Environmental components of childhood obesity prevention interventions: an overview of systematic reviews

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Abbreviations: % BF, percentage body fat; AMSTAR, Assessment of Multiple Systematic Reviews; BMI, body mass index; EPPI-Centre, Evidence for Policy and Practice Information and Co-ordinating Centre; ES, Effect Sizes; HSSS, High in Fat, Sugar and Salt, OR, odds ratio; MVPA, Moderate-Vigorous Physical Activity; PA, Physical Activity; PE, Physical Education; SE, standard error; SFT, skin fold thickness; SR, Systematic Review; SSB, Sugar Sweetened Beverage; WC, waist circumference

Abstract

Childhood obesity has a complex multi-factorial aetiology grounded in environmental and individual level factors that affect behaviour and outcomes. An ecological, systems-based approach to addressing childhood obesity is increasingly being advocated. The primary aim of this review is to summarise the evidence reported in systematic reviews on the effectiveness of population-level childhood obesity prevention interventions which have an environmental component. We conducted a systematic review of reviews published since 1995, employing a standardized search strategy in nine databases. Inclusion criteria required that reviews be systematic and evaluated at least one population-level, environmental intervention in any setting aimed at preventing or reducing obesity in children (5-18 years). Sixty-three reviews were included, ten of which were of high quality. Results show modest impact of a broad range of environmental strategies on anthropometric outcomes. Systematic reviews vary in methodological quality, and not all relevant primary studies may be included in each review. To ensure relevance of our findings to practice, we also report on relevant underlying primary studies, providing policy-relevant recommendations based on the evidence reviewed. Greater standardization of review methods and reporting structures will benefit policymakers and public health professionals seeking informed decision-making.

Introduction

Childhood obesity is a global public health challenge due to concerns about increasing prevalence [1,2], the likelihood of obesity tracking into adolescence and adulthood [3–5], and its association with a range of adverse health outcomes [6,7]. Increasingly, an ecological, systems-based approach to addressing

obesity that acknowledges its complex multi-factorial aetiology and recognizes the policy, environmental, and individual level factors that influence behaviour and outcomes is being advocated [8,9]. This entails recognition of a broad range of physical, socio-cultural, economic and political dimensions within which individuals are embedded, as well as attributes and behaviours of individuals themselves [10]. Education-based interventions to address childhood obesity have had little success [11,12] as changing human behaviour within an 'obesogenic' environment that does not support healthy choices is difficult to achieve and sustain [13]. Multi-component interventions where several environmental aspects are addressed simultaneously may lead to more sustainable results [8,14]. Childhood and adolescence are particularly vulnerable life stages requiring protective social and public health policies [15]. This is an additional challenge for decision-makers often seeking easy solutions for rapid implementation during their relatively short term in office, and represents an all the more pressing rationale for providing them with up-to-date evidence on the range and effectiveness of environmental, population-level interventions to prevent or help reverse childhood overweight and obesity. We focus on synthesising systematic reviews as they can be useful decision-making tools that objectively summarize large amounts of information in a format that is of relevance to health practitioners, policy makers and researchers in order to guide health policy, clinical guidelines and research efforts [16,17]. The applicability of review findings to practice has also been called into question, with reviews often being criticized for their narrow scope and for lacking context-specific details that are essential for knowledge-translation into policies [18,19]. To ensure relevance of our findings to practice, we also investigate and report on relevant underlying primary studies, providing policy-relevant recommendations based on the evidence reviewed.

Existing systematic reviews

Several reviews summarising the effects of built or policy environmental change on obesity outcomes have been published [20–27]. The Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI-Centre) has mapped out systematic reviews (SRs) on social and environmental interventions to address childhood obesity [28], and a number of overviews of systematic reviews [29,30] on school-based

childhood obesity interventions [18,31–33] are available. Overviews on the impact of the built environment on physical activity have also been conducted [34,35], however, to the best of our knowledge, no overview of reviews focusing specifically on environmental interventions to prevent or reduce excess weight in children exists.

Aim of this review

The primary aim of this review is to summarise the evidence reported in SRs on the range and effectiveness of population-level interventions aimed at preventing overweight or obesity in children which have an environmental component. We adopted a broad interpretation of what is meant by an 'environmental intervention', defined as a strategy that involves changing the physical surroundings and social, economic or organizational systems to facilitate healthy choices and enable people to adopt healthy behaviours without requiring significant motivation on the part of the individual. 'Effectiveness' was defined as achieving a beneficial or protective, statistically significant, anthropometric outcome. A secondary aim is to assess and critique the methodological quality of included systematic reviews.

Methods

An overview of systematic reviews was conducted. Reviews were judged to be systematic if they synthesised peer-reviewed articles; explicitly reported pre-defined objectives, search strategy details and inclusion and exclusion criteria; and clearly identified all included studies. The full text of potentially eligible environmental interventions reported upon in included SRs was also reviewed, and relevant study data extracted.

