Interventions to prevent obesity in school-aged children 6-18 years: An update of a Cochrane systematic review and meta-analysis including studies from 2015−2021

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Summary

Background Childhood obesity remains a global public health priority due to the enormous burden it generates. Recent surveillance data suggests there has been a sharp increase in the prevalence of childhood obesity during the COVID-19 pandemic. The Cochrane review of childhood obesity prevention interventions (0−18 years) updated to 2015 is the most rigorous and comprehensive review of randomised controlled trials (RCTs) on this topic. A burgeoning number of high quality studies have been published since that are yet to be synthesised.

Methods An update of the Cochrane systematic review was conducted to include RCT studies in school-aged children (6-18 years) published to 30 June 2021 that assessed effectiveness on child weight (PROSPERO registration: CRD42020218928). Available cost-effectiveness and adverse effect data were extracted. Intervention effects on body mass index (BMI) were synthesised in random effects meta-analyses by setting (school, after-school program, community, home), and meta-regression examined the association of study characteristics with intervention effect.

Findings Meta-analysis of 140 of 195 included studies (183,063 participants) found a very small positive effect on body mass index for school-based studies (SMD −0·03, 95%CI −0·06,−0·01; trials = 93; participants = 131,443; moderate certainty evidence) but not after-school programs, community or home-based studies. Subgroup analysis by age (6−12 years; 13−18 years) found no differential effects in any setting. Meta-regression found no associations between study characteristics (including setting, income level) and intervention effect. Ten of 53 studies assessing adverse effects reported presence of an adverse event. Insufficient data was available to draw conclusions on cost-effectiveness.

Interpretation This updated synthesis of obesity prevention interventions for children aged 6−18 years, found a small beneficial impact on child BMI for school-based obesity prevention interventions. A more comprehensive assessment of interventions is required to identify mechanisms of effective interventions to inform future obesity prevention public health policy, which may be particularly salient in for COVID-19 recovery planning.

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Keywords: Childhood obesity; Public health; Prevention; Systematic review

Research in context

Evidence before this study

We searched MEDLINE using the keywords "childhood obesity", "prevention", "systematic review" from Jan 1, 2017 to Feb 28, 2022, for any recent systematic reviews that aimed to synthesize international childhood obesity prevention interventions, using a randomized controlled design, conducted in any setting, targeting school-aged children aged 6-18 years. We identified three systematic reviews that included such studies across multiple settings. Two reviews (with search dates of 2010-2020 and 1990-2017) restricted study setting to school, home or community and both conducted narrative synthesis without meta-analysis. The third and most comprehensive systematic review identified, was a 2019 Cochrane review of studies published from 1990-2015 in any setting which synthesized studies via meta-analysis. The Cochrane review identified a further 315 potentially eligible studies from a 2018 search which were not synthesized, and since then an increasing volume of high quality research regarding obesity prevention interventions has been conducted. At the time of writing, no high quality systematic review and meta-analysis of randomized controlled studies of childhood obesity prevention interventions conducted in any setting was identified that synthesized studies published between 2015 and 2021.

Added value of this study

Our review of 195 randomised controlled trials, to our knowledge, is the most contemporary and high quality synthesis of global studies published to date examining the effectiveness of childhood obesity prevention interventions in school-aged children aged 6-18 years (up to June 30, 2021). We found school-based obesity prevention interventions overall to have a very small beneficial impact on child weight. No overall positive effects were found for after-school programs, community or home-based interventions, however the certainty of the evidence for interventions in these settings was low and should be interpreted with caution. Findings for health care settings were limited due to their scarcity. We found no associations between study characteristics (such as income level, intervention type, setting) and intervention effects in studies pooled across all settings. Unintended adverse effects were infrequently observed in the included studies and no conclusions could be drawn on intervention cost-effectiveness. This systematic review and meta-analysis provides the most up-to-date synthesis of the current evidence base on childhood obesity prevention interventions for school-aged children, and importantly also synthesizes available data regarding their unintended adverse effects.

Implications of all the available evidence

This systematic review and meta-analysis provides policymakers and practitioners with current evidence regarding the effectiveness of childhood obesity prevention within all settings, but also importantly any known unintended adverse intervention effects. Such information is essential to enable future investment in childhood obesity prevention interventions be prioritized for those approaches with greatest impact. The findings suggest school-based obesity prevention interventions warrant continued implementation and ongoing investment on the basis of their effectiveness and lack of serious harm. While the intervention effects observed were small, small improvements in weight status can have a meaningful effect when implemented at a population level. Our review supports recommendations from international strategies and policies to implement settings-based interventions to support healthy weight and prevent childhood obesity, and highlights the need for future research to identify the components and mechanisms of effective interventions to inform future obesity prevention public health policy.

Introduction

The prevalence of childhood obesity remains a high priority for public health policy in most high- and middle-income countries.[1] In the last two decades since the World Health Organization declared the global nature of the obesity epidemic,[2] the prevalence of unhealthy weight has continued to increase. In 2016 it was estimated that 340 million children aged 5–19 years were overweight or obese.[3,4] Additionally, recent surveillance data suggests there has been a sharp increase in the prevalence of obesity in school-aged children during the COVID-19 pandemic in some countries.[5-7]

Unhealthy weight contributes enormously to the global burden of disease, increasing the risk of many health conditions (including cancer and cardiovascular

disease), and was responsible for 4·7 million premature deaths in 2017 and between 0·7% and 2·8% of national health care costs.[8,9] Childhood obesity is linked with a range of adverse physical, mental health and societal outcomes, and children living with obesity are at a greater risk of being overweight and having life-limiting comorbidities in adulthood.[10] Allowing childhood obesity levels to rise further will likely translate into major health and economic challenges for future generations —not least vulnerability to pandemic outbreaks of viruses like COVID-19, for which overweight is an important risk factor.[11] Strategies to prevent unhealthy weight gain in children therefore represent a key strategy to mitigate this burden.

Healthy weight promotion in children is addressed by various international strategies and policy frameworks,[12–14] which make recommendations for action to support healthy weight across settings.[4,13-15] To ensure that governments are enacting policies that have the greatest impact on health outcomes, it is essential that such policies are based on the most recent and robust evidence available.[16] The evidence-base regarding childhood obesity prevention has increased markedly in recent years. The most recent Cochrane review of obesity prevention interventions targeting children 0-18 years identified 153 randomized controlled trials (RCTs) to 2015, and another 315 potentially eligible trials (not synthesized) up to January 2018.[17] This increasing volume of research enables precise estimates of obesity prevention interventions effects and importantly affords the opportunity to examine the effects of interventions in different settings, populations, and different duration and componentry to guide the development of appropriate and effective obesity prevention initiatives.[18] Additionally, policy makers and practitioners require information regarding adverse impacts of intervention options, and their delivery costs. This information is largely absent within existing reviews.[19]

Previous reviews characterizing interventions effects by their components, setting or duration have relied on examination of subgroups.[20] However when large numbers of trials exist, more sophisticated methods, such as meta-regression can identify study characteristics associated with intervention effects. In comparison to the meta-analysis approach that attempts to pool results from a number of studies into one summarised 'effect', meta-regression aims to attribute the size of summarised effects to the characteristics of studies included in a meta-analysis.[21] Meta-regression is an extension of subgroup analysis that can simultaneously account for covariates that may confound any reported associations between effect and study characteristics.[21] While such analyses can provide richer empirical information to support more effective policymaking and have been previously used to investigate intervention characteristics associated with effect,[22,23] to our knowledge, our review is the first meta-regression analyses of child obesity interventions that simultaneously investigates intervention componentry, setting, and duration.[4]

This review sought to assess the effectiveness, adverse effects and cost effectiveness of obesity prevention interventions on the weight of children aged 6-18 years and identify intervention characteristics associated with effectiveness.

Methods

A partial update of the Cochrane systematic review of obesity prevention interventions in children aged 0-18 years by Brown and Moore et al.[17] was undertaken. For this update, participant eligibility criteria were restricted to children aged 6-18 years encompassing studies included in the existing review (1990–January 2018), and those identified in a new search (January 2018–June 2021). Otherwise, the methods of the existing Cochrane review protocol were replicated with minor deviations noted (Supplementary File Table S1; PROSPERO registration CRD42020218928).

Study inclusion criteria

Eligible trials were randomized controlled trials (RCTs) that compared a child obesity prevention intervention with either a 1) non-intervention or usual care control group, or 2) an alternate intervention. Studies published before 1990 were excluded. There were no restrictions on language or country.

Trials of children with a mean age above 6 years and less than 18 years at baseline were eligible. Trials that only enrolled children who were overweight or obese, or that sampled children with critical illness or severe co-morbidities, were excluded. Trials that selected participants 'at greater risk' for obesity as compared with the general population (e.g. targeted at settings where the prevalence of childhood obesity is higher than average) were eligible.

Interventions with a rationale or underlying intention to prevent child obesity were eligible. There was no restriction on intervention type, setting or delivery personnel. Interventions to treat childhood obesity or eating disorders, those focused solely on strength and fitness training, or that included any drug, supplement or surgical intervention, were excluded.

Eligible studies reported a child weight outcome at baseline and post-intervention at least 12 weeks from baseline (irrespective of intervention duration). Eligible weight outcomes included: body mass index (BMI), prevalence of overweight/obesity, weight, per cent fat content, and skin-fold thickness. Secondary outcomes included adverse effects, absolute costs or cost-effectiveness.

Search methods

The existing published Cochrane review included and synthesized findings from 153 studies (search to June

2015). An additional search (from June 2015 to January 2018) identified a further 315 potentially eligible records and 67 ongoing studies following title and abstract screening. These studies were marked in the existing review as 'awaiting classification' as they did not undergo full text review against the eligibility criteria. A collaboration was initiated between new authors (RKH, LW) and Cochrane review team representatives (CS, THMM) to conduct an update, including full text review of 315 studies awaiting classification provided by the Cochrane team.

An updated search of electronic databases including the Cochrane Central Register of Controlled Trials (CENTRAL), Medline, Embase, Cumulative Index to Nursing and Allied Health Literature (CINAHL) and PsycINFO was conducted by an information specialist (DB) on June 30 2021 to identify new records since the last search date of January 2018. Trial registries were searched from the last search date of 22 January 2018 to 2 December 2020 (Supplementary File Appendix A).

Study selection

Two review authors (RKH, KMO) independently screened titles and abstracts from the new search. All full texts of potentially eligible records (i.e. from the existing review and updated search) were independently assessed for eligibility by two review authors (RKH, KMO). Any differences in inclusion were resolved via discussion or with a third reviewer (THMM, CS).

Data collection

Information regarding study characteristics were extracted by one author (SL) and checked by another (KMO). Data extracted included: trial authors, years of study, location, study design, study population, intervention and comparator components, duration, setting, number of participants, participants age, and information on trial outcomes and results. Primary outcome data was extracted independently by two review authors (KMO, RKH), resolved via discussion or third reviewer with statistical expertise (AH) when required.

Assessment of risk of bias and quality of evidence

Pairs of review authors independently assessed the risk of bias of included studies (KMO, SL, CS, THMM, SY) using the Cochrane risk of bias tool.[24] All recommended domains were assessed, including bias specific to cluster RCTs (C-RCTs). Small modifications were made to assessment criteria for some domains and applied to both new studies and those included in the published review (Supplementary File Table S2). Discussion or a third reviewer (RKH) was used to resolve disagreements. Review authors were not blind to study details. Studies were considered high risk of bias overall, if one or more risk of bias domains were assessed as high risk, excluding the blinding domain due to the inability to conceal intervention allocation in obesity interventions.

Quality of evidence was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE).[25] Two review authors (RKH, KMO) judged the quality of the evidence, with disagreements resolved by discussion or resolved by a third reviewer (LW). We inspected the funnel plots from meta-analyses of more than 10 studies and performed Egger's tests to investigate funnel plot asymmetry to assess reporting bias.

Data analysis and synthesis

Studies were synthesized according to the setting in which the majority (>50%) of the intervention was implemented (school, after-school program (ASP), community, home, or health care service). Health care service interventions were those delivered in clinical settings (e.g. hospital) or primary care settings (e.g. general practice). Community interventions were defined as non-health care focused community settings (e.g. community recreational groups). Interventions delivered predominantly via telehealth were classified as home-based interventions irrespective of delivery personnel (e.g. clinician or school nurse). Authors were contacted for any missing data.

