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D6.1: Systematic review and evidence synthesis report

Authors:
Mathilde Gressier, Elisa Pineda, Alexa Segal, *Imperial College London*
Boyd Swinburn, *University of Auckland New Zealand*

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Glossary of terms

Abbreviation	Definition
BMI	Body mass index
NCDs	Non-communicable diseases
PICO	Population, intervention, comparison and outcome
PROSPERO	Prospective Register of Systematic Reviews
SEP	Socioeconomic Position
SSB	Sugar sweetened beverages
TFA	*Trans*-fatty acids (in this report, used for artificially-produced TFA)

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Part one: What is the impact of food reformulation on individual's behaviour, nutrient intakes and health status? A systematic review of empirical evidence

1 Background

Non-communicable diseases (NCDs) are the leading cause of death worldwide, and in Europe, about a quarter of these deaths are attributed to poor diet (1). Modifying the healthiness of food environments has been deemed more effective to change individual's habits towards a healthier diet, hence a necessary step to reduce diet-related diseases and obesity (2,3). Food environment interventions include changes in the availability, price, information provided or composition of foods. One of the ways that food environments can change is through reformulation of packaged and processed foods (representing on average 46% of daily energy purchased by European populations[1]). Food reformulation strategies aim to enhance dietary intakes by changing the composition of foods without changing consumers' eating behaviours. Having gained attention in the mid 2000's when there was a global focus on sodium reduction, food reformulation, if implemented progressively, can have a sustained effect on the food environment. As such, a systematic change in food composition *should* result in a change in populations' food intake, leading to a decrease in dietary risk factors.

Systematic reviews on the effect of specific nutrient reformulation strategies (i.e. sodium or artificially-produced trans-fatty acids (TFA) reduction strategies) on consumers' consumption show that multiple-component interventions including reformulation are the most effective in improving diets (4–6). However, it remains unclear how consumers react to reformulated products. Previous reviews on food reformulation do not investigate the consumers' reactions to reformulated foods including consumers' acceptability of reformulated products or compensation of the decreased nutrient.

This review aims to assess the empirical evidence on the impact of food reformulation on an individual's behaviour, nutrient intakes and health status. There was no restriction on the type of reformulation strategy employed (i.e. studies were included regardless of which nutrient change the strategy was focused on changing). When possible, we also report the effect of reformulation strategies on the childhood population.

1 This statistic ranges from 32.6% to 60.9% in Portugal and in the United Kingdom, respectively (4).

2 Methods

We follow the PICO (Population, Intervention, Comparison and Outcome) framework *(Table 1).* The search strategy was designed in consultation with a specialist health subject librarian from Imperial College London (UK). We searched through EMBASE, MEDLINE and Global Health for peer-reviewed studies published until December 2018. We used keyword searches on (the search strategy for Medline is available in *Appendix 1*). The search strategy was refined by conducting sensitivity analysis in EMBASE with a test set of 15 key papers selected as example of papers answering the PICO question. Adjustments to the search strategy concluded once 85% of the key papers were identified. We also included references from four relevant systematic reviews (4,5,7,8). All studies identified were eligible if they fulfilled our PICO search strategy. The protocol was registered with Prospective Register of Systematic Reviews (PROSPERO, 2019 CRD42019127624 https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=127624) in March 2019.

PICO feature	Criteria
Population	General population (subgroup analysis for children if possible). *Studies focusing on the effect in specific subgroups with medical conditions were excluded.*
Intervention(s)	Reformulation interventions include those targeting packaged foods and/or beverages, or food sold in restaurant chains. Reformulation at a population-scale can be driven by mandatory or voluntary targets, labelling, self-regulation or public-private partnerships (PPP). *Studies evaluating consumer reaction to reformulated products in lab-experiments will be included though will be analysed separately from policies implemented at population-level.*
Comparison(s)	Comparators may include no intervention or a comparison of the same group before the implementation of the intervention.
Outcomes	Studies must focus on behaviour and long-term outcomes linked to non-communicable diseases. Primary outcomes include: choice behaviour (purchases, sales), dietary intakes and patterns, risk factors for non-communicable diseases (BMI, blood pressure, biological markers of dietary intakes) or health outcomes (mortality). *Excluded outcomes: changes in awareness, knowledge or beliefs, studies with non-quantitative outcomes, and studies evaluating only the change in food composition but not the change in consumer behaviour.*

Table 1: PICO table for the selection of studies

3 Results

The search strategy retrieved 11315 studies from the three databases. Searching the grey literature and the reference list of included studies led to the addition of 29 papers (PRISMA flow chart(9) in Figure 1). After a full-text review of 177 papers against eligibility criteria, 35 papers were included for the review (listed in Appendix 2). Some of the included papers analysed multiple outcomes or nutrients targeted by a reformulation strategy, equating to 61 total number of included studies included in this qualitative analysis. The majority of studies reported on either the consumption of reformulated foods or dietary intakes in the context of reformulation (26 and 29 studies, respectively), while only six studies reported on outcomes linked to reduction of NCD burden (dietary risk factors or diseases).