Search strategy

We conducted a search of free text terms and subject headings from January 1995 to May 2015, using the Population, Intervention, Comparison and Outcome model [36], to describe the target population (healthy children and adolescents), intervention (population-level prevention of obesity), comparison (SRs), and outcome (anthropometric outcomes). The initial search string was developed in Medline

(Appendix S1) and further refined for use in the different databases: Database of Abstracts of Reviews of Effects (DARE), Medline, Embase, PsychINFO, CINAHL PLUS, SCOPUS, Social Policy and Practice Database, Database of promoting health effectiveness reviews (DoPHER), and CENTRAL. Reference lists of identified SRs were manually searched to identify any additional reviews. A grey literature search in TRIP and Google Scholar was performed. Project websites and those of collaborative groups that conduct SRs of public health interventions (e.g. EPPI-Centre [28]; the Community Guide [37]; Health Systems Evidence [38]; Health Evidence Network [39]; Agency for Healthcare Research and Quality [40] ; Centre for Reviews and Dissemination [41]; and the National Institute for Health and Care Excellence [42]) were also searched for relevant publications, and their bibliography reviewed. No language restrictions were applied.

Inclusion and exclusion criteria

Systematic reviews were required to be: published between January 1995 and March 2015; reviewing interventions to prevent obesity and overweight in children and adolescents aged 5 - <18 years; assessing at least one population-level intervention with an environmental component; and reporting anthropometric outcome data on the effectiveness of interventions (i.e. using a standardized or accepted measure of obesity such as body mass index (BMI), BMI z-score, waist circumference (WC), skin fold thickness (SFT), percentage body fat (% BF), overweight or obesity prevalence and other anthropometric measures associated with obesity [43]).

SRs were excluded if they assessed interventions: aimed at adults only; which did not include any anthropometric outcomes, or where the only outcome of interest was behaviour modification (i.e. increasing physical activity, decreasing sedentariness or improving diet); aimed solely at treatment of existing obesity or expressly targeted weight loss (e.g. pharmacological interventions; bariatric surgery; metabolic or weight loss clinics) or aimed at participants with diagnosed complications linked to obesity; and that solely involved interaction between health professionals and individuals or groups within a clinical setting.

SRs focusing on treatment of existing obesity were excluded as it is typically harder to lose weight than to prevent an initial weight gain. Since our main interest was population-level preventive environmental

interventions, SRs exclusively assessing studies conducted in controlled clinical or laboratory settings were not considered relevant. In the case of reviews that contained a mix of interventions (e.g. aimed at both adults and children; reviewed both treatment and preventive interventions; or reported both behavioural and/or anthropometric outcomes), only data of preventive primary studies aimed at children and which had clearly defined anthropometric outcomes were extracted. Interventions in the included SRs could be multi-component or single-component. Multi-component interventions that combined individual and population-level elements were considered eligible if the population-level component was judged to be more than simple reinforcement of an individual-level intervention.

SRs were included if at least one reviewed primary study described a structural/policy change to the state, community, school, and/or home as a major component of a population-level, obesity-prevention intervention. Policies could be either formal legislative or organizational in scope [44]. Eligible policies within the school setting included changes in school lunch nutrition standards or banning of vending machines. Provision of physical activity (PA) opportunities after school hours was considered to be a population-level environmental intervention, as these can potentially be made available to children living around the school neighbourhood who are not themselves students at the school. However, for the purposes of this overview, modification of school curricula to improve dietary or PA behaviour (e.g. increasing the number, duration or quality of physical education (PE) or nutrition education lessons during school hours through staff training or employing professionally-trained staff; increase in recess time etc.) in isolation of complementary environmental approaches was not considered to be eligible as such interventions have already been adequately described elsewhere [31–33]. Additionally, evidence suggests that studies promoting healthier behaviour rather than focusing on reducing adiposity are less effective at reducing anthropometric outcomes [45,46]. Eligible community interventions included modifications to the built environment (e.g. creation of walking pathways), whereas acceptable alterations to the home environment could include installation of television monitors. We also included exergaming interventions, as this novel approach to modifying children's leisure-time behaviour can potentially be delivered at population level. Conversely, interventions that focused solely on imparting

information and knowledge (e.g. educational campaigns; nutrition classes) were ineligible because such interventions aim to directly alter individual behaviour, rather than modify children's surroundings.

Systematic review selection and data extraction

DC and KG independently examined titles, abstracts and full-text articles, and extracted data, resolving any disagreement through discussion with a third author (CK). Within each review, interventions having an eligible environmental component that reported on outcomes of interest were identified. The methodological approach of each review (databases searched; language restrictions; inclusion and exclusion criteria; synthesis method; quality evaluation of trials; stated implications for practice and research; limitations; and funding sources) and documented primary review outcome indicators and main findings were recorded. All review-level data can be found in Appendices S1-S7. To avoid biased post hoc decisions, a review protocol based on Cochrane handbook recommendations [47] was published on PROSPERO [48] prior to starting the review process.