All intervention arms were screened and only arms that met eligibility criteria included. For multi-arm interventions, data from all relevant treatment arms were included and the number of participants in the control arm divided across these.[26]

We pooled the standardized mean difference (SMD) of BMI and BMI z-scores using the generic inverse variance method in a random effects meta-analysis using the Review Manager 5 software.[27] BMI z-score was prioritized over BMI scores. The difference in means between groups at first follow-up (≥12 weeks from baseline) was selected for synthesis over change scores.[28] For studies that only reported change scores, baseline BMI data and standard deviations (SD) were used to calculate a SMD compatible with follow-up scores using the methods outlined by.[29] A range of correlation values between baseline and follow-up scores were used to estimate the SMD (0·70, 0·80, 0·90) and the most conservative (0.70) used.

We used the following hierarchy to select outcome data for pooling: 1) data adjusted for both clustering and other variables, 2) data adjusted for clustering alone, 3) data adjusted for other variables alone, then 4) unadjusted data. If SD was not reported it was derived, where possible.[27,30,31]

Meta-analyses of BMI scores were presented by setting (school, ASP, community, home) and SMDs re-expressed as BMI scores.[32,33] All other weight, adverse effect and cost outcomes were synthesized narratively using vote counting of direction of effect.

We assessed each included C-RCT for unit of analysis error. Where studies did not adjust for clustering, the reported intra-cluster correlation coefficient (ICC) or an estimated ICC of 0·04[17] was used to calculate design effects and effective sample sizes.

Statistical heterogeneity was assessed using the I^2 statistic.[34] Data were pooled irrespective of the I^2 statistic, and presence of heterogeneity (defined as I^2 ≥50%) explored in subgroup analyses by age group, intervention duration and type.

A priori subgroup analyses were conducted to investigate differential effects by mean age of participants at baseline (6-12 years; 13-18 years), with a test for subgroup difference of $p<0.05$ considered indicative of a differential effect as per best practice.[35] A post hoc subgroup analysis was additionally performed to investigate differential effects by geographical region (continent).

Sensitivity analyses were conducted to explore the impact of: 1) excluding trials at high risk of bias; 2) excluding studies where follow-up SMD were calculated from change scores; 3) to explore correlation assumptions used in the calculation of follow-up SMDs from change scores; and 4) to explore the impact of not calculating design effects and effective sample sizes for C-RCTs that did not account for clustering (i.e. adopting an ICC of 0, which was the minimum ICC reported by studies included in the review).

A random effects meta-regression was conducted pooling studies across settings to assess whether study characteristics of relevance to policymakers were associated with an effect on BMI[19]: income status by country (high-income, upper middle-income, lower middle-income),[36] setting (school, ASP, community, home, health care services), multi-setting (yes, no), theory informed intervention (yes, not reported), intervention type (diet, physical activity, diet + physical activity, other) and duration of intervention (≤12 months; >12 months). The Dersimonian and Laird estimation method was used to estimate the residual between-study variance. Knapp-Hartung variance estimator was used to estimate the standard errors and 95% confidence intervals (CI). A permutation test was conducted to assess the robustness of our multivariable meta-regression results,[37] with 1000 permutations conducted.

Role of the funding source

The study funder had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

One hundred and fourteen of the 153 studies included in the existing review were included in this review update, and 39 excluded due to participants (<6 years of age at baseline). The new search identified 9,889 unique records. Overall, across studies included in the existing review and those identified in the new search, 1524 full texts were assessed for eligibility and 195 studies were included (Table 1), of which 114 were from the existing review and 81 were new studies (Figure 1).

There were 428 trial arms and 183,063 participants in 195 included studies. Most studies were conducted in high-income countries (n = 165; Figure 2). There were 59 RCTs and 136 CRCTs (including four comparative effectiveness studies) that compared one or more interventions to control or another intervention. Studies were conducted in schools (n = 62); community (n = 11); after-school programs (n = 12); homes (n = 11); and health care services (n = 3) only; or across multiple settings (n = 96).

Most studies included children aged 6-12 years (n = 150), tested interventions targeting both diet and physical activity (n = 115), ranged in duration from 5-10 minutes to four years, were 12 months or less duration (n = 150), and their theoretical basis was reported (n = 117).

BMI or BMI z-score data was reported by 182 of 195 included studies, of which 139 were able to be synthesized in meta-analyses (school: 93 studies, ASPs: 12 studies, community: 21 studies, home: 13 studies). Other weight outcomes included: proportion of overweight/obese, percentage body fat, or weight. The first follow up point greater than 12 weeks post baseline ranged from 12 weeks to two years.

Most studies were assessed as low risk of bias for random sequence generation (51%; 100/195), unclear risk of bias for allocation concealment (67%; 131/195), high risk of bias for blinding (94%; 183/195), low risk of bias for incomplete outcome data (46%; 89/195) and low risk of bias for selective reporting (52%; 102/195) (Figure 3; Supplementary File Table S2 and S3). Most RCTs were assessed as low risk of bias for contamination, and approximately half C-RCTs were assessed as low for other bias. Overall risk of bias was assessed as high for 108 of the 195 included studies.

Meta-analysis of 93 trials (131,443 participants) comparing school-based interventions to control revealed a very small positive effect on BMI (SMD −0·03, 95% CI −0·06 to −0·01; I^2 = 56%; moderate certainty evidence; Table 2; Supplementary File Figure S1), equivalent to a 0·11 lower BMI score in the intervention compared to control group.

Meta-analysis of 12 trials (5,066 participants) comparing after-school program interventions to control revealed no overall significant effect on BMI (SMD −0·09, 95% CI −0·22 to 0·04; I^2 = 76%; very low-certainty evidence; Table 2; Supplementary File Figure S2).

Meta-analysis of 21 trials (3,292 participants) comparing community-based interventions to control revealed no overall positive effect on BMI (SMD −0·04, 95% CI −0·11 to 0·04; I^2 = 0%; low certainty evidence; Table 2; Supplementary File Figure S3).

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Adab 2018[38] UK	Design: C-RCT (School) Setting: School * + Home + Community Age group: 6-12 (6·3) Gender: mixed	2462	837	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: usual practice	BMI-z (>12 months)† Adverse assessed: Yes Adverse effect: Quality of life (no evidence of harm). Cost: Total adjusted incremental mean cost per child at 30 months (£155 (95% confidence interval [CI]: £139, £171)), incremental mean QALYs gained per child (0·006 (95% CI: -0·024, 0·036)). Incremental cost-effectiveness at 30 months per QALY (£26,815). Using a standard willingness to pay threshold of £30,000 per QALY, there was a 52% chance that the intervention was cost-effective.
Amaro 2006[39] Italy	Design: C-RCT (Classroom) Setting: School Age group: 6-12 (12·4) Gender: mixed	291	241	Arms: 1 Target: Diet Theory: NR Duration: ≤ 12 months	Control: no intervention	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Andrade 2014[40] Ecuador	Design: C-RCT (School) Setting: School Age group: 13-18 (intv = 12·8, control = 12·9) Gender: mixed	1440	1060	Arms: 1 Target: DPA Theory: SCT, IMB model, Control theory, TTM and TPB Duration: > 12 months	Control: usual care	BMI-z (> 12 months)† Adverse: NR Cost: NR
Arlinghaus 2021[41] US	Design: RCT Setting: School Age group: 6-12 (weekday 12·10, weekend 12·06) Gender: mixed	491	329	Arms: 1 Target: PA Theory: SCT Duration: ≤ 12 months	Control: usual care	BMI-z (≤ 12 months) Adverse: NR Cost: NR
Baranowski 2003[42] USA	Design: RCT Setting: Community* + Home Age group: 6-12 (intv = 8·3, control = 8·4) Gender: Girls only	35	31	Arms: 1 Target: DPA Theory: SCT and FST Duration: ≤ 12 months	Control: usual day camp	BMI (≤ 12 months)† Adverse: NR Cost: NR
Baranowski 2011[43] USA	Design: RCT Setting: Home Age group: 6-12 (42·5% = 10; 32·7% = 11; 24·8% = 12) Gender: mixed	153	134	Arms: 1 Target: DPA Theory: SCT, Self-determination and Persuasion theories Duration: ≤ 12 months	Control: health-related video games	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Barbeau 2007[44] USA	Design: RCT Setting: School (ASP) Age group: 6-12 (9·5) Gender: Girls only	309	201	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: no intervention	BMI (≤ 12 months)† Adverse: NR Cost: NR
Barnes 2015[45] Australia	Design: RCT Setting: Community* + Home Age group: 6-12 (8·49) Gender: Girls only	48	48	Arms: 1 Target: PA Theory: SCT Duration: ≤ 12 months	Control: Waitlist	BMI-z(≤ 12 months)† Adverse: NR Cost: NR
Beech 2003[46] USA	Design: RCT Setting: Community Age group: 6-12 (8·9) Gender: Girls only	60	60	Arms: 2 Target: DPA Theory: SCT and FST Duration: ≤ 12 months	Control: Attention control (focus on self-esteem)	BMI (≤ 12 months)† Adverse assessed: Yes Adverse effect: Visit to healthcare provider, unhealthy weight concern and injuries (similar between children in intervention and control) Cost: NR

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Black 2010[47] USA	Design: RCT Setting: Home* + Community Age group: 13-18 (13·3) Gender: mixed	235	184	Arms: 1 Target: DPA Theory: SCT and MI Duration: ≤ 12 months	Control: No intervention	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Bogart 2016[48] USA	Design: C-RCT (School) Setting: School + Home Age group: 6-12 (12·2) Gender: mixed	3272	1368	Arms: 1 Target: Diet Theory: SCT, ecological influences and community-based participatory research Duration: ≤ 12 months	Control: Waitlist	BMI percentiles (>12 months) Adverse: NR Cost: NR
Bohnert 2013[49] USA	Design: RCT Setting: School (ASP) Age group: 6-12 (intv = 9·02, control = 9·38) Gender: Girls only	133	76	Arms: 1 Target: DPA Theory: SCT and Sociocultural theory Duration: ≤ 12 months	Control: No intervention	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Bonsergent 2013[50] France	Design: C-RCT (School) Setting: School* + Health Service + Community Age group: 13-18 (15·8) Gender: mixed	5354	3538	Arms: 3 Target: DPA Theory: NR Duration: > 12 months	Control: No intervention	BMI and BMIz (> 12 months)† Adverse: NR Cost: NR
Brandstetter 2012[51] Germany	Design: C-RCT (Classroom) Setting: School* + Health Service + Home Age group: 6-12 (intv = 7·61, control = 7·53) Gender: mixed	1119	945	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Usual care	BMI (≤ and > 12 months)† Adverse: NR Cost: NR
Branscum 2013[52] USA	Design: C-RCT (School) Setting: School (ASP) Age group: 6-12 (NR) Gender: mixed	71	71	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	CE: Knowledge based program	BMI percentiles only (≤ 12 months) Adverse: NR Cost: NR
Breheny 2020[53] UK	Design: C-RCT (School) Setting: School Age group: 6-12 (8·9) Gender: mixed	2280	1670	Arms: 1 Target: PA Theory: BCT Duration: ≤ 12 months	Control: No active intervention	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: No adverse events were reported Cost: Chance of cost-effectiveness using standard UK thresholds (76%). Highly cost-effective in girls (£2,492 per QALY), but not in boys.
Brito Beck da Silva 2019[54] Brazil	Design: C-RCT (School) Setting: School* + Home Age group: 13-18 (14·5) Gender: mixed	895	602	Arms: 1 Target: DPA Theory: CBT Duration: ≤ 12 months	Control: Waitlist	BMI (≤ 12 months)† Adverse: NR Cost: NR
Brown 2013[55] UK	Design: RCT Setting: Community* + School (ASP) Age group: 6-12 (11·4) Gender: mixed	76	63	Arms: 1 Target: DPA Theory: TTM-Stages of Change and SCT Duration: ≤ 12 months	Control: Attention control (alcohol and drug comparison)	BMI and BMIz (≤ 12 months)† Adverse: NR Cost: NR
Caballero 2003[56] USA	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (7·6) Gender: mixed	1714	1409	Arms: 1 Target: DPA Theory: SLT, and principles of American Indian culture and practice Duration: > 12 months	Control: Usual care presumed (no details provided but school-based Intervention)	BMI (> 12 months)† Adverse: NR Cost: NR