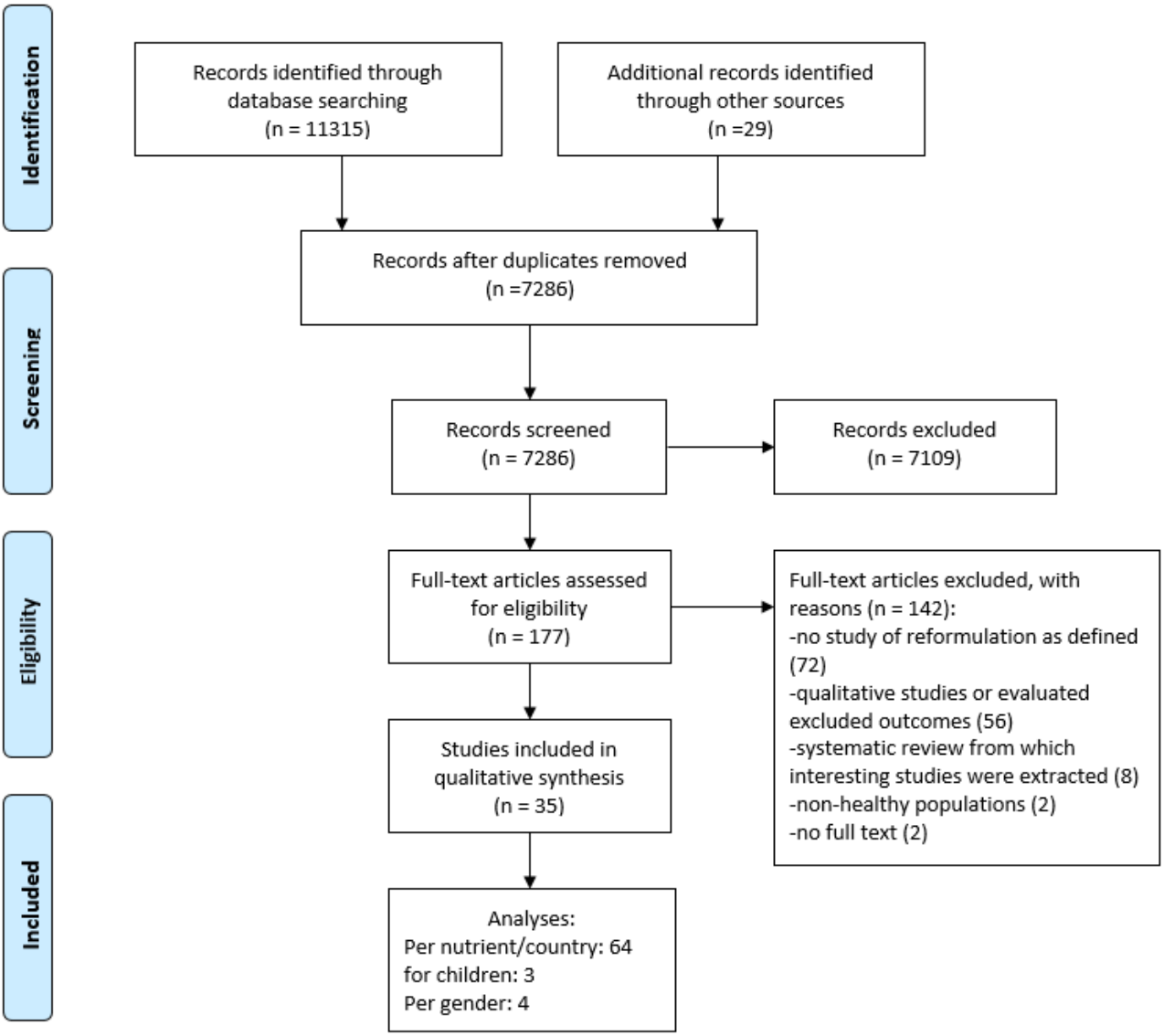

Figure 1: PRISMA flow chart showing the screening of records (from Moher et al., 2009)

3.1 Results across nutrients

Overall, reformulated food products were accepted and consumed by the population, as measured by a change in sales or in the purchase-weighted average content of a category (first column, Table 2). This phenomenon was observed for reformulation of sodium, TFA, and for improvement of the nutrient profile of products. However, we cannot conclude for energy, sugars, fibres or whole grain reformulations due to the limited evidence. It is difficult to compare the acceptability of reformulated products across nutrients due to the variability in number and nutrient-category focus of included reformulation studies. Also, the extent to which respective nutrients were reformulated (i.e. the amount reduced or added through reformulation efforts) changed depending upon the nutrient-targeted reformulation initiative. As such, studies on the percentage reduction of TFA in reformulated products was substantially larger than that of reductions in total energy or sugar, for example. Although there are no specific threshold in which to make an assumption, it was clear that reformulation strategies that precipitated larger changes in nutrients of interest had more meaningful impacts on purchase (i.e. the larger the change if food composition towards the healthier alternative, the more successful effects were observed).

For 69% of the included studies, reformulation led to improved intake of the respective nutrient/component.[2] The burden of NCDs were reduced in four of the five studies that evaluated the effect of TFA bans in packaged foods or restaurant foods. Conclusions cannot be made for other nutrients due to the lack good quality studies.

		Reformulated product purchases*		**Intake**		**Morbidity / Mortality**	
Characteristics	All outcomes (n)	Studies (n)	Positive results (%)	Studies (n)	Positive results (%)	Studies (n)	Positive results (%)
Total	61	26	81%	29	69%	6	83%
Nutrient studied							
sodium	33	9	89%	23	61%	1	1
TFA	13	3	100%	5	100%	5	0.8
several nutrients	5	5	80%				
energy	3	3	100%				
sugars	3	3	33%				
fibres	2	2	50%				
whole grains	2	1	100%	1	100%		
Type of reformulation							
Mandatory limit	5	1	100%			4	75%

[2] The majority of these studies focused on the reformulation of sodium and TFA.

voluntary reformulation*	56	25	80%	29	69%	2	100%
Part of multi-component							
No	22	17	71%	4	75%	2	50%
yes	39	9	89%	25	68%	4	100%
Effect of reformulation isolated							
no	42	16	100%	23	65%	2	50%
yes	19	10	50%	6	83%	4	100%

***Acceptability of reformulated products was either measured using:*
- *Sales/purchases of the reformulated product before and after reformulation*
- *The evolution of market-share weighted averages of a nutrient content before and after reformulation*

***Several nutrients is used either for measures of nutrient profile (e.g. score) or when several nutrients where evaluated jointly*
****Voluntary reformulation can be triggered via commitment, or the implementation of labelling.*

Table 2: Number or studies and proportion showing positive results for acceptability of reformulated products, daily intakes, and morbidity or mortality reduction resulting of the implementation of a reformulation strategy. Positive results were defined as a significant change in average nutrient content purchase, nutrient intake going in the direction of an improvement for public health (i.e. reduction for sodium, TFA, energy or sugars, increase in fibres or whole grains and improvement of the nutrient profile of foods), or a reduction in disease risk or mortality.