Quality of included reviews

Two reviewers (DC and KG) independently assessed the methodological quality of the included reviews using the 'Assessment of Multiple Systematic Reviews' (AMSTAR) tool [49]. Reviews were categorised into high (AMSTAR score 8 – 11), medium (5 – 7) or low (0 – 4) based on the Canadian Agency for Drugs and Technologies in Health evaluation criteria [50]. Any disagreement was resolved through consensus.

Identifying relevant primary studies included in the reviews

Most reviews only reported on the direction of effect on outcomes and did not report on the magnitude of effect, making it necessary to review the full text of primary studies in order to identify whether an intervention had a desirable or significant effect. Thus a list of all eligible primary studies (n=76) included in the included reviews was compiled in order to cross-check eligibility, assess clarity of information provided in SRs and to compile a comprehensive, useful list of existing environmental options. We collected information on study design, study setting (school, community, home, state),

characteristics of participants (including sample size, age), type of intervention (including type, intervention duration, length of follow-up, intervention components and source of funding), and outcome data (including difference in change from baseline for intervention vs control, direction and significance of effect). Effects without p-values, confidence intervals or a written statement regarding statistical significance were classified as non-significant. For multiple anthropometric outcomes, one or more statistically-significant benefit in any relevant outcome was counted as an overall beneficial study regardless of the number of non-significant outcomes, and vice-versa. All extracted intervention-level data can be found in Appendix S6. We did not report on quality of primary studies.

To correct for potential discrepancies between reported results for eligible environmental interventions, it was necessary to review the full text of each eligible primary study summarized in SRs. We were interested in the extent to which primary studies with environmental components were correctly identified or described as such in different SRs. In other words, would a policy-maker assessing the evidence on environmental obesity-prevention interventions be able to identify the studies of interest within an SR? We found that in many reviews, primary studies might not necessarily be classified outright as being environmental in nature, yet careful assessment of the information provided in the SR would enable an environmental component to be identified. The converse is also possible. For example, the study by James et al. 2004 [51] is classified in at least one SR [52] as having an environmental component, yet we determined the intervention to be cognitive and behavioural in nature.