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Cao 2015[57] China	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (intv = 7·01, control = 6·81) Gender: mixed	2445	1813	Arms: 1 Target: DPA Theory: NR Duration: > 12 months	Control: No intervention	BMI-z (> 12 months)† Adverse: NR Cost: NR
Carlin 2018[58] Northern Ireland	Design: C-RCT (School) Setting: School Age group: 6-12 (12·4) Gender: Girls only	199	197	Arms: 1 Target: PA Theory: SCT Duration: ≤ 12 months	Control: Usual PA, waitlist control	BMI (≤ 12 months) Adverse: NR Cost: NR
Chai 2019[59] Australia	Design: RCT Setting: Home Age group: 6-12 (9.0) Gender: mixed	46	46	Arms: 2 Target: Diet Theory: CALO-RE taxonomy of behaviour change techniques, BCT Duration: ≤ 12 months	Control: Waitlist	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Chen 2010[60] USA	Design: RCT Setting: Community Age group: 6-12 (8·97) Gender: mixed	67	67	Arms: 1 Target: DPA Theory: behaviour-change techniques related to healthy eating Duration: ≤ 12 months	Control: Waitlist	BMI (≤ 12 months)† Adverse: NR Cost: NR
Chen 2011[61] USA	Design: RCT Setting: Home Age group: 13-18 (12·52) Gender: mixed	54	50	Arms: 1 Target: DPA Theory: TTM-Stages of Change and SCT Duration: ≤ 12 months	Control: Attention control. General health information related to nutrition, dental care, safety, skin care, and risk-taking behaviours	BMI (≤ 12 months)† Adverse: NR Cost: NR
Choo 2020[62] South Korea	Design: C-RCT (Community centre) Setting: Community* + Home Age group: 6-12 (10·0) Gender: mixed	107	104	Arms: 1 Target: DPA Theory: Ecological perspective, cognitive learning theory Duration: ≤ 12 months	Control: Usual care	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Christiansen 2013[63] Denmark	Design: C-RCT (School) Setting: School + Community Age group: 13-18 (12·6) Gender: mixed	1348	989	Arms: 1 Target: PA Theory: Social Ecological Duration: > 12 months	Control: Usual care	Waist circumference (> 12 months) Adverse: NR Cost: Upgrades to school outdoor areas (10 000−20 000 €) and established Playspots (65 000−250 000 €).
Clemes 2020[64] UK	Design: C-RCT (School) Setting: School Age group: 6-12 years (9·3) Gender: mixed	176	168	Arms: 1 Target: PA Theory: COM-B with BCW, TDF Duration: ≤ 12 months	Control: Usual practice	BMI (≤ 12 months)† Adverse assessed: Yes Adverse effect: No serious adverse events were reported. Cost: NR
Coleman 2005[65] USA	Design: C-RCT (School) Setting: School Age group: 6-12 years (8·3) Gender: mixed	896	744	Arms: 1 Target: DPA Theory: NR Duration: >12 months	Control: No intervention (financial incentive to participate)	BMI (>12 months) Adverse: NR Cost: Cost-effectiveness ratio (US$900 (US$903 using Hispanic parameters)), net benefit (US$68,125 (US$43,239 using Hispanic parameters))
Coleman 2012[66] USA	Design: C-RCT (School) Setting: School (during hours* and ASP) Age group: 6-12 (8·9) Gender: mixed	579	424	Arms: 1 Target: Diet Theory: Ecological and Developmental Systems Theories and BEM Duration: >12 months	Control: Usual care presumed as no details but school-based intervention	BMI z score (>12 months) Adverse: NR Cost: NR

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Cunha 2013[67] Brazil	Design: C-RCT (Classroom) Setting: School* + Home Age group: 6-12 (intv = 11·2, control = 11·2) Gender: mixed	574	559	Arms: 1 Target: Diet Theory: TTM Duration: ≤ 12 months	Control: No intervention	BMI (≤ 12 months) Adverse: NR Cost: NR
Damsgaard 2014[68] Denmark	Design: C-RCT - crossover (School) Setting: School Age group: 6-12 (10·0) Gender: mixed	823	823	Arms: 1 Target: Diet Theory: NR Duration: ≤ 12 months	Control: Usual care (packed lunch from home)	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Davis 2021[69] US	Design: C-RCT (School) Setting: School Age group: 6-12 (9·23) Gender: mixed	3135	3135	Arms: 1 Target: Diet Theory: Social ecological-transactional model Duration: ≤ 12 months	Control: Delayed intevention	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
de Greeff 2016[70] Netherlands	Design: C-RCT (Classroom) Setting: School Age group: 6-12 (8·1) Gender: mixed	376	376	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Assume usual practice	BMI (≤ 12 months)† Adverse: NR Cost: NR
De Heer 2011[71] USA	Design: C-RCT (Classroom) Setting: School (ASP) Age group: 6-12 (intv = 9·24, control = 9·10) Gender: mixed	646	568	Arms: 1 Target: DPA Theory: Ecological principles, SCT Duration: ≤ 12 months	Control: Attention control. Health workbooks and incentives	BMI (≤ 12 months)† Adverse: NR Cost: NR
de Ruyter 2012[72] Netherlands	Design: RCT Setting: School* + Home Age group: 6-12 (intv = 8·2, control = 8·2) Gender: mixed	641	641	Arms: 1 Target: Diet Theory: NR Duration: > 12 months	Control: Similar sugar-containing drink in participants who commonly drank them	BMI-z (> 12 months)† Adverse assessed: Yes Adverse effect: Adverse events were minor. Six participants discontinued the study due to weight gain (four in the sugar group and two in the sugar-free group). Cost: NR
Dewar 2013[73] Australia	Design: C-RCT (School) Setting: School* + Home Age group: 13-18 (intv = 13·20, control = 13·15) Gender: Girls only	357	294	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Usual care presumed as no details but school-based intervention	BMI and BMIz (≤ 12 months)† Adverse: NR Cost: Yes. Standard equipment pack (USD 1300).
Donnelly 2009[74] USA	Design: C-RCT (School) Setting: School Age group: 6-12 (Grade 2: intv female = 7·7, control female = 7·8; intv male = 7·7, control male = 7·8. Grade 3: intv female = 8·7, control female = 8·7; intv male = 8·7, control male = 8·8) Gender: mixed	1527	1490	Arms: 1 Target: PA Theory: NR Duration: > 12 months	Control: Usual care - regular classroom instruction without physically active lessons	BMI (> 12 months)† Adverse: NR Cost: NR
Drummy 2016[75] Northern Ireland	Design: C-RCT (Classroom) Setting: School Age group: 6-12 (9·5) Gender: mixed	120	107	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Usual practice	BMI (≤ 12 months)† Adverse: NR Cost: NR
Duncan 2019[76] New Zealand	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (intv = 8·71, control = 8·74) Gender: mixed	675	589	Arms: 1 Target: DPA Theory: SCT, theory of reasoned action and planned behaviour Duration: ≤ 12 months	Control: Waitlist	BMI (≤ 12 months)† Adverse: NR Cost: NR

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Dunker 2018[77] Brazil	Design: C-RCT (School) Setting: School (ASP)* + Home Age group: 13-18 (13·39) Gender: Girls only	270	270	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Usual practice	BMI (≤ 12 months)† Adverse assessed: Yes Adverse effect: No observed harm or unintended effects that could be directly attributed tothe intervention. Cost: NR
Ebbeling 2006[78] USA	Design: RCT Setting: Home Age group: 13-18 (intv = 16·0, control = 15·8) Gender: mixed	103	103	Arms: 1 Target: Diet Theory: NR Duration: ≤ 12 months	Control: Usual drink consumption	BMI (≤ 12 months)† Adverse: NR Cost: NR
El Ansarai 2010[79] Egypt	Design: RCT Setting: School (ASP) Age group: 13-18 (15·7) Gender: mixed	160	160	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Usual care 'normal' exercise schedule provided by the school	BMI (≤ 12 months)† Adverse: NR Cost: NR
Elder 2014[80] USA	Design: C-RCT (Recreation centre) Setting: Community* + Home Age group: 6-12 (6·6) Gender: mixed	541	489	Arms: 1 Target: DPA Theory: NR Duration: > 12 months	Control: No intervention - measurement only	BMI-z (> 12 months)† Adverse: NR Cost: NR
Epstein 2001[81] USA	Design: RCT Setting: Home* + Community Age group: 6-12 (low fat/sugar = 8·8, fruit/vegetables = 8.6) Gender: mixed	26	26	Target: Diet Theory: NR Duration: ≤ 12 months	CE: D (fat and sugar)	Percentage overweight and BMI (≤ 12 months) Adverse: NR Cost: NR
Ezendam 2012[82] Netherlands	Design: C-RCT (School) Setting: School Age group: 13-18 (intv = 12·7, control = 12·6) Gender: mixed	883	676	Arms: 1 Target: DPA Theory: TPB, Precaution Adoption Process Model, Implementation intentions Duration: ≤ 12 months	Control: No intervention	BMI (>12 months)† Adverse: NR Cost: NR
Fairclough 2013[83] UK	Design: C-RCT (School) Setting: School Age group: 6-12 (intv = 10·6, control = 10·7) Gender: mixed	318	230	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Did not teach a specific unit focused on healthy eating and PA	BMI and BMIz (≤ 12 months)† Adverse: NR Cost: NR
Farias 2015[84] Brazil	Design: C-RCT (Classroom) Setting: School Age group: 13-18 (intv = 15·9, control = 16·0) Gender: mixed	567	386	Arms: 1 Target: PA Theory: NR Duration: < 12 months (one school year, no further details)	Control: Usual care physical activity at school	% body fat, fat mass, waist circumference and % overweight (< 12 months) Adverse: NR Cost: NR
Farmer 2017[85] New Zealand	Design: C-RCT (School) Setting: School Age group: 6-12 (intv = 8.0, control = 7·9) Gender: mixed	902	715	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Usual practice	BMI-z (> 12 months)† Adverse: NR Cost: Initial start-up funds (NZD$15 000). Reported majority of recommendations involved no to little cost
Ford 2013[86] UK	Design: RCT Setting: School Age group: 6-12 (NR) Gender: mixed	174	152	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Nomal lessons	BMI (≤ 12 months)† Adverse: NR Cost: NR

Table 1 (Continued)

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Foster 2008[87] USA	Design: C-RCT (School) Setting: School Age group: 6-12 (intv = 11·13, control = 11·2) Gender: mixed	1349	843	Arms: 1 Target: DPA Theory: settings-based approach; CDC Guidelines to Promote Lifelong Healthy Eating and PA Duration: > 12 months	Control: No intervention	BMI and BMIz (> 12 months)† Adverse assessed: Yes Adverse effect: Proportion of underweight children and body satisfaction (no evidence of adverse impact). Cost: NR
French 2011[88] USA	Design: C-RCT (Home) Setting: Home* + Community Age group: 13-18 (NR) Gender: mixed	75	75	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: No intervention	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Fulkerson 2010[89] USA	Design: RCT Setting: Community* + Home Age group: 6-12 (NR) Gender: mixed	44	44	Arms: 1 Target: Diet Theory: SCT Duration: ≤ 12 months	Control: No intervention	BMI-z (≤ 12 months) Adverse: NR Cost: NR
Fulkerson 2015[90] USA	Design: RCT Setting: Community* + Home Age group: 6-12 (10·3) Gender: mixed	160	149	Arms: 1 Target: Diet Theory: Social Cognitive Theory and a socio-ecological framework, BCT Duration: ≤ 12 months	Control: Attention only - received a monthly family -focused newsletter and and did not receive the HOME Plus intervention program	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: No serious adverse events were reported. Cost: Program costs per famiy (personnel training = $20, program materials = $49, intervention delivery = $44 per session. Childcare costs $20 per session for up to 6 children, transportation $12·50 per session)
Gentile 2009[91] USA	Design: C-RCT (School) Setting: School* + Community + Home Age group: 6-12 (intv = 9·6, control = 9·6) Gender: mixed	1323	1201	Arms: 1 Target: DPA Theory: SEM Duration: ≤ 12 months	Control: Community component only	BMI (≤ 12 months)† Adverse: NR Cost: Yes. Print based manuals and resources (approximately $60 per student)
Gortmaker 1999a[92] USA	Design: C-RCT (School) Setting: School + Home Age group: 6-12 (11·7) Gender: Girls only	1560	1295	Arms: 1 Target: DPA Theory: Behavioural Choice and SCT Duration: > 12 months	Control: Usual care, health curricula and PE classes	Prevalence of obesity (> 12 months) Adverse assessed: Yes Adverse effect: Extreme dieting behaviour (students reported similarly low levels) Cost: Intervention cost ($33,677), intervention cost per student per year ($14), cost per QALY saved ($4305), estimated net saving to society ($7313)
Greve 2015[93] Denmark	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (intv = 10·07, control = 10·22) Gender: mixed	Unclear	9438	Arms: 1 Target: DPA Theory: NR Duration: > 12 months	Control: Usual practice	BMI (> 12 months)† Adverse: NR Cost: Schools received subsidies based on completion of intervention tasks (DKK80 per student in 2008/09, 2009/10 and DKK40 per student in 2010/2011.
Griffin 2019[94] UK	Design: RCT Setting: Community Age group: 6-12 (7·7) Gender: mixed	43	22	Arms: 1 Target: DPA Theory: Family systems theory and SCT Duration: ≤ 12 months	Control: Attention control - voucher for a single family visit to a leisure centre	BMI-z (≤ 12 months) Adverse assessed: Yes Adverse effect: No adverse events requiring hospitalisastion or medical attention during the intervention. Cost: Per-family program delivery cost (ranged from £150 for 15 families to £235 for 8 families excluding training)