3.2 Isolation of the effect of reformulation

Over half of the 61 studies analysed multiple-component interventions, where the observed effect cannot be attributed to solely the reformulation strategy of interest. It was not possible to evaluate differential effect between multiple- and single-component interventions because of the limited number of studies. Systematic reviews on sodium and TFA showed that multi-component strategies including a reformulation scheme were the most promising to improve diets for the two nutrients (4,10).

3.3 Childhood and adolescent populations

Only three studies evaluated the effect of interventions specifically in the childhood or adolescent populations (11–13). Studies showed that there was not a differential effect of reformulation in that of the young population compared to that of the adult population. All three studies reported on changes in dietary intakes following the reformulation intervention. No studies evaluated the acceptability of reformulated products in the childhood population.

3.4 Result by gender

The majority of studies did not reported results by gender. The Cochrane review on salt reduction strategies by McLaren found a larger effect for men than for women (4). Two recent studies on salt reformulation found no effect of the strategy neither for men nor for women (14,15).

3.5 Result by type of incentive

More than 90% of the studies included evaluated voluntary reformulation. It is suggested that mandatory reformulation was more effective to lead to favourable results than voluntary reformulation. However this conclusion is made with evidence on TFA reformulation only as mandatory standards were not found for other nutrients.

3.6 Results by nutrient

3.6.1 Sodium reformulation

In total, 33 studies evaluated the impact of initiatives to reduce sodium in food products.

Nine studies evaluated consumer acceptance of decreased sodium products by analysing the sodium content purchased before and after reformulation. Studies show that the decreased mean sodium content in food products translated into a change in the mean sodium purchased (either measured across all purchases of a household, or for food categories targeted in the initiative). This means that consumers accepted these reduced-sodium products, and did not switch to higher sodium products.

However, only in 60% of studies show that consumer's successfully reduce their sodium intakes following reformulation. Some studies suggest that a plausible reason that reformulation was not successful in decreasing sodium intake is attributed to an insufficient number of product categories reformulated in countries where only few products were reformulated.

Only one study evaluated the impact of sodium reformulation on health outcomes. Results suggest that the reduction in sodium intake observed in the UK coincided to a decrease in blood pressure (16). This intake reduction was mainly due to reformulation (17,18).

3.6.2 TFA reformulation

Thirteen studies evaluated the impact of TFA reduction strategies.

Consistent with previous review (5,8), included studies showed that products were accepted by the population and resulted in decreased TFA intake (19,20). However, when reformulation was voluntary, some high-TFA products remained in the market. Hence, some individuals still exceeded the recommended intake of TFA, even after reformulation efforts.

Five studies evaluated the effect of a TFA ban (in the US, Denmark and Austria) on cardiovascular diseases or mortality. In all countries except Austria, studies observe that there was reduced CVD mortality compared to the control countries (21–23). Austria observes no differences in CVD reduction between Austria and control countries, though it is suggested that an increased smoking prevalence in may explain this absence of beneficial effect observed after the TFA ban (24).

3.6.3 Multi-nutrient reformulation

Five studies analysed several nutrients together by using nutrient profiling systems, or evaluating trends of different nutrients in a category. Studies indicated that some food categories showed improvement in more than one nutrient, which translates into an improvement of the whole nutrient profile of purchases from the specific food category. However, the reformulation of several nutrients simultaneously, or the controlling for other nutrients than the one targeted by the intervention was rarely measured.

No study was found evaluating the impact of reformulation of the nutrient profile of foods on nutrient intakes or health status.

3.6.4 Total energy reformulation

Only three papers analysed initiatives aimed at the reduction of energy in food products. Studies suggested that reduction of the energy density of packaged products led to a decreased energy density bought from the respective food category.

However, no study analysed if this trend led to an overall reduced daily energy intake, or improved health status.

3.6.5 Sugar reformulation

Three papers analysed sugar reduction in food categories that are major contributors of sugar intakes. The quantity of sugar reduced in the reformulated product was often small, resulting in mixed overall results regarding the effect of sugar purchased from this category. The amount of sugar purchased by consumers decreased in some categories, but not all[3].

No study reported on the impact of sugar reduction strategies on intakes, hence we cannot conclude if consumers compensated for reduced sugar in some categories by increasing their sugar intakes in other categories.

3.6.6 Whole grain and fibre reformulation

Four studies analysed reformulation strategies aimed at increasing the amount of fibre or whole grain contents in products. Two studies showed that an increase in whole grain or fibre in food products resulted in an increase in the fibres/whole grain content of purchases. However, one study showed that a small increase in fibre content of foods did not increase fibre purchased from this category of foods.

[3] For example, the UK sugar reduction strategy resulted in reduced sales-weighted sugar content average for yoghurts, breakfast cereals and sweet spreads, but not for biscuits, puddings or ice-creams (26).

One study suggested that increasing whole grain content in products while increasing populations' awareness of whole grains led to increased whole grain consumption.

No study was found reporting on possible health consequences of fibre or whole grain reformulation.

4 Discussion

This systematic review aims to evaluate how population-wide reformulation of food products impacts an individual's health status. Overall, reformulated products were accepted by consumers, as we observed that a change in foods' composition was followed by a change in purchases composition or intakes. Further, compensation (overconsumption or change in dietary patterns) did not rule out the effect of reformulation. Some compensation mechanisms occurred (especially reported for sodium) highlighted by the fact that reformulation did not led to decreased intakes (or the percentage change across the food offer was bigger than the percentage change in intakes). Due to the variability in both the number and nutrient-category of reformulation studies, it was not possible to quantify the size of the compensation, nor identify specific context in which compensation occurred. Yet, other factors in addition to reformulation initiatives, including changed advertising techniques, could have contributed the change in consumer behaviour (including compensation) observed after reformulation.