Results

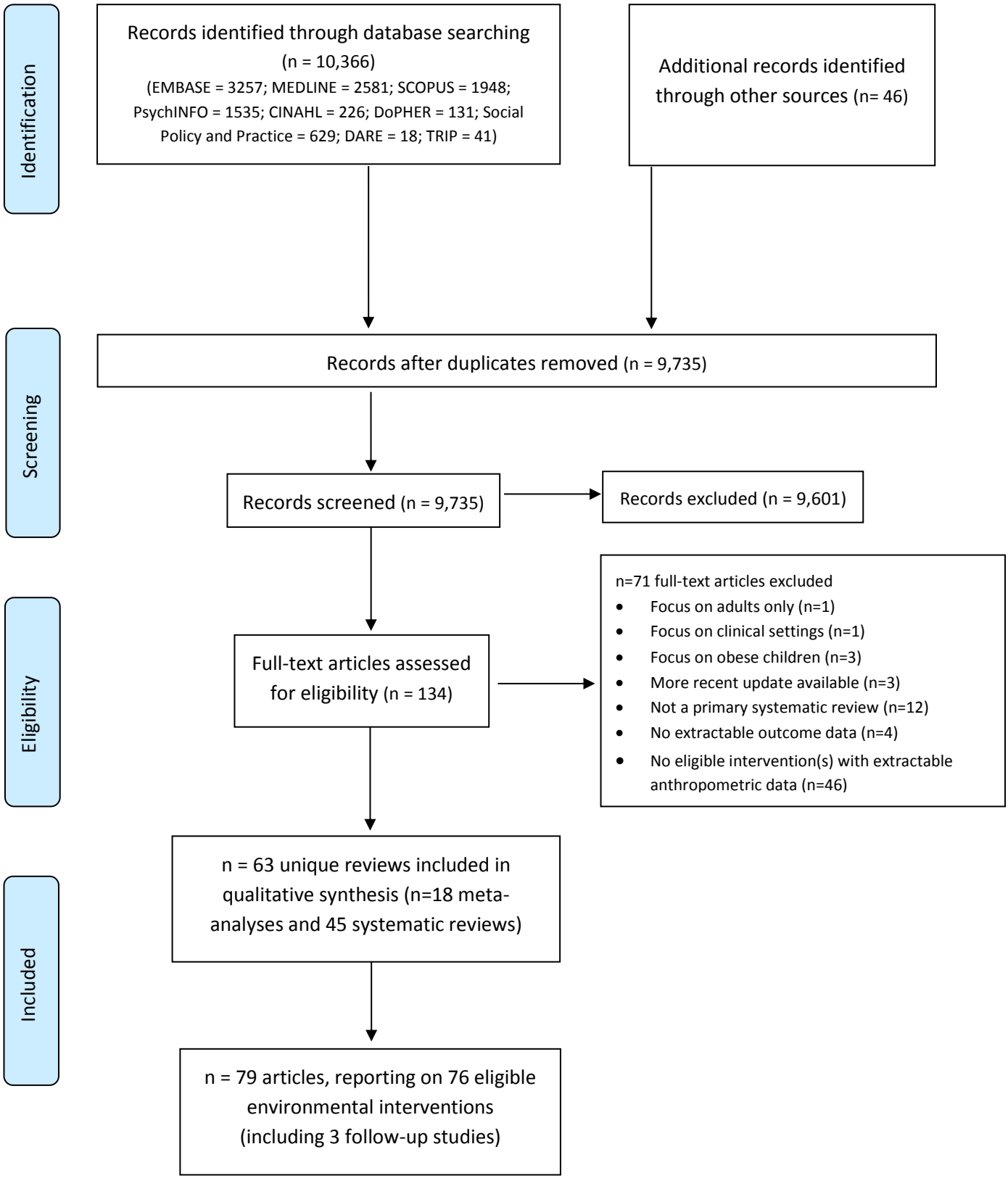
Review characteristics

We included 63 systematic reviews (Figure 1) in our study. These searched databases up to 2014, reporting on a wide range of primary studies. Seven reviews focussed specifically on policies or environmental strategies, five explored mainly behavioural interventions, four looked at exergaming or active video games as their intervention of interest, and two concentrated on educational interventions in the school. The remainder (n=45) summarised the effects of a broad mix of interventions. The overall aim of all SRs was broadly to summarise obesity prevention studies – however there was substantial

heterogeneity in terms of setting, population of interest, type of intervention assessed, outcomes considered, review methodology, presentation of results and interpretation of findings (Appendix S3, S4). Eighteen of the reviews were meta-analyses, while the remaining 45 SRs provided a narrative synthesis of results. Twenty-eight SRs restricted their search to articles published in English only, eight SRs did not report on language in their search strategy, while the remainder widened their search to two or more languages. When analysed by setting, 28 assessed school-based studies exclusively [53–80], six summarised community-based interventions [24,81–85], two reviews discussed home or family based interventions [86,87], and the remainder (n = 27) did not specify study settings in their search strategy [45,52,88–111]. Most reviews (62%, n=39) assessed quality of the primary studies.

Review quality

Over four-fifths (84%) of the included reviews were assessed to be of low (n = 23) or medium (n = 30) quality according to AMSTAR criteria (Appendix S5). Ten reviews, six of which were meta-analyses, were judged to be of high quality [52,60,76,81,87,91,92,99,104,111].



Source: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

Figure 1: PRISMA flow chart of selection procedure

Summary of potentially effective environmental strategies according to high quality reviews

Fewer than half (n = 26 or 42%) of all SRs specifically discussed built or policy environmental strategies, with most stating that such strategies show promise but require further rigorous assessment and evaluation of social, psychosocial, behavioural, and anthropometric outcomes to prove benefit (Table 1). Overall, reviews were cautious about providing definitive recommendations on which environmental strategies should be implemented. This was due to the often suboptimal methodological quality of primary studies and the challenge of distinguishing which specific components of interventions were necessary to achieve positive outcomes [91,111]. Thus, few SRs provided clear statements on the importance of environmental strategies to address childhood obesity, and findings were mixed. However, some environmental interventions were highlighted across high-quality reviews as being particularly promising and likely to be effective in preventing or reducing overweight and obesity in children, especially if part of long-term comprehensive efforts [76]. These included increased PA sessions [111]; purchase of PE equipment [60]; improvements in nutritional quality of the food supply in schools [111]; ; creation of environments and cultural practices that support consumption of healthier foods and PA at school [60,111] and at home [76,87,92,111]; and capacity building or professional development for teachers to implement health promotion strategies and activities [111].

Table 1: Systematic review comments on environmental strategies to prevent childhood obesity

Environmental interventions….	**No. of reviews**	**References: first author and year of publication**
are promising, effective strategies that can support and increase effectiveness of other obesity prevention programmes	10	Avery 2015 [88], Brandt 2010 [53], De Bourdeaudhuij 2010 [58], Ickes 2014 [62], Katz 2008 [65], Kesten 2011 [100], Kropski 2008 [67], Peterson 2007 [71], Sharma 2007 [72], Sobol-Goldberg 2013 [76]
should be prioritised or at least considered for obesity prevention	7	Beauchamp 2014 [89], Budd 2006 [55], Ickes 2014 [62], Kamath 2008 [52], Sharma 2007 [72], Showell 2013 , Stice 2006 , Waters 2011
minimise health inequalities	1	Beauchamp 2014 [89]
[specific examples of environmental interventions provided]	15	Avery 2015 [88], Beauchamp 2014 [89], Brandt 2010 [53], Budd 2006 [55], Chriqui 2014 , De Bourdeaudhuij 2010 [58], de Sa 2008 , Kamath 2008 [52], Katz 2008 [65], Kropski 2008 [67], Li 2008 [112], Peterson 2007 [71], Sharma 2007 [72], Showell 2013 [87], Waters 2011 [111]
are of unclear effectiveness or viability	2	Marsh 2014 [86], Towns 2014 [109]
require further rigorous assessment/evaluation of associated policy and environmental, social, psychosocial, behavioural, and biological outcomes	10	Calancie 2015 [24], Chriqui 2013 [94], de Sa 2008 [59], Ickes 2014 [62], Jaime 2009 [63], Katz 2008 [65], Peterson 2007 [71], Reilly 2003 [107], Stice 2006 [45], Waters 2011 [111]
need for more widespread recognition of environmental influences operating counter to school activities	5	Budd 2006 [55], De Bourdeaudhuij 2010 [58], Katz 2008 [65], Peterson 2007 [71], Stice 2006 [45]
need for research to explore feasibility, cost and effectiveness of environmental strategies	4	Calancie 2015 [24], Jaime 2009 [63], Knowlden 2013 [66], Showell 2013 [87]
need for research on options outside of the school	9	Calancie 2015 [24], Chriqui 2013 [94], Chriqui 2014 [95], de Sa 2008 [59], Jaime 2009 [63], Kesten 2011 [100], Knowlden 2013 [66], Peterson 2007 [71], Reilly 2003 [107]
need for improved longitudinal data with obesity-related outcomes	4	Chriqui 2014 [95], De Bourdeaudhuij 2010 [58], Jaime 2009 [63], Katz 2008 [65]