Table 1 (Continued)

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Grydeland 2014[95] Norway	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (intv = 11·2, control = 11·2) Gender: mixed	2165	1361	Arms: 1 Target: DPA Theory: SEM Duration: > 12 months	Control: Usual care presumed as no details but school-based intervention	BMI and BMIz (> 12 months)† Adverse: NR Cost: NR
Gustafson 2019[96] USA	Design: C-RCT (School) Setting: Home Age group: 13-18 (15·0) Gender: mixed	530	411	Arms: 1 Target: Diet Theory: NR Duration: ≤ 12 months	Control: Waitlist	BMI-z percentile (unclear) Adverse: NR Cost: Incentives for text message communications ($5 per student per week).
Gutin 2008[97] USA	Design: C-RCT (School) Setting: School (ASP) Age group: 6-12 (8·5) Gender: mixed	601	447	Arms: 1 Target: PA Theory: Environmental change Duration: > 12 months	Control: No intervention presumed as no details (after-school intervention)	BMI (> 12 months) Adverse: NR Cost: Intervention cost ($174,070, $558 per student). Intervention cost per student who attended > or = 40% of the intervention sessions ($956), usual after-school care costs ($639/student). Students who attended > or = 40% of the intervention reduced % BF by 0·76% (95%CI: -1·42 to -0·09) at an additional cost of $317/student.
Habib-Mourad 2014[98] Lebanon	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (intv = 10·39, control = 10·1) Gender: mixed	374	363	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Usual curriculum	BMI (≤ 12 months)† Adverse: NR Cost: NR
Habib-Mourad 2020[99] Lebanon	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (9·95) Gender: mixed	1239	974	Arms: 1 Target: DPA Theory: SCT Duration: > 12 months	Control: Waitlist	BMI (> 12 months) Adverse: NR Cost: NR
Haerens 2006[100] Belgium	Design: C-RCT (School) Setting: School* + Home Age group: 13-18 (13·1) Gender: mixed	2840	2291	Arms: 1 Target: DPA Theory: an ecological framework Duration: > 12 months	Control: Usual care presumed as no details but school-based intervention	BMI-Z (> 12 months)† Adverse: NR Cost: NR
Haire-Joshu 2010[101] USA	Design: C-RCT (Community settings) Setting: Community* + Home Age group: 6-12 (intv = 8·3, control = 8·7) Gender: mixed	782	451	Arms: 1 Target: DPA Theory: SCT, ecological model Duration: ≤ 12 months	Control: Usual care	BMI-z (≤ 12 months) Adverse: NR Cost: NR
Haire-Joshu 2015[102] USA	Design: C-RCT (Communities) Setting: Home* + School Age group: 13-18 (17·8) Gender: Girls only	1325	814	Arms: 1 Target: DPA Theory: SCT and an ecological framework Duration: ≤ 12 months	Control: Usual care	BMI success - as maintaining or reducing BMI (≤ 12 months) Adverse: NR Cost: NR
Han 2006[103] China	Design: C-RCT (School) Setting: School Age group: 6-12 (NR) Gender: mixed	2800	2670	Arms: 1 Target: Diet Theory: NR Duration: >12 months	Control: Usual care presumed as no details but school-based	Unclear (>12 months) Adverse: NR Cost: NR

Table 1 (Continued)

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Hannon 2018[104] USA	Design: RCT Setting: Community* + Home Age group: 6-12 (mothers only group = 11·3, mothers and children group = 11.8) Gender: mixed	128	100	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	CE: Mothers only	BMI percentiles (≤ 12 months) Adverse: NR Cost: NR
Harrington 2018[105] UK	Design: C-RCT (School) Setting: School Age group: 13-18 (12·8) Gender: Girls only	1753	1361	Arms: 1 Target: PA Theory: SCT Duration: ≤ 12 months	Control: Usual practice	BMI-z (≥ 12 months)† Adverse assessed: Yes Adverse effect: No serious adverse events reported. Cost: Intervention cost per school (£1054 to £3498 per year).
HEALTHY Study Gp 2010[106] USA	Design: C-RCT (School) Setting: School Age group: 6-12 (intv = 11·3, control = 11·3) Gender: mixed	6413	4603	Arms: 1 Target: DPA Theory: NR Duration: > 12 months	Control: No intervention - assessment only	BMI-z (> 12 months)† Adverse assessed: Yes Adverse effect: Adverse events associated with health screening (<3%, reports proportion nearly equivalent in intervention and control schools). Extreme dieting (similar low levels in control and intervention groups). "One 8th-grade girl in a control school committed suicide. The site investigators, the investigators from the National Institute of Diabetes and Digestive and Kidney Diseases, and the data and safety monitoring board determined that the event was unrelated to the study." Cost: NR
Hendy 2011[107] USA	Design: RCT Setting: School Age group: 6-12 (NR) Gender: mixed	382	312	Arms: 1 Target: DPA Theory: SCT, Self-determination theory, Group Socialization theory Duration: ≤ 12 months	Control: Token rewards for three "Good Citizenship Behaviors."	BMI percentiles (≤ 12 months) Adverse: NR Cost: Estimated dollar costs per child for small prizes (2 USD per month). Additional cost for pedometers per child (5 USD per month)
Herscovici 2013[108] Argentina	Design: C-RCT (School) Setting: School Age group: 6-12 (intv = 9·64, control = 9·76) Gender: mixed	405	369	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Usual care presumed as no details but school-based intervention	BMI and BMIz (≤ 12 months)† Adverse: NR Cost: NR

Table 1 (Continued)

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Hollis 2016[109] Australia	Design: C-RCT (School) Setting: School* + Community + Home Age group: 6-12 (12·0) Gender: mixed	1233	985	Arms: 1 Target: PA Theory: SCT and socio-ecological theory Duration: > 12 months	Control: Usual practice	BMI-z (> 12 months)† Adverse assessed: Yes Adverse effect: Underweight students (no evidence of adverse effects. Proportion of underweight students decreased). Cost: Intervention cost (AUD $329,952 over 24 months, or AUD$394 per student). Cost effectiveness ratio (AUD $56 ($35−$147) per additional minute of MVPA, AUD$1 ($0·6−$2·7) per MET hour gained per person per day, AUD$1408 ($788−$6,570) per BMI unit avoided, AUD$563 ($282−$3,942) per 10 % reduction in BMI z-score)
Hovell 2018[110] USA and Mexico	Design: C-RCT (Orthodontist practices) Setting: Health care service Age group: 6-12 (12·1) Gender: mixed	693	468	Arms: 1 Target: DPA Theory: BEM and Geoffrey Rose model Duration: > 12 months	Control: Attention control - tobacco and second hand smoke avoidance	BMI z-score (> 12 months) Adverse: NR Cost: Overall intervention cost was not reported. Offices received payment per a prescription health message per patient ($1·50)
Howe 2011[111] USA	Design: RCT Setting: School (ASP) Age group: 6-12 (9·75) Gender: Boys only	106	106	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: No intervention and were not allowed to stay for the after-school intervention but rather instructed not to change their daily after-school routine	BMI (≤ 12 months)† Adverse: NR Cost: NR
Hull 2018[112] USA	Design: C-RCT (Family) Setting: Community* + Home Age group: 6-12 (6.2) Gender: mixed	319	206	Arms: 1 Target: DPA Theory: SCT, behavioural choice theory and food preference theory Duration: ≤ 12 months	Control: Attention control - oral health intervention	BMI-z (≥12 months) Adverse: NR Cost: NR
Ickovics 2019[113] USA	Design: C-RCT (School) Setting: School* + Community + Home Age group: 6-12 (10·9) Gender: mixed	756	595	Arms: 3 Target: Diet, PA, DPA Theory: NR Duration: > 12 months	Control: Attention control - delayed intervention schools health-focused messages not related with obesity prevention were implemented	BMI-z score and BMI percentile (> 12 months) Adverse assessed: Yes Adverse effect: There were no adverse effects reported. Cost: Intervention cost was not reported. Schools received $500/year to support a member of the school community to lead a School Wellness Team.
James 2004[114] UK	Design: C-RCT (Classroom) Setting: School Age group: 6-12 (8·7) Gender: mixed	644	574	Arms: 1 Target: Diet Theory: NR Duration: ≤ 12 months	Control: Usual care presumed as no details but school-based intervention	BMI and BMIz (> 12 months)† Adverse: NR Cost: NR

Table 1 (Continued)

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Jansen 2011[115] Netherlands	Design: C-RCT (School) Setting: School Age group: 6-12 (Grade 3-5: intv = 7·7, control = 7·8; Grade 6-8: intv = 10·8, control = 10·8) Gender: mixed	2770	2622	Arms: 1 Target: DPA Theory: TPB, Ecological Model Duration: ≤ 12 months	Control: Usual care curriculum	BMI (≤ 12 months)† Adverse: NR Cost: NR
Johnston 2013[116] USA	Design: C-RCT (School) Setting: School* + Community + Home Age group: 6-12 (intv = 7·8, control = 7·7) Gender: mixed	835	629	Arms: 1 Target: DPA Theory: NR Duration: > 12 months	Control: Self-help	BMI-z (> 12 months)† Adverse: NR Cost: NR
Jones 2015[117] Australia	Design: RCT Setting: School (ASP)* + Home Age group: 6-12 (girls = 9·6, boys = 9·9) Gender: mixed	37	37	Arms: 2 Target: PA Theory: SCT Duration: ≤ 12 months	CE: Healthy lifestyle (HL) education programs (active comparison group)	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: There were no adverse events reported. Cost: NR
Kain 2014[118] Chile	Design: C-RCT (School) Setting: School Age group: 6-12 (6·6) Gender: mixed	1949	1468	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Usual care presumed as no details but school-based intervention	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Kennedy 2018[119] Australia	Design: C-RCT (School) Setting: School* + Home Age group: 13-18 (14·1) Gender: mixed	607	600	Arms: 1 Target: PA Theory: SCT and social-determination theory Duration: ≤ 12 months	Control: Waitlist	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: There were no injuries or adverse events reported. Cost: NR
Khan 2014[120] USA	Design: RCT Setting: Community Age group: 6-12 (intv = 8·8, control = 8·8) Gender: mixed	220	220	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Maintain regular after-school routine, financial incentive for measurements	BMI and BMIz (≤ 12 months)† Adverse: NR Cost: NR
Kipping 2008[121] UK	Design: C-RCT (School) Setting: School Age group: 6-12 (9·4) Gender: mixed	531	472	Arms: 1 Target: DPA Theory: SCT and Behavioural Choice theory Duration: ≤ 12 months	Control: Waitlist	BMI (≤ 12 months)† Adverse: NR Cost: Cost of teacher training (£110 per teacher), cost of resources (£2 per pupil)
Kipping 2014[122] UK	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (9·5) Gender: mixed	2221	1825	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Standard teaching	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Klesges 2010[123] USA	Design: RCT Setting: Community Age group: 6-12 (9·3) Gender: Girls only	303	243	Arms: 1 Target: DPA Theory: NR Duration: > 12 months	Control: Attention control, self-esteem and social efficacy	BMI (> 12 months)† Adverse: NR Cost: NR
Kobel 2017[124] Germany	Design: C-RCT (Classroom) Setting: School* + Home Age group: 6-12 (7·1) Gender: mixed	525	479	Arms: 1 Target: DPA Theory: Bandura's social cognitive theory Duration: ≤ 12 months	Control: Regular school curriculum	BMI (≤ 12 months)† Adverse: NR Cost: Intervention cost per child/year (€25.04). Costs per incidental case of averted abdominal obesity (varied between €1515 and €1993, depending on the size of the target group)