The relationship between reformulation and health status was inconclusive, meaning it is not possible to generalize the effect of reformulation on health status. Only TFA-specific reformulation studies were reported on health status, while studies on the health effect of reformulation for other nutrients was lacking. For TFA however, the improvement of food composition led to improved health status. Observing an improvement in health status as a result of reformulation is a consequence of the type of nutrient reformulated (i.e. TFA has more direct impact on health compared to that of other nutrients), so the effect of reformulation for other nutrients on health may be more difficult to observe. Regardless, the combination of a complete removal of TFA from the food supply in some countries, in addition to the strong correlation between TFA intake and health status, created favourable conditions in which to measure improvements in health status of respective populations.

The goal of reformulation is to create small changes in food composition without changing consumer behaviour. The effectiveness of reformulation depends upon the scale and type of implementation strategy (e.g. how many products are reformulated or whether the high-selling products are reformulated). For example, mandatory standards were more effective in reducing intakes compared to that of voluntary standards, though only TFA reformulation was mandatory in the studies investigated. In cases when TFA reformulation was voluntary, studies show that high-TFA products still remained in the market, meaning that some individuals still had the opportunity to consume high levels of TFA.

The extent to which reformulation strategies were implemented (i.e. number of products reformulated, proportional reduction in products) may explain the absence of measured improvement in nutritional status when reformulation was not widely followed. For all nutrients, it appeared that a reformulation across the maximum of food products (and at a measurable size) was

needed to see significant changes. These conditions limit the choices for consumers to compensate for the changed nutrient. Another reason why some studies observed null effects could be attributed to an inadequate study design. Several studies reported a lack of power, most commonly due to a small sample sizes and a small effect size. Some studies also mentioned that the presence of confounders may have changed the observed effect of the reformulation strategy (e.g. in Austria, the impact of the TFA ban occurred concurrently to an increase in smoking prevalence). In the majority of included studies, the changes in nutrient purchases or intakes were evaluated at an aggregated level (category or households purchases from stores). However, in these studies, it was not possible to evaluate the type of reformulation that occurred. Reformulation has been used to change the food environment through multiple means. One of these is by replacing the original product with a similar looking and tasting product that has an improved nutritional profile. Another method used by manufacturers is adding a new product derived from an existing one, or reducing the portion size of products. In this review, we tried to limit our definition of reformulation to the first change – when an improved-nutrient product replaces the original one. However, it was not easy to differentiate the diverse strategies implemented in studies. The way reformulation could impact consumer choice is not the same for the three strategies listed above although they are often implemented all together. We could not conclude from this review about the different consequences of those strategies.

Reformulation initiatives were often done in conjunction to other initiatives to educate populations. Country-wide reformulation initiatives for the reduction of sodium and TFA were done in conjunction with public health campaigns that informed consumers about the harmful effects of excessive intake of those nutrients. Another type of reformulation included incentivising food products by means of front-of-pack labelling. As such, the effect of nutrient reformulation of food products cannot be untangled from the effect that the labelling had on consumers' food purchasing habits. Further, many reformulation efforts to increase whole grains and fibre were done at the same time that promotion techniques were modified to promote the reformulated products (e.g. with a logo or a claim). For all of these interventions containing different components, the specific effect of reformulation directly on consumer behaviour was only investigated in two studies (17,25). Using panels of household purchases, the two studies estimated the change in nutrient content purchased coming from reformulation, consumers changing their purchase patterns and the introduction/delisting of products.

There were no studies included on the health effect of reducing energy in foods. Most of the reformulation strategies included in this review were iso-caloric changes. This means that when sodium, TFA or sugar were reduced, the energy density of the product was unchanged (e.g. TFA was replaced with other types of fat and sugars by carbohydrates, with the total energy density held constant). Given that reformulation is a strategy designed to gradually improve the food environment,

it may be inadequate to tackle energy density. This is because it is unlikely that major reductions in energy density of products can be achieved in without changing the characteristics of that product.

5 Conclusion

Reformulation of existing food products appear to be a strategy having the potential to improve populations' health. Changes in food composition appear to transfer to a change in the composition of food purchased. Overall, the evidence shows that a reduction in sodium or TFA contents in foods results in a change in the intakes of those nutrients. Further, reductions of TFA in foods tends to be associated with decreased mortality from cardiovascular diseases at a population level. However, many reformulation initiatives lack a robust evaluation of the impact the initiative has on food choices, intakes and health. Hence, the conclusions of this review are based on a subsample of reformulation initiatives, and thus is not a full representation of all reformulation initiatives. Due to limited studies, it was not possible to make a conclusion on the impact of reformulation on the childhood population, though the three studies included show no differential effects for this population. Also, this review suggests that reformulation may be helpful in changing the consumption of some nutrients, but it is not enough to tackle obesity as a global pandemic. Given the challenges to favour healthy choices in populations, reformulation should be encouraged as a strategy to improve the food environment and cardio-vascular disease morbidity. Nonetheless, it should be noted that the effectiveness of reformulation is closely linked to the number of manufacturers changing their products' composition, and the extent to which the nutritional profile of products is improved.

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Part two: Systematic Review and Evidence Synthesis Report on Food Environment Interventions in Schools for the Prevention of Childhood Obesity

1 Background

Obesity is a complex public health issue that requires large-scale, population-based solutions (1-3). Schools are key locations for the prevention of obesity (4). Schools are the place where children spend most of their time; therefore, school meals could have a great impact on food intake and health (4). The food environment is one of the multiple factors that poses an important influence on childhood obesity and overall health. It is defined as a combination of physical, economic, political, and sociocultural surroundings as well as opportunities and conditions that influence food choice. It incorporates geographic access, food availability, food affordability and food quality (5).

The food environment within schools includes canteens, kiosks and vending machines, whilst the food environment outside schools includes food retailers such as convenience stores and fast-food outlets. Regarding vending machines, its use has been previously associated with low dietary quality among children whilst stringent regulated school meals and kiosks seem to be associated with healthier weights (6).