Effect Sizes reported in Meta-Analyses

The meta-analyses identified in our search (Appendix S3, S4) reported BMI/zBMI reduction effect sizes (ES) for interventions aiming to prevent obesity in children. While it is not possible to extract the contribution to overall effect size of specific environmental elements within these interventions, the meta-analyses reported a wide range of effect sizes for different types, settings and duration of interventions. Across all settings, strategies targeting sedentary behaviour emerged as the most consistently successful [57,65,104,110], with ES ranging from -0.14 [-0.23, -0.05] [110] to -0.35 [-0.63, -0.06] [65]. The impact of physical activity interventions was unclear [52,65,79,111], as ES ranged from potential increases in BMI +1.87 [1.31, 2.42] [65] to reductions of -0.11 [-0.19, -0.02] [111]; whereas dietary interventions [52,57,65,111] showed a consistently modest beneficial impact, with an ES ranging from -0.02 [-0.07, 0.02][79] to -0.39 [-0.56, -0.23][65]. Williams et al. calculated effect sizes on BMI for provision of school breakfast or lunch to students in isolation [79]. Effect sizes for these interventions varied from a disappointing BMI increase of +0.04 [-0.19, 0.27] following the introduction of school lunches, to a minimal reduction in student BMI of -0.08 [-0.14, -0.02] following the introduction of a healthy school breakfast. Possibly reflecting the wide spread of ES above, meta-analyses assessing combined dietary and PA interventions [52,65,79,91,104,111] calculated more modest ES ranging from 0.00 [-0.47, 0.47] [79] (no impact) to a small reduction in children's BMI of -0.18 [-0.27,-0.09] [111]. With regards to the settings where interventions took place, Wolfenden et al. [85] reported a minor but beneficial (ES: -0.09 [-0.16, 0.02]) impact resulting from community-based interventions of any type, whereas a number of meta-analyses of school-based interventions [64,65,68,74,76,77,79,111] reported a mix of results, with ES ranging from +0.17 [-0.38, 0.72] [64] to -029 [-0.45, -0.14] [65]. Duration of intervention [45,52,57,77,111] also seems to positively influence intervention outcome, as interventions lasting more than 12 months showed ES ranging from -0.095 [77] to -0.12 [-0.21, -0.03] [111]. Lastly, specific components of interventions reviewed in meta-analyses included parental involvement [57,76,77], which resulted in small but consistently positive ES ranging from -0.094 [p = <0.001] [77] to -0.151 [-0.334, 0.031] [76]; and substitution of SSB with zero-calorie replacements [99,105], where results are less clear (ES: +0.06 [-0.01, 0.13] [99] to -0.17 [-0.39, 0.05] [105]).

Primary studies

Appendix S6 reports on primary study characteristics including the range of environmental strategies undertaken and their effect on anthropometric outcomes, whereas Appendix S7 illustrates the overlap of all eligible primary studies (n = 76) across all SRs. Around half (48%; n = 37) of the primary studies did not result in a significant desirable effect on anthropometric outcomes (i.e. improvement in outcome of intervention compared to control), with some studies showing significant worsening outcomes for the intervention group [113–115] or mixed results [116–118]. Few RCTs consisted of purely environmental strategies or reported outcome data that can be attributed to environmental change directly. Most studies incorporated modifications to the environment as part of an overall strategy that included nutrition/PE education and curricular changes, and hence it is difficult to disentangle the impact of the environmental component from the overall impact.

