We have highlighted the instances when there were significant associations that varied from what we reported (either in terms of direction or significance) in the Supporting Information Appendix. Davis *et al.* (39) presented associations on the school food environment and body weight within three buffer sizes: 0–0.25 miles, 0.25–0.5 miles and 0.5–0.75 miles. We showed the results from 0.5 miles, which again were in the same direction of association as the other two buffer sizes, although the association between fast food outlets and BMI was not significant at the 0.5–0.75 mile area of exposure while it was significant at the two smaller sizes. Therefore, choosing to present the results as we did may have altered our assessment of the number of associations that are significant compared to if we had chosen to use the larger buffer. Finally, Currie (43) presented associations with exposure at 0.1, 0.25 and 0.5 mile buffers and we presented the latter. For exposure to 'other restaurants', the results are in the same direction and at the same significance level, but for fast food exposure, the associations were not significant at the smaller buffer sizes (as they were at the larger size for fifth graders). For dietary outcomes, please see the Supporting Information Appendix for a full list of results and how our inclusion decision may have altered the assessment. For example, Svastisalee *et al.* reported additional analyses assessing interactions between fast food and supermarkets and associations with fruit and vegetable consumption according to social class and found that children from low and middle social class backgrounds attending schools with high fast food and low supermarket exposure were most likely to report infrequent fruit intake. A final limitation is that despite a comprehensive search in 10 databases and hand-searching references, we failed to identify one paper that did not have MeSH headings attached. Fortunately, this paper was identified by a reviewer and it is represented here.

Implications for policy

Overall, this review did not find strong evidence at this time to support policies aimed at regulating food environments around schools. However, given that food retailing is already influenced by a number of other policy drivers (related to economics, antisocial behaviour, litter and pollution, food hygiene, etc.), it is important that broader public health evidence is also considered. However, it is not possible to draw conclusions until a higher quality evidence base is developed.

Implications for research

To improve the quality of the evidence base, future longitudinal data are required to account for changes that may occur in the food environment over time. As earlier reviews found (7), the research has relied on cross-sectional data with the most common approach to characterizing the retail food environment in this body of literature being to calculate the density or proximity of outlets within a buffer using indirect sources of food outlet data (such as directories or large databases). These methods bring up several questions about data accuracy and comprehensiveness, especially given that food outlet data are imperfect (53), which may have implications for exposure assessment accuracy. Questions also remain about which types of outlets to focus on. Earlier reviews noted a focus on fast food outlets and recommended that future studies include other types of outlets in their exposure measures (7), but we found that a much wider range of food outlet types were included, such as fast food, convenience stores, grocery stores and supermarkets. While this may provide a more comprehensive picture of the retail food environment, it brings up questions about the best way to classify a food outlet and how to compare results from studies using different classification systems. To enable between-study comparisons, future work should integrate validated classification systems into the design (54). Future studies should also explore the capacity of alternative methods for validating exposure data, including Google Street View (55,56).

Additionally, future work should also incorporate a child's usual mode of travel to and from school into decisions about appropriate buffer distances. We found only three of the studies in this review accounted for mode of travel in their final analyses. If buffers are to reflect the real ability of children to walk or cycle to school (and hence their real exposure to environments), it is important that studies account for transport exposure and adjust for active vs. motorized transport as Harrison's (33) study did. Capturing this individual-level data may become easier as advances in measurement technologies foster a new era of 'people-based' rather than 'place-based' exposure measures (57–59). Promising examples include the use of GPS devices or interactive mapping tools to capture individual mobility patterns, characterize the individual's activity space and then quantify outlets within that space (60–62). The specificity that individual-level measures of exposure to the food environment would allow is vital if we are to accurately measure what is likely to be a small-effect size.

In addition to improving these GIS-based measures of the food environment (e.g. density of food outlets), future work may benefit from collecting complementary measures of both qualitative (participant perception-based) and quantitative measures of food access (63).

Future research needs to collect outcome measures that are appropriate relative to the exposures. For example, all of the papers assessed daily or habitual diet patterns, but these outcomes cannot be linked to the school food environment without knowing the time or place of consumption, and where the food was originally sourced. Future studies concerned with specific environments should collect this additional contextual information.

The age range of included studies encompassed both primary and secondary school settings and there are potentially important theoretical differences regarding how age may influence a child's interaction with the food environment as he grows older and develops more autonomy. This may lead to differences in travel time, distance travelled, availability of pocket change and other factors.