Table 1 (Continued)

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Kocken 2016[125] The Netherlands	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (intv = 9·2, control = 9·1) Gender: mixed	1112	790	Arms: 1 Target: DPA Theory: TPB, Behavior change theory Duration: ≤ 12 months	Control: Usual curriculum	BMI-z (> 12 months)† Adverse: NR Cost: NR
Kriemler 2010[126] Switzerland	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (1st graders = 6·9; 5th graders intv = 11·0, control = 11·3) Gender: mixed	502	502	Arms: 1 Target: PA Theory: SEM Duration: ≤ 12 months	Control: Not informed of an intervention group	BMI (≤ 12 months)† Adverse: NR Cost: NR
Kubik 2021[127] US	Design: RCT Setting: School (ASP)* + Home Age group: 6-12 (9·3) Gender: mixed	132	122	Arms: 1 Target: DPA Theory: Social−ecological framework, healthy learner model for student chronic condition management Duration: ≤ 12 months	Control: Newsletter only	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: There were no serious adverse events reported. Cost: NR
Lana 2014[128] Spain and Mexico	Design: RCT Setting: School* + Home Age group: 13-18 (intv: 26·6% = 12, 38·5% = 13, 25·7% = 14, 9·2% = ≥15; control: 20·5% = 12, 42·7% = 13, 27·4% = 14, 9·4% = ≥15) Gender: mixed	2001	737	Arms: 1 Target: DPA Theory: ASE, TTM Duration: ≤ 12 months	Control: No intervention presumed as no details	BMI - reported as prevalence of obesity not BMI (≤ 12 months) Adverse: NR Cost: NR
Lappe 2017[129] USA	Design: RCT Setting: Community Age group: 13-18 (intv = 13·5, control = 13·5) Gender: Girls only	274	274	Arms: 1 Target: Diet Theory: NR Duration: ≤ 12 months	Control: Asked to continue usual diet, avoid calcium supplements	BMI percentiles (≤ 12 months) Adverse assessed: Yes Adverse effect: There were no study-related adverse events. Cost: NR
Lazaar 2007[130] France	Design: C-RCT (School) Setting: School Age group: 6-12 (7·4) Gender: mixed	425	428	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Usual care presumed as no details but school-based intervention	BMI (≤ 12 months)† Adverse: NR Cost: NR
Leme 2016[131] Brazil	Design: C-RCT (School) Setting: School* + Home Age group: 13-18 (16·05) Gender: Girls only	253	194	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Waitlist	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: No injuries or adverse effects were reported Cost: NR
Lent 2014[132] USA	Design: C-RCT (School-store) Setting: Community* + School Age group: 6-12 (intv = 10·97, control = 10·99) Gender: mixed	767	511	Arms: 1 Target: Diet Theory: SCT Duration: > 12 months	Control: No intervention	BMI-z (> 12 months)† Adverse: NR Cost: NR
Levy 2012[133] Mexico	Design: C-RCT (School) Setting: School Age group: 6-12 (intv 78·6% = 10; control: 75·3% = 10) Gender: mixed	1020	997	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Usual care presumed as no details but school-based intervention	BMI (≤ 12 months)† Adverse: NR Cost: NR

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Li 2010a[134] China	Design: C-RCT (School) Setting: School Age group: 6-12 (9·3) Gender: mixed	4700	4187	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: No intervention	BMI and BMIz (≤ 12 months)† Adverse assessed: Yes Adverse effect: Underweight/ health of underweight children (No effect on BMI-z of underweight children). Physical injuries (no effect). Cost: NR
Li 2019[135] China	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (intv = 6·15, control = 6·14) Gender: mixed	1641	1581	Arms: 1 Target: DPA Theory: Behaviour change techniques, social marketing principles, MRC framework Duration: ≤ 12 months	Control: Usual practice	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: There was no evidence of adverse effects or harms. Cost: Cost effectiveness (estimated £1,760 per QALY with the probability of the intervention being cost effective compared with usual care being at least 95% at a willingness to pay threshold of £20,000 to 30,000 per QALY)
Lichtenstein 2011[136] Germany	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (7·3) Gender: mixed	445	414	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: No intervention	BMIz (≤ 12 months)† Adverse: NR Cost: NR
Liu 2019[137] China	Design: C-RCT (School) Setting: School Age group: 6-12 (9·0) Gender: mixed	1889	1839	Arms: 1 Target: DPA Theory: ANGELO framework, SCT Duration: ≤ 12 months	Control: No intervention	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: Percentage underweight (4·9% in intervention vs. 5·3% in control, p = 0·75). There were no adverse events reported. Cost: NR
Llargues 2012[138] Spain	Design: C-RCT (School) Setting: School Age group: 6-12 (6·03) Gender: mixed	704	509	Arms: 1 Target: DPA Theory: Investigation, Vision, Action and Change (IVAC) Methodology Duration: > 12 months	Control: Usual care presumed as no details but school-based intervention	BMI (> 12 months)† Adverse: NR Cost: Average cost per treated child (245·8€). Ratio of net intervention costs and net intervention effects (41 €/1·13 kg/m2 or 25·6€/kg)
Lloyd 2018[139] England	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (intv = 9·8, control = 9·7) Gender: mixed	1324	1265	Arms: 1 Target: DPA Theory: Intervention mapping approach, behaviour change theories, HPSF Duration: ≤ 12 months	Control: Usual practice	BMI-z (≥ 12 months)† Adverse assessed: Yes Adverse effect: One adverse event was reported by a concerned parent about her child's eating and activity behaviours (overexercising and restricting food intake). After discussion with the chief investigator, the parent was happy for their child to remain in the study and continue to participate in the intervention. Cost: Intervention cost (£210 per child). The intervention was not cost-effective compared with control.

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Lubans 2011[140] Australia	Design: C-RCT (School) Setting: School* + Home Age group: 13-18 (intv = 14·4, control = 14·2) Gender: boys only	100	100	Arms: 1 Target: PA Theory: SCT Duration: ≤ 12 months	Control: Waitlist	BMI and BMIz (≤ 12 months)† Adverse assessed: Yes Adverse effect: There were no injuries or adverse effects reported during the activity sessions or assessments. Cost: NR
Luszczynska 2016[141] Poland	Design: RCT Setting: School Age group: 13-18 (16·35) Gender: mixed	702	506	Arms: 2 Target: Diet Theory: SCT, BCT, self efficacy or planning Duration: ≤ 12 months	Control: Attention control. In the group component, participants were asked to read the materials and fill in the forms provided. Participants received a set of educational materials (including crosswords) about healthy nutrition, which focused on FV consumption	BMI (≥ 12 months)† Adverse: NR Cost: NR
Luszczynska 2016b[142] Poland	Design: RCT Setting: School Age group: 13-18 (16·45) Gender: mixed	1217	1217	Arms: 3 Target: PA Theory: SCT, BCT, planning or self efficacy Duration: ≤ 12 months	Control: Attention control - Education only.	Reported as body fat outcome (≥ 12 months) Adverse: NR Cost: NR
Lynch 2016[143] USA	Design: C-RCT (Classroom) Setting: School Age group: 6-12 (Median = 8) Gender: mixed	51	50	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Assume usual practice	BMI (≤ 12 months) Adverse: NR Cost: NR
Macias-Cervantes 2009[144] Mexico	Design: RCT Setting: Community* + Home Age group: 6-12 (Median intv = 8·0, control = 7·5) Gender: mixed	76	62	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Maintain the same level of physical activity	BMI (≤12 months)† Adverse: NR Cost: NR
Madsen 2013[145] USA	Design: C-RCT (School) Setting: School (ASP) Age group: 6-12 (intv = 9·8, control = 9·8) Gender: mixed	156	150	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: No intervention presumed as no details provided	BMI-z (≤ 12 months) Adverse: NR Cost: NR
Madsen 2015[146] USA	Design: C-RCT (School) Setting: School* + Community Age group: 6-12 (NR) Gender: mixed	1079	676	Arms: 1 Target: DPA Theory: NR Duration: > 12 months	Control: Waitlist	BMI-z (> 12 months)† Adverse: NR Cost: NR
Madsen 2021[147] USA	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (NR) Gender: mixed	20482	16622	Arms: 1 Target: BMI Theory: NR Duration: ≤ 12 months	Control: Screening only	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: Weight satisfaction (declined after 2 years compared to control), peer weight talk (increased after 1 year compared to control), and weight control behaviours (declined after 1 year compared to control). Cost: NR

Table 1 (Continued)

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Magnusson 2012[148] Iceland	Design: C-RCT (School) Setting: School Age group: 6-12 (intv = 7·3, control = 7·4) Gender: mixed	321	185	Arms: 1 Target: DPA Theory: NR Duration: > 12 months	Control: Usual practice + incentives	BMI (> 12 months)† Adverse: NR Cost: NR
Marcus 2009[149] Sweden	Design: C-RCT (School) Setting: School* and ASP) Age group: 6-12 (intv = 7·4, control = 7·5) Gender: mixed	3135	2838	Arms: 1 Target: DPA Theory: NR Duration: > 12 months	Control: Normal curriculum	BMI (> 12 months) Adverse assessed: Yes Adverse effect: There were no adverse effects reported. BMI of lean children and unhealthy food restraint (no adverse effects). There were no adverse effects reported. Cost: NR
Martinez-Vizcaino 2014[33] Spain	Design: C-RCT (School) Setting: School (ASP) Age group: 6-12 (intv = 9·4, control = 9·5) Gender: mixed	1592	912	Arms: 1 Target: PA Theory: SEM Duration: ≤ 12 months	Control: Standard physical education curriculum(2 h/week of physical activity at low to moderate intensity)	BMI (> 12 months)† Adverse assessed: Yes Adverse effect: No important adverse events were reported. Percentage of underweight children (no difference. RR 1·00 (0·53, 1·88) Baseline RR 1·03 (95% CI 0.57 to 1·86). Dizziness during baseline venipuncture occurred in 2% of the children at baseline, and in 1·1% of the children at the end of the study. No other adverse events were reported by students during health examinations. Two minor ankle sprains occurred during the sessions of the program (9 months incidence risk: 0·4 %). One boy was expelled from the program for aggressive behavior toward peers; his parents and the School Board made the decision by consensus. Cost: Intervention cost (28 euros/month per child)
Mauriello 2010[150] USA	Design: C-RCT (School) Setting: School Age group: 13-18 (NR) Gender: mixed	1800	1182	Arms: 1 Target: DPA Theory: TTM of Behaviour Change Duration: ≤ 12 months	Control: No intervention	BMI (≤ 12 months) Adverse: NR Cost: NR
Melnyk 2013[151] USA	Design: C-RCT (School) Setting: School + Home Age group: 13-18 (intv = 14·75, control = 14·74) Gender: mixed	807	627	Arms: 1 Target: DPA Theory: Cognitive theory Duration: ≤ 12 months	Control: Attention control programme − safety and common health topics/issues	BMI (≤ 12 months)† Adverse assessed: Yes Adverse effect: Depressive and anxiety symptoms (no adverse effect). Note: subgroup analysis was conducted for teens with severe depression at baseline. The COPE group had significantly lower depressive symptom (within normal range at 12 months) compared with Healthy Teens group depression scores (COPE=42·39 (SE 3·94);Healthy Teens =57·90 (SE 3·77)), p-value =0.03. Cost: NR

Table 1 (Continued)