Effective environmental strategies discussed in systematic reviews

A total of forty eligible primary studies across all SRs demonstrated a significant beneficial or protective effect on one of the anthropometric measures of childhood overweight and obesity (see Appendix S6 for study outcomes), and were reviewed in further detail to identify potentially effective environmental components. Almost all were primarily school-based, with the exception of two interventions that mainly took place in the home [119,120]. The majority contained an educational or information-dissemination component aimed at reinforcing the overall aim of each study. Environmental programme components - with or without additional behavioural and educational components - which appear to have contributed to the beneficial effects observed are outlined below. Anthropometric outcomes (changes from baseline for intervention groups compared to control groups) are provided where the intervention consisted mainly of a single environmental element.

- **Improvement of overall school food environment:** measures included implementation of school nutrition standards/policies; removal of vending machines selling sugar sweetened beverages (SSB) or snacks high in fat, sugar or salt (HFSS); banning sales of HFSS food; reformulation of school lunches to reduce fat content [116,117,121–126]

- **Purchase of new PE/sports equipment:** this was made available during recess and at other times throughout the school day, as well as during PE lessons [122,124,125,127–131]
- **Daily formal PA session organized after-school:** typically lasting 90 minutes to two hours, involving a substantial proportion of time spent doing MVPA, with or without a healthy snack provided to participants [123,132–136]. Three studies assessing impact of two-hour after-school interventions reported improvements in BMI ranging from -0.16 [-0.40, 0.07] [135] to -0.45 [-0.79, -0.12] [132]; and differences in percentage body fat (%BF) from -0.76 [-1.42, -0.09] [135,136] to -2.01 [-2.98, -1.04] [132]
- **Provision of free or low-cost fruit:** ensuring that fruit [128,131,137] and freshly made fruit juices [137] were available at school, and at home
- **Availability of school playgrounds for structured/unstructured PA after regular school hours** [124,125,137,138]
- **Provision of free/low cost water in school:** either through installation of water fountains, provision of water bottles or through lowering the cost of bottled water compared to other drinks in the school canteen [128,130,131,139–141]. An intervention focusing solely on enhancing water provision in schools reported a small reduction in zBMI (-0.004 [-0.045, 0.036]) and a significant reduction in the risk of overweight (31% reduction, p = 0.04) among the intervention group [141].
- **Provision of a healthy breakfast at school** (BMI: -0.11 (P=<0.05) in boys; -0.02 (P = <0.05 in girls) [142]
- **Substitution of sweetened beverages**: replacement of SSB with artificially sweetened, zero-calorie substitute (BMI: between -0.13 [-0.21, -0.05; p = 0.001] and -0.14 [-0.54 to -0.26] [119,143]
- **Reduction in screen time**: at home through the installation of an electronic television time manager device to limit TV watching (BMI: -0.45 [-0.73, -0.17; p = 0.002] [120]

Adjunct elements commonly adopted in the above studies and which are likely to contribute to overall effectiveness, but which our inclusion criteria precluded from further assessment, include: an increase in opportunities for PA during the school day [123,124,128–131,138]; increase in number, duration or quality

(e.g. proportion of time spent doing MVPA) of PE lessons [116,117,122]; parental involvement [126,128,129] and provision of training for food service staff or PE teachers [127].

Few identifiable patterns emerged regarding single or multi-component interventions which failed to show any significant beneficial anthropometric outcomes. All active videogame studies, and all after-school PA programmes of less than 90 minutes duration, did not have a significant impact. Multi-level primary studies that had achieved significant positive results in certain contexts and settings (e.g. comprising components such as nutritional changes in schools or increased opportunities for PA, as shown above) failed to show effectiveness elsewhere, suggesting that contextual factors might have an important role in determining intervention success.

Discussion

This study provides a broad and comprehensive overview of environmental strategies to prevent childhood obesity at population level. Most interventions had at best a small to modest impact on childhood anthropometric outcomes (Appendix S6). Single-level interventions that focus on reducing screen time or increasing time spent performing MVPA may also be particularly beneficial. There was no clear link between the number and range of components of an intervention, and effectiveness of outcomes. However, our findings provide some support for consideration of obesity-prevention interventions having one or more environmental components, which may be particularly attractive for increasingly autonomous adolescents who may not respond to conventional nutrition education and behavioural counselling [144,145]. It is now important to understand which of these strategies can be combined into an ideal package at population level [111]. Most SRs did not provide clear recommendations regarding environmental components that should be considered for implementation by policymakers. At primary study level, the main focus was on school-based programmes, with few trials assessing potential environmental influences in the home, community or country setting.