Another issue related to between-country generalizability. As Feng noted in his review, most of the associations came from North America, but food environments vary between countries (6,64). It was promising to see that one included study by Heroux *et al.* (65) looked at between-country food environments and outcomes. Future work is needed to develop standardized tools to monitor local food environments across countries (66).

Conclusions

In conclusion, we did not find strong evidence at this time to justify policies related to regulating the food environments around schools. Our findings may provide some timely insight to debate about prevention of obesity among children. Future work with longitudinal cohorts and more refined exposure and outcome measures may lead to higher quality evidence that may inform more effective public health interventions. Additionally, these improvements will allow researchers to better understand how this particular component of the food environment in the school neighbourhood interacts with other components of a child's environment and investigate the effects this may have on obesity risk.

Conflict of interest statement

None declared.

Author contributions

PS was the PI, supervised the data collection and contributed to finalization of the manuscript. NR conducted the keyword search. JW and AM completed the data extraction. JW drafted the manuscript. AM, CF, GC, NR, PS and MR assisted with writing the manuscript.

Acknowledgements

Funding for the study was provided by the National Health Service (NHS) Berkshire (JW) and the British Heart Foundation (PS, AM, GC, CF, MR, JW).

Supporting information

Additional Supporting Information may be found in the online version of this article, http://dx.doi.org/10.1111/obr.12142

Appendix S1. Medline search terms
Appendix S2. Quality assessment of studies assessing the relationship between the school food environment and food purchase, consumption or body weight
Appendix S3. Food outlets around schools and student body weight (all results)
Appendix S4. Food outlets around schools and student consumption or purchase of food high in fat, sugar or salt (HFSS) (all results)
Appendix S5. Food outlets around schools and student consumption of fruit and vegetables and healthy eating indexes (all results)*

References

1. Han JC, Lawlor DA, Kimm SYS. Childhood obesity. *Lancet* 2010; **375**: 1737–1748.
2. Lobstein T, Baur L, Uauy R. Obesity in children and young people: a crisis in public health. *Obes Rev* 2004; **5**: 4–85.
3. Egger G, Swinburn B. An 'ecological' approach to the obesity pandemic. *BMJ* 1997; **315**: 477–480.
4. Holsten JE. Obesity and the community food environment: a systematic review. *Public Health Nutr* 2009; **12**: 397–405.
5. Caspi CE, Sorensen G, Subramanian SV, Kawachi I. The local food environment and diet: a systematic review. *Health Place* 2012; **18**: 1172–1187.
6. Feng J, Glass TA, Curriero FC, Stewart WF, Schwartz BS. The built environment and obesity: a systematic review of the epidemiologic evidence. *Health Place* 2010; **16**: 175–190.
7. Charreire H, Casey R, Salze P *et al.* Measuring the food environment using geographical information systems: a methodological review. *Public Health Nutr* 2010; **13**: 1773–1785.
8. de Vet E, de Ridder DTD, de Wit JBF. Environmental correlates of physical activity and dietary behaviours among young people: a systematic review of reviews. *Obes Rev* 2011; **12**: e130–e142.
9. Caraher M, O'Keefe E, Lloyd S, Madelin T The planning system and fast food outlets in London: lessons for health promotion practice. Revista Portuguesa de Saúde Pública, 2013.
10. Harrison F, Jones AP. A framework for understanding school based physical environmental influences on childhood obesity. *Health Place* 2012; **18**: 639–648.
11. Adamson A, Spence S, Reed L *et al.* School food standards in the UK: implementation and evaluation. *Public Health Nutr* 2013; **16**: 968–981.
12. Mitchell C, Cowburn G, Foster C. Assessing the options for local government to use legal approaches to combat obesity in the UK: putting theory into practice. *Obes Rev* 2011; **12**: 660–667.
13. Dugan E. *Pupils Face Takeaway Ban in Bid to Fight Childhood Obesity*. The Independent: London, 2013.
14. Parker L, Burns AC, Sanchez E. *Local Government Actions to Prevent Childhood Obesity*. National Academies Press: Washington, DC, 2009.
15. Model Healthy Food Zone Ordinance. *National Policy and Legal Analysis Network to Prevent Childhood Obesity*: 2009.
16. Coveney J. Residents revolt against planned McDonald's near primary school. The conversation 2012.
17. School Food Trust. Barking and Dagenham Council press release: 'Council defeats hot food takeaway giant at planning appeal'. 2011.
18. Healthyplaces. Barking and Dagenham planning policy on new hot food takeaways 'Saturation Point'. Case studies: 2011.