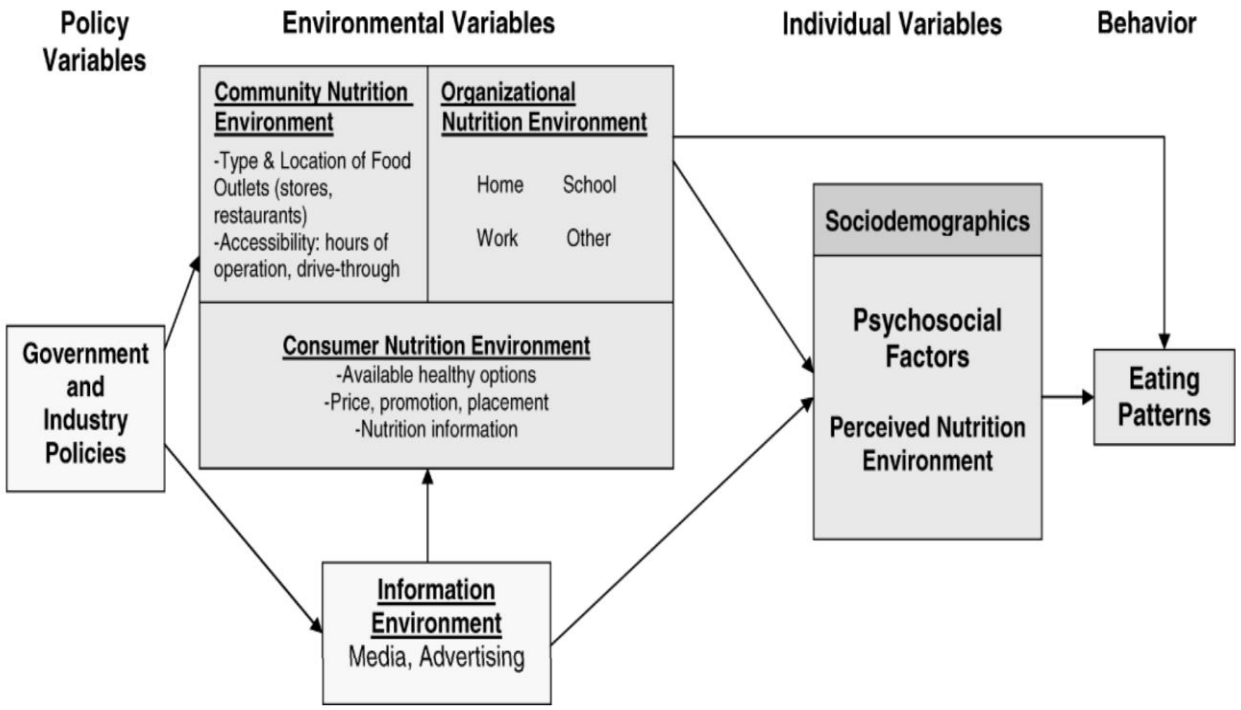

Figure 2: Community nutrition environment Framework (7)

This study aims to assess what food environment initiatives are effective in the prevention of childhood obesity in schools by systematically reviewing the effects of interventions on the food

environment in order to improve children's obesity-related outcomes and by identifying the features of interventions of the food environment in schools that enable or impede their implementation or effectiveness, specifically setting and sociodemographic characteristics. In this review interventions will be defined as a combination of programme elements, strategies, policies or laws that are designed to prevent childhood of obesity.

2 Methods

The search strategy was planned using the PICO framework (population, intervention, comparison and outcome) shown in Table 4. The search strategy was designed in consultation with a specialist subject (health) librarian from Imperial College London. Six databases were searched for relevant articles published in scholarly journals until December 2018 through keyword searches on six databases: CINAHL, EMBASE, Global Health, Medline, Scielo and Cochrane. Full search strategy for each database is available in Appendix 3. The search strategy was refined by conducting sensitivity analysis in EMBASE with a test set of 10 key papers selected from existing systematic reviews. Adjustments to the search strategy concluded once 90% of the key papers were identified. A bias assessment was implemented employing Grading of Recommendations Assessment, Development and Evaluation (short GRADE) to determine the grading quality (or certainty) of evidence and strength of recommendations. The protocol was registered with Prospective Register of Systematic Reviews (PROSPERO, CRD42019125039) using the reference managing software, Rayyan, a second reviewer conducted a reliability check on 10% of abstracts, of which, there were three conflicts that were resolved after discussion and were subsequently included for full-text review.

Table 3: PICO table

PICO feature	Criteria
Population	**Inclusion:** Children 5 to ≤18 years of age. **Exclusion:** Children with a critical illness or severe co-morbidities (e.g. Diabetes) or special populations (e.g. blind, physically disabled).
Intervention(s)	Modification of the food environment in schools to prevent obesity/improve dietary intake.
Comparison(s)	Comparators may include no intervention, or a comparison of the same group before the implementation of the intervention.
Outcomes	**Primary outcomes**: weight and height, per cent fat content, BMI, ponderal index, skin-fold thickness, waist circumference, waist-hip ratio, prevalence of overweight and obesity, Z-score, dietary intake, food purchasing. **Excluded outcomes:** Changes in awareness, knowledge or beliefs. **Adverse outcomes:** detrimental effects on primary outcomes. Cost to participants ($ or time), disappointment at failing to decrease obesity-related outcomes, health inequity.

3 Results

The search strategy, applied to six databases: CINAHL, EMBASE, Global Health, Medline, Scielo and Cochrane, retrieved 4,307 studies, and searches in the grey literature and in the reference list of included studies led to 29 additional papers (Figure 3). The full text of 110 papers was checked against eligibility criteria, and 21 papers were selected (listed in Appendix 4).