A comparison of SR conclusions suggests that most SRs are cautious about summarising the evidence regarding the relative effectiveness of environmental components, or fail entirely to do so. With few notable exceptions, such as the SR by Waters et al. [111], review authors provide limited descriptions of

individual studies without identifying which intervention elements might be most effective. Hence, they are likely to be of limited use to policy makers looking for concrete suggestions regarding which elements are most likely to successfully stop or reverse childhood obesity. This led to our analysis of primary studies within SRs in an attempt to identify those components which achieved the largest magnitude of effect. However, any statement of effectiveness emerging from these studies must be interpreted with caution given the overall methodological challenges and lack of detail provided even in the higher quality reviews and primary studies. In addition, observed changes in weight outcomes in preventive studies having a normal population distribution may be subject to interpretation. For example, in studies where increases in BMI were observed, it is often difficult to discern whether these were due to normal child growth that is within acceptable limits; reflective of normalization of weight outcomes for previously underweight children; or due to an increase in muscle mass. A comparison of intervention effectiveness and cost-effectiveness was beyond the scope of this research, although questions remain regarding whether subjective judgements on the magnitude of a study's impact are useful or acceptable (e.g. is a 10% reduction in risk of population obesity a less or more beneficial outcome than a 0.1 reduction in population BMI?); or whether the ratio of study cost to benefit provided should be considered when evaluating interventions. Furthermore, heterogeneity of data; generic lack information on costs; the wide range of programme components reviewed; and the difficulties of disentangling the individual contribution of distinct strategies packaged within multi-component programmes to the final magnitude of effect means that it is not possible to distinguish which of these components are the most beneficial. These problems limit our ability to conclude that one strategy or combinations of strategies are more important than others in the prevention of childhood obesity [146]. We sought to identify a shortlist of environmental components having at least some evidence of successful implementation, and identified several strategies that show promise. This is not to say that they will always be effective, or that they can be easily scaled up to population level. Although the 1999 study by Robinson et al. aiming to reduce sedentary behaviour at home by installing a TV locking device was particularly effective, similar studies failed to show a significant impact [147] or even resulted in higher BMI [148,149]. There are also issues around acceptability, long-term sustainability and economic viability of scaling up such interventions [146].

Gaps in the research

Our results enable us to identify a number of gaps in the existing evidence. We confirm that relatively little review-level evidence is available on the impact of environmental interventions on children and adolescents, and most of what is available concerns school-based interventions [28]. We purposely selected only reviews which reported anthropometric outcomes – and presented only relevant adiposity-related data for the identified primary studies– because achieving improved nutrition and PA levels does not necessarily translate into improved anthropometric outcomes, and the latter tend to be the main outcomes of interest to policy makers. While this resulted in a good number of reviews for inclusion, preliminary searches showed that there is a dearth of high-quality reviews focusing specifically on upstream environmental approaches to tackling childhood obesity. In addition, few SRs of any quality explicitly addressed macro-level interventions such as the introduction of school food and beverage policies [59,63,94,95] or implementation of broad community-based strategies [24,83]. It is unclear whether this is a genuine gap in the literature or a direct consequence of few relevant primary studies having been published in this area. In addition, the search strategy adopted by each review tends to inherently limit the range of primary studies included, and hence the scope of review conclusions and recommendations. In any case, we echo previous calls for further primary and secondary research into this key paradigm of population-level obesity prevention [65,111].

Implications for Research and Practice

Policy/environmental approaches to addressing childhood obesity show promise and should be strongly recommended for obesity prevention; however more studies, ideally large, longitudinal natural experiments conducted outside of the school environment with sufficient sampling power to ascertain effect sizes with some confidence, should be carried out [98,111,150]. The fact that almost a third of reviews focused on school-based studies indicates that schools are considered to be key sites for childhood and adolescent obesity prevention interventions, presumably because children spend a substantial portion of their day there, and the relative ease with which interventions can be trialled. However, interventions

in schools that were successful in reducing obesity at first glance have been shown to lose their effect during the summer [113] and are often difficult to sustain among the same population in the longer term. Thus, engagement of the community and environmental support within the home are essential aspects of successful interventions. Studies should also implement more rigorous analysis and evaluation of associated social, psychosocial, behavioural, and biological outcomes, particularly adiposity outcomes. Undertaking formal economic evaluations would also add substantially to the utility of a study for policymakers [111], yet these are rarely performed, and there is little review-level economic data in this regard.

Limitations

Publication bias may be a potential limitation of this overview. Other SRs might exist but have not been submitted or accepted for publication and therefore could not be identified during our search. We are also aware that since the searches for this overview were carried out in March 2015, other reviews on this topic may have been published. Our criteria with regards to what constitutes an 'environmental' intervention meant that a large number of primary studies focusing on improving PE lessons during school hours, which possibly contributes towards achieving desirable anthropometric outcomes, were excluded. Quality appraisal of included reviews using the AMSTAR tool presented a number of issues which have also been raised by other assessors [151]. For example, only four reviews (including two Cochrane reviews) achieved a 'yes' rating in the 'conflict of interest included' criterion, which specifies that sources of funding or support for both the review itself as well as for each of the included studies should be reported. It is debatable whether indicating source of funding for primary studies reflects quality of reporting, rather than methodological quality of the review itself. Additionally, we encountered some difficulty in ascertaining multiple publications evaluating the same study, particularly in the case of long term studies. It was rarely immediately clear that publications were contiguous unless the project name was used in the title of the article, as in the case of the Medical College of Georgia FitKid Project [113,135] or APPLE project [130,131] publications. In other cases, including ICAPS [138] or the Dutch Obesity Prevention Intervention in Teenagers [116,117], references to previous publications were buried in the full text. Our exclusion of non-anthropometric outcomes means that

impact of interventions on other potentially valid outcomes such as improvements in PA or nutrition behaviour, VO2 max, blood pressure and blood cholesterol levels were not assessed. However, there is evidence to suggest that these do not necessarily translate into reduced BMI [46,152].