19. London Food Board and Chartered Institute of Environmental Health. Takeaways Toolkit. A London Food Board and Chartered Institute of Environmental Health Publication Based on a Consultancy Report by Food Matters, London, 2012.
20. Public Health England. Healthy people, healthy places briefing. Obesity and the environment: regulating the growth of fast food outlets. In: Chartered Institute of Environmental Health, Local Government Association (ed.). *Obesity and the Environment Briefing: regulating the Growth of Fast Food Oultets*. Public Health England: London, 2013, pp. 1–11.
21. Fleischhacker SE, Evenson KR, Rodriguez DA, Ammerman AS. A systematic review of fast food access studies. *Obes Rev* 2011; **12**: e460–e471.
22. Leal C, Chaix B. The influence of geographic life environments on cardiometabolic risk factors: a systematic review, a methodological assessment and a research agenda. *Obes Rev* 2011; **12**: 217–230.
23. Williams AJ, Wyatt KM, Hurst AJ, Williams CA. A systematic review of associations between the primary school built environment and childhood overweight and obesity. *Health Place* 2012; **18**: 504–514.
24. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc* 2000; **32**: 963–975.
25. Dunton GF, Kaplan J, Wolch J, Jerrett M, Reynolds KD. Physical environmental correlates of childhood obesity: a systematic review. *Obes Rev* 2009; **10**: 393–402.
26. Zaza S, Wright-De Agüero LK, Briss PA *et al*. Data collection instrument and procedure for systematic reviews in the guide to community preventive services. *Am J Prev Med* 2000; **18**: 44–74.
27. Kmet LMLR, Cook LS. *Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields*. Alberta Heritage Foundation for Medical Research (AHFMR): Edmonton, 2004.
28. Rossen LM, Curriero FC, Cooley-Strickland M, Pollack KM. Food availability en route to school and anthropometric change in urban children. *J Urban Health* 2013; **90**: 653–666.
29. Smith D, Cummins S, Clark C, Stansfeld S. Does the local food environment around schools affect diet? Longitudinal associations in adolescents attending secondary schools in East London. *BMC Public Health* 2013; **13**: 70.
30. Gebremariam MK, Andersen LF, Bjelland M *et al*. Does the school food environment influence the dietary behaviours of Norwegian 11-year-olds? The HEIA study. *Scand J Public Health* 2012; **40**: 491–497.
31. van der Horst K, Timperio A, Crawford D, Roberts R, Brug J, Oenema A. The school food environment: associations with adolescent soft drink and snack consumption. *Am J Prev Med* 2008; **35**: 217–223.
32. Timperio AF, Ball K, Roberts R, Andrianopoulos N, Crawford DA. Children's takeaway and fast-food intakes: associations with the neighbourhood food environment. *Public Health Nutr* 2009; **12**: 1960–1964.
33. Harrison F, Jones AP, van Sluijs EM, Cassidy A, Bentham G, Griffin SJ. Environmental correlates of adiposity in 9–10 year old children: considering home and school neighbourhoods and routes to school. *Soc Sci Med* 2011; **72**: 1411–1419.
34. Gilliland JA, Rangel CY, Healy MA *et al*. Linking childhood obesity to the built environment: a multi-level analysis of home and school neighbourhood factors associated with body mass index. *Can J Public Health Revue Canadienne de Sante Publique* 2012; **103**: eS15–eS21.
35. He M, Tucker P, Irwin JD, Gilliland J, Larsen K, Hess P. Obesogenic neighbourhoods: the impact of neighbourhood restaurants and convenience stores on adolescents' food consumption behaviours. *Public Health Nutr* 2012; **15**: 2331–2339.