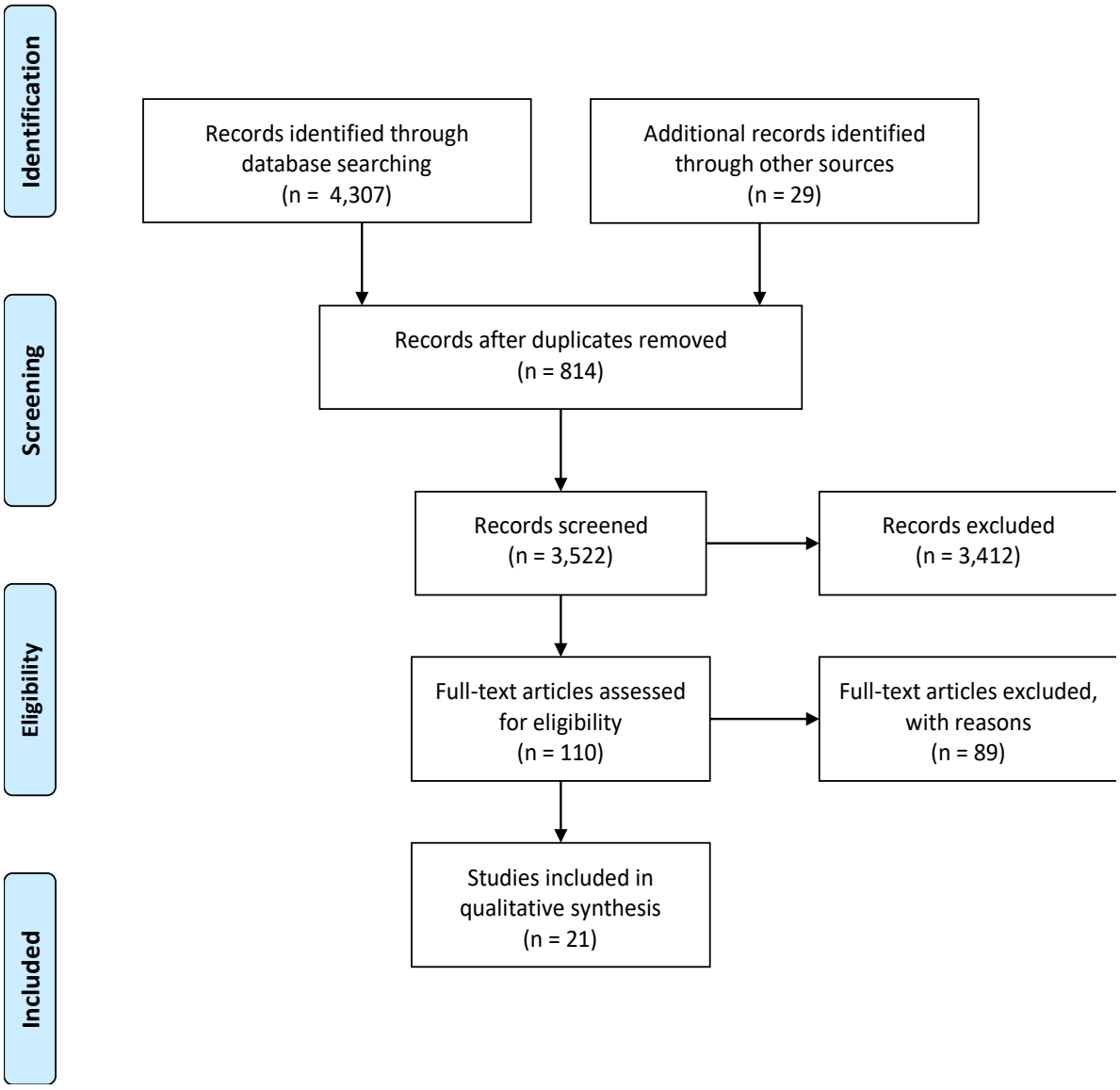

Figure 3: PRISMA flow chart for the screening of studies.

The 21 food environment initiatives included consisted of 13 (62%) interventions, 2 (10%) policies, 3 (14%) laws and 3 (14%) systematic reviews related to food enviornment interventions and obesity. Eight (38% of revised studies) countries were included in this literature review. Four (19%) of the revised interventions focused on the food environment within schools and outside of schools whilst 17 (81%) focused only on the food environment within schools. Four (19%) interventions focused on vending machines. Regarding the study design, one intervention (5%) was a natural experiment, two (6%) were quasi-experiments, one (5%) study was non-randomised, and four (19%) had a

randomized study design. The main outcome was BMI-z score (n = 13, 62%) whilst four studies, (19%) focused on dietary intake or consumption of sugar sweetened beverages (n = 1, 5%). Of the 21 analysed documents, 15 (71%) found a positive relationship within the improvement of the food environment and the prevention of childhood obesity. Furthermore, six (29%) interventions addressed socioeconomic position or social inequalities in their research. Eleven (52%) studies had a physical activity component that formed part of the intervention. Interventions on school food environment most commonly addressed the regulation of vending machines, school stores, cafeterias and menu offerings. Summary of findings may be found in Table 5.

Table 5. General characteristics and summary of results of revised studies

Reference	Inside or around schools?	Country	Intervention/regulation general focus	Positive or negative finding	Do findings fit hypothesis?
Amini et al., 2016	Within	Iran	Canteen modification	(+)	Yes
Bhave et al., 2017	Within	India	Fast-food elimination	(-)	No
Coleman et al., 2012	Within	USA	Unhealthy food elimination	(-)	No
The healthy study group, 2010	Within	USA	Cafeteria, vending machines, a la carte options, snack bars, school stores	(-)	No
Garcia gabriel et al., 2009	Within	Brazil	Healthy food in canteens	(-)	No
Datar et al., 2017	Within	USA	Competitive foods and beverages in schools	(+)	Yes
Taber et al., 2013	Within	USA	School meals	(+)	Yes
Bourdeaudhuij et al., 2011	Within	Europe	School-based interventions promoting both physical activity and healthy eating	(+)	Yes
Belansky et al., 2010	Within	USA	Local wellness policy on school nutrition	(-)	No
Ermetici et al., 2016	Within	Italy	Alternative healthy vending machines	(+)	Yes
Fu et al., 2018	Within	China	School Accreditation Scheme	(+)	Yes
Nanney et al., 2016	within	USA	School vending machines and school stores	(+)	Yes
Cullet et al., 2009	Within	USA	National School Lunch Program meal and snack bar/a la carte offerings	(-)	No
Mobley et al., 2013	Within	USA	School meals	(+)	Yes
Hanks et al., 2012	Within	USA	Convenience line with healthy options in cafeterias	(+)	No
Heelan et al., 2005	Both	USA	Healthier school food environment strategies	(+)	No
Kain et al., 2004	Both	Chile	Healthy kiosks	(+)	No
Rausch herscovici et al., 2013	Both	Argentina	Healthy Snack Bars	(+)	Yes
Reilly et al., 2018	Within	Australia	Canteen	(+)	Yes
Sharma et al., 2016	Both	USA	school-based food co-op	(+)	No
Williamson et al., 2012	Within	USA	School cafeteria modifications	(+)	NA