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Meng 2020[152] USA	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (intv = 9·12, control = 9·18) Gender: mixed	121	109	Arms: 1 Target: DPA Theory: NR in this paper Duration: ≤ 12 months	Control: Assume usual practice	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Mihas 2010[153] Greece	Design: RCT Setting: School Age group: 13-18 (intv = 13·1, control = 13·3) Gender: mixed	213	191	Arms: 1 Target: Diet Theory: Social Learning theory Duration: ≤ 12 months	Control: Usual care presumed as no details but school-based intervention	BMI (≤ 12 months)† Adverse: NR Cost: NR
Morgan 2011[154] Australia	Design: RCT Setting: Community Age group: 6-12 (8·2) Gender: mixed	71	71	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Waitlist	BMI-Z (≤ 12 months)† Adverse: NR Cost: NR
Morgan 2014[155] Australia	Design: RCT Setting: Community Age group: 6-12 (8·1) Gender: mixed	132	132	Arms: 1 Target: DPA Theory: SCT, FST Duration: ≤ 12 months	Control: Waitlist	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Muckelbauer 2010[156] Germany	Design: C-RCT (School) Setting: School Age group: 6-12 (intv = 8·26, control = 8·34) Gender: mixed	3817	2950	Arms: 1 Target: Diet Theory: TPB Duration: ≤ 12 months	Control: No intervention	BMI (≤ 12 months) Adverse assessed: Yes Adverse effect: There were no adverse effects reported. Cost: Initial costs per water fountain (∼2500 euros), long-term costs per enrolled child (∼13 euros per year)
Muller 2016[157] Germany	Design: C-RCT (Classroom) Setting: School Age group: 6-12 (11·0) Gender: mixed	366	236	Arms: 1 Target: PA Theory: NR Duration: > 12 months	Control: Usual practice. Standard curriculum	BMI percentile (> 12 months) Adverse: NR Cost: NR
Muller 2019[158] South Africa	Design: C-RCT (School) Setting: School Age group: 6-12 (intv 1 = 10.0, intv 2 = 10.1, control = 9·9) Gender: mixed	1009	519	Arms: 3 Target: PA Theory: NR Duration: ≤ 12 months	Control: Usual practice	BMIz (>12 months)† Adverse assessed: Yes Adverse effect: There were no adverse events reported. Cost: NR
Muzaffar 2019[159] USA	Design: C-RCT (After school care group) Setting: School (ASP) Age group: 6-12 (11·6) Gender: mixed	109	101	Arms: 1 Target: DPA Theory: SCT and Stages of Change model Duration: ≤ 12 months	CE: Adult-led intervention	BMI percentile (≤ 12 months) Adverse: NR Cost: NR
Nct 2014[160] USA	Design: C-RCT (Practice) Setting: Health care service* + Home Age group: 6-12 (10·6) Gender: mixed	430	219	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Usual practice	BMI-z (≤ 12 months) Adverse assessed: Yes Adverse effect: One enrolled patient death occurred during the study period (not related to participation in the research study). Cost: NR

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Neumark-Sztainer 2003[161] USA	Design: C-RCT (School) Setting: School* + Home Age group: 13-18 (intv = 14·9, control = 15·8) Gender: Girls only	201	190	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Regular physical education class and minimal intervention (written materials on healthy eating and physical activity at baseline)	BMI (≤ 12 months) Adverse assessed: Yes Adverse effect: Unhealthy behaviours in last month, binge eating, self-acceptance/self-worth (no difference between groups) Cost: NR
Neumark-Sztainer 2010[162] USA	Design: C-RCT (School) Setting: School* + Home Age group: 13-18 (15·8) Gender: Girls only	356	336	Arms: 1 Target: DPA Theory: SCT, Stages of Change Duration: > 12 months	Control: All-girls PE class during the first semester then usual PE	BMI (> 12 months) Adverse assessed: Yes Adverse effect: Unhealthy weight control behaviours, binge eating, body satisfaction (no difference between groups). Improved self worth (Harter scale (scale 5-20), mean intervention=15·3, n=182; Control=14·4, n=174; effect size=−0·9, difference between control and intervention at follow-up, P=0·024) Cost: NR
Newton 2014[163] USA	Design: RCT Setting: Home Age group: 6-12 (8·7) Gender: mixed	27	27	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Attention control - access to website	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Nollen 2014[164] USA	Design: RCT Setting: Home Age group: 6-12 (intv = 11·3, control = 11·3) Gender: Girls only	51	44	Arms: 1 Target: DPA Theory: 'Behavioural weight control principles' Duration: ≤ 12 months	Attention control - same content in a written manual but no prompting	BMI (≤ 12 months)† Adverse: NR Cost: NR
Nyberg 2015[165] Sweden	Design: C-RCT (Classroom) Setting: School* + Home Age group: 6-12 (intv = 6·2, control = 6·2) Gender: mixed	243	239	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Waitlist	BMI-z (≤ 12 months) Adverse assessed: Yes Adverse effect: Prevalence of underweight (reported no change) Cost: NR
Nyberg 2016[166] Sweden	Design: C-RCT (Classroom) Setting: Preschool*+ Home Age group: 6-12 (6.3) Gender: mixed	378	332	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Waitlist	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
O'Connor 2020[167] USA	Design: RCT Setting: Community* + Home Age group: 6-12 (8·5) Gender: mixed	64	46	Arms: 1 Target: DPA Theory: SCT, FST Duration: ≤ 12 months	Control: Waitlist	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Paineau 2008[168] France	Design: C-RCT (School) Setting: Home* + School Age group: 6-12 (intv A = 7·7, intv B = 7·8, control = 7·6) Gender: mixed	1013	949	Arms: 2 Target: Diet Theory: NR Duration: ≤ 12 months	Control: No advice	BMI-Z (≤ 12 months)† Adverse: NR Cost: NR

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Papadaki 2010[169] Netherlands, Denmark, UK, Greece, Germany, Spain, Bulgaria, and Czech Republic	Design: RCT Setting: Community Age group: 6-12 (boys = 11·9, girls = 12·4) Gender: mixed	800	460	Arms: 4 Target: Diet Theory: NR Duration: ≤ 12 months	Control: Usual care. National dietary guidelines, with medium protein content and no specific instructions on glycaemic index	BMI and BMIz (≤ 12 months)† Adverse: NR Cost: NR
Pate 2005[170] USA	Design: C-RCT (School) Setting: School + Home Ccommunity Age group: 13-18 (13·6) Gender: Girls only	1604	1539	Arms: 1 Target: PA Theory: SEM drawn from SCT Duration: ≤ 12 months	Control: Usual care. Enrolled in PE class	Reported as % in each BMI percentile (≤ 12 months) Adverse: NR Cost: NR
Patrick 2006[171] USA	Design: RCT Setting: Home* + Health care service Age group: 13-18 (intv girls = 12·8, boys = 12·6; control girls = 12·6, boys = 12·8) Gender: mixed	819	690	Arms: 1 Target: DPA Theory: Behavioural Determinants model; SCT; TTM Behaviour Change Duration: ≤ 12 months	Control: Attention control - Sun protection plus lottery tickets for small cash prizes	BMI z-score (≤ 12 months) Adverse: NR Cost: NR
Peralta 2009[172] Australia	Design: RCT Setting: School* + Home Age group: 13-18 (12·5) Gender: Boys only	33	33	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Usual care. Physical activity curriculum sessions	BMI (≤ 12 months)† Adverse: NR Cost: NR
Pfeiffer 2019[173] USA	Design: C-RCT (School) Setting: School (ASP) Age group: 6-12 (12·05) Gender: Girls only	1519	1519	Arms: 1 Target: PA Theory: Health promotion model, self-determination theory Duration: ≤ 12 months	Control: Usual practice	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Polonsky 2019[174] USA	Design: C-RCT (School) Setting: School* + Community + Home Age group: 6-12 (10·8) Gender: mixed	1362	793	Arms: 1 Target: Diet Theory: NR Duration: > 12 months	Control: Usual practice	BMI-z (> 12 months)† Adverse assessed: Yes Adverse effect: Child weight status (approximately 3-fold increase in incidence of obesity in the intervention group) Cost: NR
Prina 2014[175] Mexico	Design: RCT Setting: School* + Home Age group: 6-12 (basic = 9·80, risk = 9·84, compare = 9·85, control = 9·78) Gender: mixed	2746	2462	Arms: 3 Target: DPA Theory: Health Belief Model Duration: ≤ 12 months	Control: No intervention	BMI (≤ 12 months)† Adverse assessed: Yes Adverse effect: Yes. No adverse effects reported. Cost: NR
Ramirez-Rivera 2021[176] Mexico	Design: RCT Setting: School* + Home Age group: 6-12 (10·2) Gender: mixed	41	41	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: General nutrition recommendations	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: No adverse effects were observed. Costs: NR
Reed 2008[177] Canada	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (NR) Gender: mixed	268	237	Arms: 1 Target: PA Theory: SEM Duration: ≤ 12 months	Control: Usual care	BMI (≤ 12 months)† Adverse: NR Cost: NR
Rerksuppaphol 2017[178] Thailand	Design: RCT Setting: School* Age group: 6-12 (10·7) Gender: mixed	218	217	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Feedback only from research assistants. No interaction with online software	BMI-z (≤ 12 months)† Adverse: NR Cost: NR

Table 1 (Continued)

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Rhodes 2019[179] Canada	Design: RCT Setting: Home Age group: 6-12 (8·93) Gender: mixed	102	102	Arms: 1 Target: PA Theory: Health Action Process Approach and the Multi-Process Action Control Approach Duration: ≤ 12 months	Attention control education only	BMI (≤ 12 months)† Adverse assessed: Yes Adverse effect: Yes reported. No participants cited harms associated with the study Cost: NR
Robbins 2006[180] USA	Design: C-RCT (Grade) Setting: School* + Home Age group: 6-12 (intv grade 6 = 11·45, grade 7 = 12·37, grade 8 = 13·00; control grade 6 = 11·25, grade 7 = 12·27, grade 8 = 13·44) Gender: Girls only	77	77	Arms: 1 Target: PA Theory: Health Promotion Model and TTM Duration: ≤ 12 months	Attention control: Handout listing the PA recommendations	BMI (≤ 12 months)† Adverse: NR Cost: NR
Robinson 2003[181] USA	Design: RCT Setting: Community* + Home Age group: 6-12 (9·5) Gender: Girls only	61	60	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Attention control: health education programme to promote healthful diet and activity patterns via newsletters and delivering health education lectures	BMI (≤ 12 months)† Adverse: NR Cost: NR
Robinson 2010[182] USA	Design: RCT Setting: Community* + Home Age group: 6-12 (intv = 9·5, control = 9·4) Gender: Girls only	261	225	Arms: 1 Target: PA Theory: SCM Duration: > 12 months	Attention control: Information-based health education	BMI and BMIz (> 12 months)† Adverse assessed: Yes Adverse effect: Weight concerns (no effect), percent underweight (no difference), body dissatisfaction (no effect), depressive symptoms (reduced for intervention group). No injuries or illness were judged to be probably or definitely related to study participation. Cost: NR
Rodearmel 2006[183] USA	Design: RCT (Family) Setting: Home Age group: 6-12 (intv target girls = 10·1, target boys = 9·8, other girls = 12·8, other boys = 11·8; control target girls = 9·9, target boys = 9·9, other girls = 11·8, other boys = 12·0) Gender: mixed	118	88	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Maintain usual eating and step patterns (given step counter and logs same as intervention group)	Reports % BMI-for-age as outcome (≤ 12 months) Adverse: NR Cost: NR
Rosario 2012[184] Portugal	Design: C-RCT (School) Setting: School Age group: 6-12 (8·3) Gender: mixed	464	294	Arms: 1 Target: Diet Theory: Health Promotion Model and SCT Duration: ≤ 12 months	Control: Usual care presumed as no details but school-based intervention	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Rosenkranz 2010[185] USA	Design: C-RCT (Girl scout troops) Setting: Community* + Home Age group: 6-12 (intv = 10·6, control = 10·5) Gender: Girls only	76	72	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: No intervention presumed (Girl Scouts USA)	BMI and BMIz (≤ 12 months)† Adverse: NR Cost: NR
Rush 2012[186] New Zealand	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (NR) Gender: mixed	3352	1352	Arms: 1 Target: DPA Theory: NR Duration: > 12 months	Control: No additional resourcing or information	BMI-z (> 12 months) Adverse: NR Cost: Intervention cost (<$40 New Zealand dollars per child per year)

Table 1 (Continued)