36. Li M, Dibley MJ, Yan H. School environment factors were associated with BMI among adolescents in Xi'an City, China. *BMC Public Health* 2011; **11**: 792.
37. Park S, Choi BY, Wang Y, Colantuoni E, Gittelsohn J. School and neighborhood nutrition environment and their association with students' nutrition behaviors and weight status in Seoul, South Korea. *J Adolesc Health* 2013; **53**: 655–662, e12.
38. Chiang P-H, Wahlqvist ML, Lee M-S, Huang L-Y, Chen H-H, Huang ST-Y. Fast-food outlets and walkability in school neighbourhoods predict fatness in boys and height in girls: a Taiwanese population study. *Public Health Nutr* 2011; **14**: 1601–1609.
39. Davis B, Carpenter C. Proximity of fast-food restaurants to schools and adolescent obesity. *Am J Public Health* 2009; **99**: 505–510.
40. Grier S, Davis B. Are all proximity effects created equal? Fast food near schools and body weight among diverse adolescents. *J Public Policy Mark* 2013; **32**: 116–128.
41. Nixon H, Doud L. Do fast food restaurants cluster around high schools? A geospatial analysis of proximity of fast food restaurants to high schools and the connection to childhood obesity rates. *J Agric, Food Syst Community Dev* 2011; **2**: 181–194.
42. Sánchez BN, Sanchez-Vaznaugh EV, Uscilka A, Baek J, Zhang L. Differential associations between the food environment near schools and childhood overweight across race/ethnicity, gender, and grade. *Am J Epidemiol* 2012; **175**: 1284–1293.
43. Currie J, DellaVigna S, Moretti E, Pathania V. The effect of fast food restaurants on obesity and weight gain. *Am Econ J-Econ Policy* 2010; **2**: 32–63.
44. Howard PH, Fitzpatrick M, Fulfrost B. Proximity of food retailers to schools and rates of overweight ninth grade students: an ecological study in California. *BMC Public Health* 2011; **11**: 68.
45. He M, Tucker P, Gilliland J, Irwin JD, Larsen K, Hess P. The influence of local food environments on adolescents' food purchasing behaviors. *Int J Environ Res Public Health [Electron Resour]* 2012; **9**: 1458–1471.
46. An R, Sturm R. School and residential neighborhood food environment and diet among California youth. *Am J Prev Med* 2012; **42**: 129–135.
47. Svastisalee CM, Holstein BE, Due P. Fruit and vegetable intake in adolescents: association with socioeconomic status and exposure to supermarkets and fast food outlets. *J Nutr Metab* 2012; **2012**: 185484.
48. Börnhorst C, Huybrechts I, Ahrens W *et al*. Prevalence and determinants of misreporting among European children in proxy-reported 24 h dietary recalls. *Br J Nutr* 2012; **1**: 1–9.
49. Matthews SA (ed). Spatial polygamy and the heterogeneity of place: studying people and place via egocentric methods. In: *Communities, Neighborhoods, and Health*. Springer: New York, NY, 2011, pp. 35–55.
50. Cummins S. Commentary: investigating neighbourhood effects on health – avoiding the 'Local Trap'. *Int J Epidemiol* 2007; **36**: 355–357.
51. Penchansky R, Thomas JW. The concept of access: definition and relationship to consumer satisfaction. *Med Care* 1981; **19**: 127–140.
52. Ni Mhurchu C, Vandevijver S, Waterlander W *et al*. Monitoring the availability of healthy and unhealthy foods and non-alcoholic beverages in community and consumer retail food environments globally. *Obes Rev* 2013; **14**: 108–119.