4 Discussion

4.1 Effect of laws and policies

Standards for healthier school meals include the increase of fruits and vegetables, the replacement of full fat dairy products with reduced fat dairy products and refined carbohydrates with whole grains. In the US, it has been shown that the implementation of laws that require stringent nutrition standards contributes to the reduction of obesity prevalence: in states where there were stringent school lunch regulations childhood obesity prevalence was lower (8). Furthermore, although children of lower SEP were more exposed to obesity than children of higher SEP, children of low income families that inhabited states with stringent nutrition standards in schools tended to be less obese than those children in states with no school meal regulations. It was also observed that students in states with stricter nutrition standards in schools consumed fewer calories and less fat and sugar at school and did not gain as much weight compared to students in states with less stringent standards (9-11). In sum, school meals are a good starting point to tackle childhood obesity.

Furthermore, it was observed that when schools implemented a multisystem approach (environment, education and services) to tackle obesity and this system was continuously monitored, the reduction of obesity was more effective. As an example of multisystem approach, the EatSmart programme implemented in primary schools in Hong Kong included administrative measures, the provision and availability of healthy lunch and snacks, complementary nutritional education, advertisement and shouldered the responsibility of advocating a healthy eating environment in the school sector by the improvement of the food environment (healthy availability and accessibility of food). Part of the success of this programme was the monitoring and the motivation for schools to obtain an accreditation and the availability of precise nutritional guidelines that were required be implemented for full accreditation (12).

Two studies analysed the effect of state competitive food and beverage regulations on childhood overweight and obesity. They reported a significant association between a lower BMI z-scores, lower odds of overweight or obesity, and better dietary outcomes in states with a strong food or policy compared to states with no regulatory policies (13) (14).

One negative aspect of the policies in the USA included in the reviews was the lack of precision of the food meal policies and therefore the lack of effective implementation in schools. Another limitation that these policies confront is the political pressures from the food industry which demand inclusion of food items that can increase the caloric intake of children in schools. In sum, canteen personnel and managers in schools requires technical and financial assistance to effectively implement evidence based practices (15).

Among the most common nutrition guideline components that were addressed in policies were the regulation of vending machines, school kiosks and a la carte food options.

4.2 Programmes and interventions

There were seven studies that assessed the influence of vending machines on children's weight. Healthy changes in vending machines, either by removal or by replacing food items by healthy choices, can represent an easy way to change the food environment within schools, although a continuous supervision of sales for nutritional quality continuity is important. In one of the revised studies, the weight of students and the nutrition environment improved significantly (16). The regulation of vending machines was also associated with the decrease of SSB consumption in children (17). However, when the availability of SSB remains within or outside schools, partial SSB restrictions seem to not be effective in reducing their intake (18)

Even though there was a positive correlation between the modification of the availability of food within schools and the prevention of obesity, studies like the Healthy Experience (19) did not differentiate between the intervention and control group and therefore could not be considered for this review

In sum, when it comes to vending machines, when the availability of healthy and low calorie foods increase (including the elimination of SSB), the SSB availability is eliminated and this is combined with effective labelling and reduced prices, students tend to make healthier choices that contribute to lower BMIs (20).

5 Conclusions

Schools offer many opportunities for developing obesity-prevention strategies. Many environmental changes, such as the increase in availability of vegetables, the provision of healthy meals, the regulation or banning of vending machines and SSB can contribute to the reduction of childhood obesity. Limited evidence shows that schools can provide more healthful food options without economical loss by limiting non healthy foods and key modifications in the availability of foods (21). Achieving a healthier school environment is a long-term project involving multiple strategies of education and incentives, as well as regulation. These must involve staff, parents and students. A school-based multicomponent intervention conducted at both environmental and individual levels may be effective for reducing adiposity measures mainly in adolescents with overweight/obesity. Long-lasting reforms require involvement from government such as enforcement and continuous supervision of the implementation of regulations. Effective interventions for the prevention of obesity must focus on full ban of SSB, the increase in availability and accessibility of fruits and particularly vegetables for children from an early age and multisystem approaches that include the collaboration, training, education and integration of the school staff, parents and students to increase acceptability, adaptability according to the local needs and sustainability of programmes. Once the environment is altered then it is easier to modify individual behaviour.

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Appendix 1: search strategy on Medline for part one (systematic review on reformulation)

1	sodium, dietary/ or Sodium Chloride/ or sodium chloride, dietary/ or exp ENERGY INTAKE/ or dietary fats/ or Fats, Unsaturated/ or Fatty Acids, Unsaturated/ or Dietary Sugars/ or Dietary fiber/ or exp Nutritive value/ or whole grains/ or dietary carbohydrates/ or dietary proteins/
2	(salt or sodium or sugar* or energy or calori* or saturated fat* or "trans fat*" or trans?fat* or fibre* or fiber* or whole?grain* or wholegrain* or "whole grain*" or carbohydrate* or protein* or fatty acid* or nutrient*).ab.
3	1 or 2
4	reformulat*.ab.
5	3 and 4
6	((salt or sodium or sugar* or saturated fat* or "trans fat*" or trans?fat or TFA) adj5 (target* or limit* or restrict* or regulat* or reduc*)).ab.
7	((fibre* or fiber* or whole?grain* or wholegrain* or whole grain*) adj5 (improv* or increas* or promot* or favo?r*)).ab.
8	((energy or calori*) adj5 (reduc* or limit* or target*)).ab.
9	(((improve* or better or enhance* or health*) adj5 (composition* or profile*)) and (nutrition or food or nutrient)).ab.
10	5 or 6 or 7 or 8 or 9
11	(sold or sales or intake* or purchase* or consumption or diet* or overweight or diabetes or bmi or cholesterol or "coronary heart disease" or cardiovascular or "dietary habit*" or "heart disease risk" or "consumer behaviour" or "consumer behavior" or "blood pressure" or hyperglyc?emia or "glucose tolerance" or "insulin resistance" or hypertension or hyperlipidemia or dyslipidemia).ab.
12	(grocery or groceries or store or stores or supermarket or supermarkets or retailer or retailers or market or markets or food industry or food dispensers or vending or point-of-purchase or point-of-selection or package* or packages or front-of-pack).ab.
13	((regulat* or polic* or legislation* pledge* or ban or bans or standard or standards or strategy or strategies or intervention* or restriction*) and food*).ab.
14	12 or 13
15	exp animals/ not humans.sh.
16	(restaurant* or fast-food* or "fast food*" or fastfood* or takeaway* or take-away* or "take-away*").ab.
17	14 or 16
18	10 and 11 and 17
19	18 not 15