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Safdie 2013[187] Mexico	Design: C-RCT (School) Setting: School Age group: 6-12 (intv plus = 9·7, intv basic = 9·7, control = 9·8) Gender: mixed	886	830	Arms: 2 Target: DPA Theory: Ecological principles, Theory of Planned Behaviour, SCT„ Health Belief Model Duration: > 12 months	Control: No changes were made to existing nutrition or physical activity practices	BMI (> 12 months)† Adverse: NR Cost: NR
Sahota 2001[188] UK	Design: C-RCT - crossover (School) Setting: School Age group: 6-12 (intv = 8·36, control = 8·42) Gender: mixed	613	595	Arms: 1 Target: PA Theory: multi-component health promotion programme, based on the Health Promoting Schools concept Duration: ≤ 12 months	Control: Usual care presumed as no details but school-based intervention	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: BMI, psychological measures and dieting behaviours (no difference between groups). Global self-worth (higher in obese children in intervention group). Cost: NR
Sahota 2019[189] England	Design: C-RCT (School) Setting: School Age group: 6-12 (year 2 intv = 6·2, control = 6·3; year 4 = 8·3; overall 7·2) Gender: mixed	358	311	Arms: 1 Target: DPA Theory: Behaviour Theory, BCW Duration: > 12 months	Control: Usual practice	BMI-z (> 12 months)† Adverse assessed: Yes Adverse effect: Body shape and dieting behavior (results suggest no negative impact) Cost: NR
Sallis 1993[190] USA	Design: C-RCT (School) Setting: School Age group: 6-12 (9·25) Gender: mixed	745	549	Arms: 2 Target: PA Theory: Behaviour Change and self-management Duration: > 12 months	Control: Usual care PE	BMI (> 12 months) Adverse: NR Cost: NR
Salmon 2008[191] Australia	Design: C-RCT (Classroom) Setting: School Age group: 6-12 (10·7) Gender: mixed	295	268	Arms: 3 Target: PA Theory: SCT and Behavioural Choice theory Duration: ≤ 12 months	Control: Usual care curriculum	BMI (≤ 12 months) Adverse assessed: Yes Adverse effect: Happiness with body weight and shape and eating to gain or lose weight (no effect). Cost: NR
Santos 2014[192] Canada	Design: C-RCT (School) Setting: School Age group: 6-12 (intv = 9·3, control = 8·8) Gender: mixed	687	647	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Usual care regular curriculum	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Sekhavat 2014[193] Canada	Design: RCT Setting: Health care service Age group: 6-12 years (8·9) Gender: mixed	168	106	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Waitlist	BMI-z (≤ 12 months) Adverse: NR Cost: NR
Sevinc 2011[194] Turkey	Design: C-RCT (group − 2 schools in each group schools) Setting: School Age group: 6-12 (NR) Gender: mixed	6847	6366	Arms: 2 Target: Diet and DPA Theory: NR Duration: ≤ 12 months	Control: Usual care presumed as no details but school-based intervention	BMI (≤ 12 months)† Adverse: NR Cost: NR

Table 1 (Continued)

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Sgambato 2019[195] Brazil	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (NR) Gender: mixed	2743	2276	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Assume usual practice	BMI (≤ 12 months) Adverse assessed: Yes Adverse effect: BMI (increased more in the intervention group than in the control group (Δ=0·3 kg/m2; P=0·05) with a greater decrease in %body fat among boys (Δ=−0·6 %; P=0·03) in the control group). The subgroup that received both the school and home interventions had an increase in % body fat greater than in the control group (Δ=0·89 %; P=0·01). Cost: NR
Sherwood 2019[196] USA	Design: RCT Setting: Home* + Health care service Age group: 6-12 (6·6) Gender: mixed	421	363	Arms: 1 Target: DPA Theory: SCT, MI informed Duration: ≤ 12 months	Attention control: intervention focused on general health, safety, and injury prevention	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Shin 2015[197] USA	Design: RCT Setting: Community Age group: 13-18 (13·0) Gender: mixed	242	152	Arms: 1 Target: Diet Theory: SCT Duration: ≤ 12 months	Control: No intervention	BMI percentile (≤ 12 months) Adverse: NR Cost: NR
Shomaker 2019[198] USA	Design: RCT Setting: Community Age group: 13-18 (mindfulness = 13·97, health education = 14·49) Gender: mixed	54	54	Arms: Target: Mindfulness Theory: Mindfulness-based Duration: ≤ 12 months	Control: Health education control group - which met for six one-hour sessions, once per week. control condition matched for instruction time and designed to parallel health knowledge presented in a middle/high school health class. sessions covered six topics: alco	BMIz (≤ 12 months)† Adverse: NR Cost: NR
Sichieri 2008[199] Brazil	Design: C-RCT (School) Setting: School Age group: 6-12 (10·9) Gender: mixed	1134	927	Arms: 1 Target: Diet Theory: NR Duration: ≤ 12 months	Attention control: 2×1-h general sessions on health issues and printed general advices regarding healthy diets	BMI (≤ 12 months)† Adverse: NR Cost: NR
Siegrist 2013[200] Germany	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (8·4) Gender: mixed	826	724	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Usual care	BMI and BMIz (≤ 12 months)† Adverse assessed: Yes Adverse effect: Underweight ("children below the 10th centile for weight, and several underweight children in both intervention and control groups showed a decrease in waist circumference. There were no significant differences between the intervention and control groups however. This suggests that these reductions were not related to the intervention") Cost: NR
Siegrist 2018[201] Germany	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (11·1) Gender: mixed	620	434	Arms: 1 Target: DPA Theory: SCT Duration: > 12 months	Control: Usual practice - normal PE program	BMI (> 12 months)† Adverse: NR Cost: NR
Simon 2008[202] France	Design: C-RCT (School) Setting: School* + ASP Age group: 6-12 (intv = 11·7, control = 11·6) Gender: mixed	954	954	Arms: 1 Target: PA Theory: Behaviour Change and SEM Duration: > 12 months	Control: Usual care school curriculum	BMI (> 12 months)† Adverse: NR Cost: NR

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Simons 2015[203] The Netherlands	Design: RCT Setting: Home Age group: 13-18 (13·9) Gender: mixed	270	257	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Waitlist	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: Injuries (bruises or strained muscles/tendons while playing Move video games, 20%) Cost: NR
Singh 2009[204] The Netherlands	Design: C-RCT (School) Setting: School Age group: 13-18 (intv boys = 12·8, girls = 12·6; control boys = 12·9, girls = 12·7) Gender: mixed	1108	1108	Arms: 1 Target: DPA Theory: Intervention mapping protocol, Behaviour Change and Environmental frameworks Duration: ≤ 12 months	Control: Usual care regular curriculum	BMI (≤ 12 months)† Adverse: NR Cost: NR
Smith 2014[205] Australia	Design: C-RCT (School) Setting: School* + Home Age group: 13-18 (12·7) Gender: Boys only	361	361	Arms: 1 Target: PA Theory: Self-determination theory and SCT Duration: ≤ 12 months	Control: Waitlist and usual practice (i.e. regularly scheduled school sports and PE)	BMI (≤ 12 months)† Adverse assessed: Yes Adverse effect: No adverse events or injuries were reported during the school sports sessions, lunchtime leadership sessions, or assessments. Psychological wellbeing (small but significant positive effect) Cost: Cost of fitness equipment pack provided to schools (1500 AUD)
Spiegel 2006[206] USA	Design: C-RCT (Classroom) Setting: School* + Home Age group: 6-12 (NR) Gender: mixed	1191	1013	Arms: 1 Target: DPA Theory: Theory of Reasoned Action, Constructivism Duration: ≤ 12 months	Control: Data collection only	BMI-z (≤ 12 months) Adverse: NR Cost: NR
Stettler 2015[207] USA	Design: C-RCT (Practice) Setting: Health care service Age group: 6-12 (beverage-only intervention = 10·8, multiple behaviour intervention = 10·7, control = 10·8) Gender: mixed	173	121	Arms: 2 Target: DPA Theory: Behavioral economics Duration: ≤ 12 months	Control: Attention control - control intervention of the same intensity unrelated to weight (friendship making intervention)	BMI-z (≤ 12 months)† Adverse: NR Cost: Payment to clinician per completed session ($35).
Story 2003a[208] USA	Design: RCT Setting: School (ASP)* + Home Age group: 6-12 (intv = 9·4, control = 9·1) Gender: Girls only	53	53	Arms: 1 Target: DPA Theory: SCT, youth development, and resiliency based approach Duration: ≤ 12 months	Control: "active placebo," non-nutrition/PA condition, promoting self-esteem and cultural enrichment	BMI (≤ 12 months)† Adverse assessed: Yes Adverse effect: Weight concern behaviours (Higher moderate and less healthy weight concern behaviours in intervention group at follow-up) Cost: NR
Telford 2012[209] Australia	Design: C-RCT (Schools) Setting: School Age group: 6-12 (NR) Gender: mixed	Unclear	620	Arms: 1 Target: PA Theory: NR Duration: > 12 months	Control: Usual care, common practice PE	Outcome reported as percentage change of body fat (> 12 months) Adverse: NR Cost: NR
TenHoor 2018[210] The Netherlands	Design: C-RCT (School) Setting: School Age group: 13-18 (12·97) Gender: mixed	695	293	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Usual curriculum	Only weight kg and fat mass reported (≤ 12 months) Adverse: NR Cost: NR

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Thivel 2011[211] France	Design: C-RCT (School) Setting: School Age group: 6-12 (NR) Gender: mixed	457	457	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Not aware of the intervention in other schools	BMI (≤ 12 months)† Adverse: NR Cost: NR
Treviño 2004[212] USA	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (intv = 9·79, control = 9·77) Gender: mixed	1993	1221	Arms: 1 Target: DPA Theory: SCT and a socio-ecological framework Duration: ≤ 12 months	Control: Assume usual practice	Body fat % (≤ 12 months) Adverse: NR Cost: NR
Velez 2010[213] USA	Design: RCT Setting: School Age group: 13-18 (16·14) Gender: mixed	31	28	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: No intervention	BMI (≤ 12 months)† Adverse: NR Cost: NR
Viggiano 2015[214] Italy	Design: C-RCT (School) Setting: School Age group: 13-18 (intv = 13·3, control = 13·0) Gender: mixed	3110	2156	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: No intervention	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Viggiano 2018[215] Italy	Design: C-RCT (School) Setting: School Age group: 6-12 (NR) Gender: mixed	1313	1007	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: No intervention	BMI-z (≤ 12 months)† Adverse: NR Cost: NR
Vizcaino 2008[216] Spain	Design: C-RCT (School) Setting: School (ASP) Age group: 6-12 (intv boys = 9·4, girls = 9·4; control boys = 9·5, girls = 9·4) Gender: mixed	1119	1044	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Standard PE curriculum (3 h/week of PA at low to moderate intensity)	BMI (≤ 12 months)† Adverse: NR Cost: Intervention cost (EUR 28 per child per month)
Wang 2012[217] China	Design: C-RCT (Schools) Setting: School Age group: 6-12 (NR) Gender: mixed	1003	931	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Usual care presumed as no details but school-based intervention (translated)	Prevalence of overweight/obesity (≤ 12 months) Adverse: NR Cost: NR
Wang 2018[218] China	Design: C-RCT (School) Setting: School* + Community + Home Age group: 6-12 (10·5) Gender: mixed	10091	9858	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: No intervention	BMI-z (≤ 12 months)† Adverse assessed: Yes Adverse effect: stated no adverse events were reported. Cost: NR
Warren 2003[219] England	Design: RCT Setting: School* + Home Age group: 6-12 (6·1) Gender: mixed	218	172	Arms: 3 Target: Diet, PA, DPA Theory: Social Learning theory Duration: > 12 months	Control: Educational programme about food in a 'non-nutrition' = Be Smart sense	Reported as percentage overweight/obese (> 12 months) Adverse: NR Cost: NR
Waters 2017[220] Australia	Design: C-RCT (School) Setting: School* + Community + Home Age group: 6-12 (NR) Gender: mixed	3222	2743	Arms: 1 Target: DPA Theory: Health Promoting Schools Framework (based on health promotion theory and consistent with a socio-environmental theoretical framework) and International Obesity Task Force '10 guiding principles for obesity prevention' Duration: > 12 months	Control: Usual practice	BMI-z (> 12 months)† Adverse assessed: Yes Adverse effect: Body image sensitivity protocol (no findings reported) Cost: Estimated cost (discounted) of a community development worker ($55,868 per school over study period, $229 per student)