53. Cummins S, Macintyre S. Are secondary data sources on the neighbourhood food environment accurate? Case-study in Glasgow, UK. *Prev Med* 2009; **49**: 527–528.
54. Lake AA, Burgoine T, Greenhalgh F, Stamp E, Tyrrell R. The foodscape: classification and field validation of secondary data sources. *Health Place* 2010; **16**: 666–673.
55. Rundle AG, Bader MD, Richards CA, Neckerman KM, Teitler JO. Using Google Street View to audit neighborhood environments. *Am J Prev Med* 2011; **40**: 94–100.
56. Miller DK. Using Google Street View to audit the built environment: inter-rater reliability results. *Anns Behav Med* 2013; **45**: 108–112.
57. Rainham D, McDowell I, Krewski D, Sawada M. Conceptualizing the healthscape: contributions of time geography, location technologies and spatial ecology to place and health research. *Soc Sci Med* 2010; **70**: 668–676.
58. Kwan M-P. From place-based to people-based exposure measures. *Soc Sci Med* 2009; **69**: 1311–1313.
59. Doherty AR, Hodges SE, King AC *et al*. Wearable cameras in health: the state of the art and future possibilities. *Am J Prev Med* 2013; **44**: 320–323.
60. Gustafson A, Christian J, Lewis S, Moore K. Jilcott S. Food venue choice, consumer food environment, but not food venue availability within daily travel patterns are associated with dietary intake among adults, Lexington Kentucky 2011. *Nutr J* 2013; **12**: 17.
61. Zenk SN, Schulz AJ, Matthews SA *et al*. Activity space environment and dietary and physical activity behaviors: a pilot study. *Health Place* 2011; **17**: 1150–1161.
62. Chaix B, Kestens Y, Perchoux C, Karusisi N, Merlo J, Labadi K. An interactive mapping tool to assess individual mobility patterns in neighborhood studies. *Am J Prev Med* 2012; **43**: 440–450.
63. Moore LV, Roux AVD, Brines S. Comparing perception-based and geographic information system (GIS)-based characterizations of the local food environment. *J Urban Health* 2008; **85**: 206–216.
64. Cummins S, Macintyre S. Food environments and obesity – neighbourhood or nation? *Int J Epidemiol* 2006; **35**: 100–104.
65. Heroux M, Iannotti RJ, Currie D, Pickett W, Janssen I. The food retail environment in school neighborhoods and its relation to lunchtime eating behaviors in youth from three countries. *Health Place* 2012; **18**: 1240–1247.
66. Thornton L, Cameron A, McNaughton S *et al*. Does the availability of snack foods in supermarkets vary internationally? *Int J Behav Nutr Phys Act* 2013; **10**: 56.
67. Buck C, Bornhorst C, Pohlabeln H *et al*. Clustering of unhealthy food around German schools and its influence on dietary behavior in school children: a pilot study. *Int J Behav Nutr Phys Act* 2013; **10**: 65.
68. Forsyth A, Wall M, Larson N, Story M, Neumark-Sztainer D. Do adolescents who live or go to school near fast-food restaurants eat more frequently from fast-food restaurants? *Health Place* 2012; **18**: 1261–1269.
69. Harris DE, Blum JW, Bampton M *et al*. Location of food stores near schools does not predict the weight status of Maine high school students. *J Nutr Educ Behav* 2011; **43**: 274–278.
70. Langellier BA. The food environment and student weight status, Los Angeles County, 2008–2009. *Prev Chronic Dis* 2012; **9**: E61.
71. Laska MN, Hearst MO, Forsyth A, Pasch KE, Lytle L. Neighbourhood food environments: are they associated with adolescent dietary intake, food purchases and weight status? *Public Health Nutr* 2010; **13**: 1757.
72. Leatherdale ST, Pouliou T, Church D, Hobin E. The association between overweight and opportunity structures in the built environment: a multi-level analysis among elementary school youth in the PLAY-ON study. *Int J Public Health* 2011; **56**: 237–246.
73. Richmond TK, Spadano-Gasbarro JL, Walls CE *et al*. Middle school food environments and racial/ethnic differences in sugar-sweetened beverage consumption: findings from the Healthy Choices study. *Prev Med* 2013; **57**: 735–738.
74. Schafft KA, Jensen EB, Hinrichs CC. Food deserts and overweight schoolchildren: evidence from Pennsylvania. *Rural Sociol* 2009; **74**: 153–177.
75. Seliske LM, Pickett W, Boyce WF, Janssen I. Association between the food retail environment surrounding schools and overweight in Canadian youth. *Public Health Nutr* 2009; **12**: 1384–1391.
76. Currie, J., DellaVigna, S., Moretti, E., Pathania, V. The Effect of Fast Food Restaurants on Obesity and Weight Gain (No. w14721). National Bureau of Economic Research, 2009.
77. Grier S, Davis B. Are All Proximity Effects Created Equal? Fast Food Near Schools and Body Weight Among Diverse Adolescents. *J Public Policy Mark* 2013; **32**, 116–128.
78. Leatherdale ST, Pouliou T, Church D, Hobin E. The association between overweight and opportunity structures in the built environment: a multi-level analysis among elementary school youth in the PLAY-ON study. *Int J of Public Health* 2011, **56**: 237–246.
79. Rossen LM, Curriero FC, Cooley-Strickland M, Pollack KM. Food availability en route to school and anthropometric change in urban children. *J Urban Health* 2013; **90**: 653–666.
80. Forsyth A, Wall M, Larson N, Story M, Neumark-Sztainer D. Do adolescents who live or go to school near fast-food restaurants eat more frequently from fast-food restaurants?. *Health Place* 2012; **18**: 1261–1269.
81. Grier, S., & Davis, B. Are all proximity effects created equal? Fast food near schools and body weight among diverse adolescents. *J Public Policy Mark* 2013; **32**: 116–128.