Appendix 2: List of included studies in part one (systematic review on reformulation)

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Zupanič, N., Hribar, M., Kupirovič, U.P., Kušar, A., et al. (2018) Limiting trans fats in foods: Use of partially hydrogenated vegetable oils in prepacked foods in Slovenia. *Nutrients*. [Online] 10 (3), 355. Available from: doi:http://dx.doi.org/10.3390/nu10030355.

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Appendix 3: Search strategy on EMBASE for part two (systematic review on school environments)*

*Search strategies of other databases are available upon request.

Embase Classic + Embase 1947 to 2019 February 14

No.	Searches	Results
1	exp catering service/	18268
2	restaurant*.mp.	6402
3	exp fast food/	6792
4	supermarket*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	4066
5	chain grocer*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	30
6	canteen*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	1001
7	cafe*1.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	4921
8	kiosk*1.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	517
9	vending machine*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	679
10	exp food availability/	3858
11	fastfood*.mp.	52
12	(food adj3 supply).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	4937
13	(food adj3 desert*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	267
14	(food adj3 swamp*1).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	25
15	(food adj3 environment*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	8937
16	(food adj3 provi*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	5670

17	(food adj3 retail*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	1036
18	(food adj3 store).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	574
19	(food adj3 stores).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	1013
20	(food adj3 access*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	4988
21	(food adj3 availab*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	9840
22	(food adj3 diver*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	1256
23	fast food*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	8445
24	(food adj3 outlet*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	748
25	(food adj3 shop*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	674
26	(market*1 adj3 food*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	1290
27	(market*1 adj3 fruit*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	189
28	(farmer* adj3 market*1).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	468
29	(market*1 adj3 vegetable*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	228
30	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29	68378
31	exp obesity/	478449
32	obes$.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	533791
33	exp body weight gain/	8679
34	exp body weight change/	1761
35	BMI.mp.	267305

36	exp body mass/	369486
37	body mass index.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	236886
38	overweight.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	94592
39	overeat$.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	3511
40	over eat$.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	567
41	weight.mp.	1451775
42	31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41	2056429
43	exp school/	367682
44	school*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	692337
45	43 or 44	896812
46	exp child/	2820018
47	child*.mp.	2779944
48	exp adolescent/	1550634
49	adolescen*.mp.	1644397
50	teen*.mp.	39437
51	boy*1.mp.	201883
52	girl*1.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	204479
53	kid*1.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	11559
54	youth*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	83967
55	juvenile*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	147124
56	p?ediatric*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]	575378
57	46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56	4321180

58	30 and 42 and 45 and 57	2329
59	(exp animal/ or nonhuman/) not exp human/	6809919
60	58 not 59	2320

7 Appendix 4: List of included studies in Part two (Food Environment Intervention Review)

1. Amini M, Djazayery A, Majdzadeh R, Taghdisi MH, Sadrzadeh-Yeganeh H, Abdollahi Z, et al. A school-based intervention to reduce excess weight in overweight and obese primary school children. Annals of Nutrition and Metabolism. 2015;1):409.

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3. Bhave S, Pandit A, Yeravdekar R, Madkaikar V, Chinchwade T, Shaikh N, et al. Effectiveness of a 5-year school-based intervention programme to reduce adiposity and improve fitness and lifestyle in Indian children; the SYM-KEM study. Archives of Disease in Childhood. 2016;101(1):33-41.

4. Bourdeaudhuij Id, Cauwenberghe Ev, Spittaels H, Oppert JM, Rostami C, Brug J, et al. School-based interventions promoting both physical activity and healthy eating in Europe: a systematic review within the HOPE project.

5. Chriqui JF, Turner L, Taber DR, Chaloupka FJ. Association between district and state policies and us public elementary school competitive food and beverage environments. JAMA Pediatrics. 2013;167(8):714-22.

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8. Datar A, Nicosia N. The Effect of State Competitive Food and Beverage Regulations on Childhood Overweight and Obesity. Journal of Adolescent Health. 2017;60(5):520-7.

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14. Kain J, Concha F, Moreno L, Leyton B. School-based obesity prevention intervention in chilean children: Effective in controlling, but not reducing obesity. Journal of Obesity. 2014;2014 (no pagination)(618293).

15. Kovalskys I, Herscovici C, De Gregorio V, Ruben MJ, Schvartz M, Tron M, et al. A school based obesity prevention programmed in Rosario, Argentina: Impact on Intake changes of healthy and unhealthy foods. Obesity Reviews. 2010;1):469.

16. Mobley CC, Stadler DD, Staten MA, El ghormli L, Gillis B, Hartstein J, et al. Effect of nutrition changes on foods selected by students in a middle school-based diabetes prevention intervention program: The HEALTHY experience. Journal of School Health. 2012;82(2):82-90.

17. Nanney MS, MacLehose RF, Kubik MY, Davey CS, O'Connell MJ, Grannon KY, et al. School Obesity Prevention Policies and Practices in Minnesota and Student Outcomes: A Longitudinal Cohort Study. American Journal of Preventive Medicine. 2016;51(5 Supplement3):656-63.

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