Like Woodman et al., we had expected to find greater overlap of primary studies between reviews, and agree with their view that this can be attributed to differences in inclusion criteria and outcome assessments of SRs rather than erroneous search strategies [153]. Where unique primary studies were included in multiple reviews, their intervention design and findings were not necessarily consistently reported, potentially leading to type II errors during this overview process. Furthermore, inconsistencies in the definition of what constitutes an 'environmental' component of an intervention were seen. We suggest that the reporting structure of SRs could be improved by specifying the types of strategies (e.g. cognitive, educational, behavioural, parental, environmental) that included interventions employ, perhaps in table form as done by Sobol-Goldberg et al. [76] or Kamath et al. [52]. We found this approach particularly useful because it enabled us to directly assess the primary studies of interest, rather than go through the description of all included studies to judge whether one of its components was environmental in nature. On the other hand, this experience highlights the challenge of understanding what is meant by an 'environmental intervention': how is the term operationalized when conducting the review? Few SRs provided a clear, explicit definition, with most opting for, at most, a brief illustrative example [24]. More detailed and pragmatic frameworks for describing primary studies would be valuable [28].

Our methods led to the exclusion of a number of high quality SRs which implicitly or explicitly addressed environmental interventions, such as those by Matson-Koffman et al. [23] and Wang et al. [150]. These failed to provide sufficient descriptive or outcome data for us to clearly identify which included interventions were environmental in nature, or whether they had any impact on obesity-related outcomes in school-aged children. However, to 'test' the comprehensiveness of our approach to identifying primary studies using review-level data, we compared the primary studies included in the Wang et al. review [150] with our final list of 76 eligible primary studies having an environmental

component (Table S5). Wang et al. identify ten studies as having an environmental component in the main text of their article. Five of these were included in our list because they overlapped with SRs that we had included in our overview. Three primary studies were not eligible according to our inclusion criteria. However, our approach missed two relevant primary studies with clearly reported environmental components and anthropometric outcomes [154,155] that were reported in Wang et al.'s article. The intervention by Pettman et al. (2014) [154] had not been reported upon in any of the SRs included in our study. However, the study by Chang et al. (2010) [155] had been cited the review by Bleich et al. (2010) [83] that we had included in our overview, but which was described by the review authors as having "social marketing, strategic partnerships, knowledge mobilization, strategies in multiple sectors" elements. There was no indication of any environmental component for this intervention. Based solely on the study description provided by Bleich et al.'s reporting, and taking into consideration that the SR had clearly described several other primary interventions as being 'environmental' in nature (or described a study component in sufficient detail to enable its classification as 'environmental' overview authors), we did not look at the full text of the Change et al. (2010) study and thus missed the opportunity to include it in our list of environmental interventions. This highlights one of the disadvantages of using review-level evidence to inform policy: the evidence obtained is only as useful as the quality of presentation of data in the reviews.

Strengths

There are several strengths of this study. As many decisions as possible were made a priori to limit potential bias throughout the overview. All stages of the overview (i.e., inclusion criteria, exclusion criteria, data extraction, AMSTAR tables) were conducted in duplicate to minimize error. Our search strategy was sensitive and inclusive of several databases and grey literature, and our definition of 'environmental interventions' was broad. No language restrictions were applied. Consequently, the reviews analysed here, and the list of primary obesity prevention studies having an environmental component derived from this overview, are likely to represent the majority of relevant reviews and interventions available at the time of our search.

Conclusions

Environmental interventions may be modestly effective in addressing childhood obesity. However, there is a dearth of research into the feasibility and effectiveness of implementing environmental strategies in non-school settings, and information on programme cost that may be of use to policymakers seeking to translate evidence into practice is lacking. Most reviews suffered from poor methodology and presentation, making it difficult to assess the true effects of interventions on adiposity outcomes and necessitating retrieval of full texts of primary studies to ensure comprehensiveness.

Author contributions

DC performed the systematic review search, reviewed articles for inclusion, extracted data, generated tables (including appendices) and drafted the manuscript. KG independently reviewed articles for inclusion, extracted data, and reviewed and edited text. CK helped develop the research question, designed and piloted the extraction form for a portion of included articles, and reviewed and edited text. MP helped develop the research question and reviewed and edited text.

Supporting information

Appendix S1. Ovid-Medline search strategy

Appendix S2. Excluded Systematic reviews

Appendix S3. Characteristics of included systematic reviews (part 1)

Appendix S4. Characteristics of included systematic reviews (part 2)

Appendix S5. Quality assessment of systematic reviews (AMSTAR)

Appendix S6. Characteristics of primary studies having an eligible environmental component

Appendix S7. Overlap of primary studies across systematic reviews

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