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Weeks 2012[221] Australia	Design: RCT Setting: School Age group: 13-18 (boys = 13·8, girls = 13·7) Gender: Boys only	99	81	Arms: 1 Target: PA Theory: NR Duration: ≤ 12 months	Control: Regular PE warm-up	BMI (≤ 12 months)† Adverse: NR Cost: NR
Wendel 2016[222] USA	Design: C-RCT (Classroom) Setting: School Age group: 6-12 (8·8) Gender: mixed	343	111	Arms: 3 Target: PA Theory: NR Duration: > 12 months	Control: No intervention	BMI (> 12 months)† Adverse assessed: Yes Adverse effect: Reports "no harm to students" Cost: NR
White 2019[223] USA	Design: RCT Setting: Community* + Home Age group: 6-12 (9·35) Gender: mixed	228	125	Arms: 1 Target: DPA Theory: SCT, experiential 4-H learning model Duration: > 12 months	Control: No intervention	BMI-z (> 12 months)† Adverse: NR Cost: NR
Whittemore 2013[224] USA	Design: C-RCT (Classroom) Setting: School* + Home Age group: 13-18 (15·31) Gender: mixed	384	365	Arms: 1 Target: DPA Theory: Theory of interactive technology, Social Learning theory Duration: ≤ 12 months	Attention control: health education and behavioral support	BMI (≤ 12 months)† Adverse: NR Cost: NR
Wieland 2018[225] USA	Design: RCT Setting: Home Age group: 13-18 (13·5) Gender: mixed	81	66	Arms: 1 Target: DPA Theory: SCT Duration: ≤ 12 months	Control: Delayed intervention	BMI (≤ 12 months)† Adverse: NR Cost: NR
Wilksch 2015[226] Australia	Design: C-RCT (Classroom) Setting: School Age group: 13-18 (13·21) Gender: mixed	820	820	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Usual school class	BMI (≤ 12 months)† Adverse assessed: Yes Adverse effect: Concerns about shape and weight, risk of eating disorders (Girls in the Life Skills intervention reported higher eating concern at 12-month follow-up compared to the control group). High weight and shape concern participants had higher levels of eating concern at 12-month follow-up in the intervention group compared to control Cost: NR
Williamson 2012[227] USA	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (PP = 10·5, SP = 10·5, control = 10·6) Gender: mixed	2060	1697	Arms: 2 Target: DPA Theory: SLT Duration: > 12 months	Control: No intervention	BMI-z (> 12 months)† Adverse: NR Cost: NR
Xu 2015[228] China	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (10·2) Gender: mixed	1182	1108	Arms: 1 Target: DPA Theory: NR Duration: ≤ 12 months	Control: Usual practice	BMI (≤ 12 months)† Adverse assessed: Yes Adverse effect: There was no observable adverse event in the intervention group. Cost: NR

Table 1 (Continued)

Author year Country	Study characteristics Design (cluster type) Setting Age group years (mean age) Gender	Number of participants Randomised	Analysed	Intervention Treatment arms Targeted behaviour Theory Duration	Comparator	Outcomes Weight outcomes (length of follow up from baseline category) Adverse effects Cost/cost-effectiveness
Xu 2017[229] China	Design: C-RCT (School) Setting: School* + Home Age group: 6-12 (9·2) Gender: mixed	9867	8573	Arms: 3 Target: Diet, PA, DPA Theory: NR Duration: ≤ 12 months	Control: no intervention	BMI and BMIz (≤ 12 months)† Adverse assessed: Yes Adverse effect: Effect on malnourished students (no negative effect observed. > increase in BMI and BMI-z score in intervention group) Cost: Cost-effectiveness ratio in combined intervention ($120·3 for 1 kg/m^2 BMI reduction, $249·3 for one unit of BMI-z score reduction), cost for avoiding one overweight and obesity case ($1308·90). Cost utility ratio (¥11,505·9, $1646·0) per QALY, cost-benefit ratio (¥1·2 benefit per ¥1 cost), and net saving (¥73,659·6, $10,537·9) for combined intervention.
Zhou 2019[230] China	Design: C-RCT (School) Setting: School* (some groups ASP) + Home Age group: 13-18 (12·66) Gender: mixed	758	681	Arms: 3 Target: DPA Theory: SEM, CMT Duration: ≤12 months	Control: Usual care	Only weight kg and body fat % reported (≤12 months) Adverse: NR Cost: NR
Zota 2016[231] Greece	Design: C-RCT (School) Setting: School* + Home Age group: 6-12; 13-18 (NR) Gender: mixed	21261	3627	Arms: 1 Target: Diet Theory: NR Duration: ≤12 months	Attention control: environmental intervention (received a healthy daily meal)	Reported as underweight vs. overweight/obese (≤12 months) Adverse assessed: Yes Adverse effect: Percentage of children and adolescents improving BMI from underweight to normal (Higher in multicomponent intervention group compared to environmental intervention only). Cost: Average cost of meals (€1·50)

***Table 1*: Characteristics of included studies.**

*Majority setting **Included in meta-analysis.

ASE = Attitude, social influence and self-efficacy model, BCW = Behaviour Change Wheel, BEM = Behavioral Ecological Model, CE = comparative effectiveness trial, CMT = competence motivation theory, C-RCT = cluster randomised controlled trial, DPA = diet and physical activity, FST = Family Systems Theory, HPSF = Health Promoting Schools Framework, IMB model = information-motivation-behavioural skills model, Intv = intervention, MI = Motivational Interviewing, NR = not reported, PA = physical activity, SEM = Social Ecological Model, SCM = social cognitive model, SCT = Social Cognitive Theory, SLT = Social learning theory, TDF = theoretical domains framework, TPB = Theory of planned behaviour, TTM = Transtheoretical model (Stages of Change).

	Studies	Participants	SMD (95% CI)*	I^2	Test of subgroup	GRADE certainty of evidence
School	93	131443	**-0·03 [-0·06, -0·01]**	56%	NA	⊕⊕⊕ Moderate[a]
Subgroup: age 6−12 years	72	114451	**-0·03 [-0·05, -0·01]**	21%	Chi^2 = 0·17 (P = 0·68)	
Subgroup: age 13−18 years	21	16992	-0·05 [-0·14, 0·04]	84%	NA	
Sensitivity: ROB	42	54132	**-0·03 [-0·05, 0·00]**	13%	NA	
Sensitivity: excl change scores	82	116127	**-0·04 [-0·07, -0·01]**	59%	NA	
Sensitivity: correlation est 0·80	93	131443	**-0·03 [-0·06, -0·01]**	57%	NA	
Sensitivity: correlation est 0·90	93	131443	**-0·03 [-0·05, -0·01]**	59%	NA	
Sensitivity: ICC=0	93	131443	**-0·03 [-0·05, -0·00]**	65%	NA	
Subgroup: Intv duration <= 12 months	67	90478	**-0**·04 **[-0·08, -0·01]**	64%	Chi^2 = 2·10 (P = 0·15)	
Subgroup: Intv duration > 12 months	26	40965	-0·02 [-0·04, 0·01]	0%	NA	
Subgroup: Intv type - Diet only	11	14999	-0·00 [-0·07, 0·06]	51%	Chi^2 = 1·22 (P = 0·75)	
Subgroup: Intv type - PA only	25	16935	**-0·05 [-0·10, 0·00]**	37%	NA	
Subgroup: Intv type - Diet + PA	58	82887	**-0·04 [-0·07, -0·0**1]	61%	NA	
Subgroup: Intv type - Other	1	16622	-0·03 [-0·08, 0·02]	-	NA	
Subgroup: Continent Africa	1	519	-0·23 [-0·45, -0·01]	-	Chi^2 = 2·02 (P = 0·73)	
Subgroup: Continent Asia	10	35905	-0·04 [-0·09, 0·01]	53%	NA	
Subgroup: Continent Australia	11	7167	-0·04 [-0·10, 0·03]	25%	NA	
Subgroup: Continent Europe	42	43979	-0·04 [-0·09, 0·00]	72%	NA	
Subgroup: Continent North America	23	39253	-0·02 [-0·04, 0·01]	0%	NA	
Subgroup: Continent South America	6	4620	-0·00 [-0·07, 0·06]	0%	NA	
After-school program	12	5066	-0·09 [-0·22, 0·04]	76%	NA	⊕ Very low[a,b,c]
Subgroup: age 6−12 years	10	4636	-0·02 [-0·09, 0.05]	15%	Chi^2 = 1·89 (P = 0·17)	
Subgroup: age 13−18 years	2	430	-0·67 [-1·60, 0·25]	93%	NA	
Sensitivity: ROB	9	4316	-0·14 [-0·30, 0·01]	79%	NA	
Sensitivity: excl change scores	NA	NA	NA	NA	NA	
Sensitivity: correlation est 0·80	NA	NA	NA	NA	NA	
Sensitivity: correlation est 0·90	NA	NA	NA	NA	NA	
Sensitivity: ICC=0	12	5066	-0·09 [-0·22, 0·04]	76%	NA	
Subgroup: Intv duration <= 12 months	12	5066	-0·09 [-0·22, 0·04]	76%	NA	
Subgroup: Intv duration > 12 months	NA	NA	NA	NA	NA	
Subgroup: Intv type - Diet only	NA	NA	NA	NA	NA	
Subgroup: Intv type - PA only	7	3977	**-0·18 [-0·34, -0·01]**	82%	Chi^2 = 4·20 (P = 0·04)	
Subgroup: Intv type - Diet + PA	5	1089	0·08 [-0·10, 0·26]	27%	NA	
Subgroup: Intv type - Other	0	0	NA		NA	
Subgroup: Continent Africa	1	160	-1·14 [-1·48, -0·81]	-	Chi^2 = 0·36 (P = 0·55)	
Subgroup: Continent Australia	1	35	-0·60 [-1·28, 0·08]	-	NA	
Subgroup: Continent Europe	2	1956	-0·04 [-0·13, 0·05]	0%	NA	
Subgroup: Continent North America	7	2645	-0·00 [-0·10, 0·11]	16%	NA	
Subgroup: Continent South America	1	270	-0·20 [-0·54, 0·14]	-	NA	
Community	21	3292	-0·04 [-0·11, 0·04]	0%	n/a	⊕⊕ Low[a,c]
Subgroup: age 6−12 years	20	3238	-0·04 [-0·12, 0·03]	0%	NA	
Subgroup: age 13−18 years	1	54	0·11 [-0·42, 0·65]	-	NA	
Sensitivity: ROB	12	1211	-0·02 [-0·12, 0·09]	0%	NA	
Sensitivity: excl change scores	17	2816	-0·04 [-0·13, 0·05]	0%	NA	
Sensitivity: correlation est 0·80	21	3292	-0·02 [-0·09, 0·04]	0%	NA	
Sensitivity: correlation est 0·90	21	3292	-0·02 [-0·07, 0·04]	0%	NA	
Sensitivity: ICC=0	21	3292	-0·05 [-0·12, 0·02]	0%	NA	
Subgroup: Intv duration <= 12 months	16	1699	-0·03 [-0·13, 0·06]	0%	Chi^2 = 0·01 (P = 0·92)	
Subgroup: Intv duration > 12 months	5	1593	-0·04 [-0·16, 0·07]	0%	NA	

Table 2 *(Continued)*

	Studies	Participants	SMD (95% CI)*	I^2	Test of subgroup	GRADE certainty of evidence
Subgroup: Intv type - Diet only	4	1174	-0·07 [-0·22, 0·09]	0%	Chi^2 = 0·38 (P = 0·82)	
Subgroup: Intv type - PA only	4	555	-0·00 [-0·15, 0·14]	0%	NA	
Subgroup: Intv type - Diet + PA	13	1563	-0·04 [-0·15, 0·06]	0%	NA	
Subgroup: Intv type - Other	0	0	NA	-	NA	
Subgroup: Continent Asia	1	104	-0·31 [-0·72, 0·10]	-	Chi^2 = 1·75 (P = 0·42)	
Subgroup: Continent Australia	3	251	-0·08 [-0·28, 0·11]	0%	NA	
Subgroup: Continent Europe	2	523	-0·14 [-0·35, 0·07]	0%	NA	
Subgroup: Continent North America	15	2414	0·00 [-0·09, 0·09]	0%	NA	
Home	13	2400	0·01 [-0·07, 0·09]	0%	NA	⊕⊕ Low[a,c]
Subgroup: age 6—12 years	7	1665	-0·04 [-0·14, 0·06]	0%	Chi^2 = 2·99 (P = 0·08)	
Subgroup: age 13—18 years	6	735	0·11 [-0·03, 0·25]	0%	NA	
Sensitivity: ROB	7	1927	0·02 [-0·11, 0·14]	33%	NA	
Sensitivity: excl change scores	9	1255	0·05 [-0·08, 0·18]	19%	NA	
Sensitivity: correlation est 0·80	13	2400	0·00 [-0·07, 0·07]	0%	NA	
Sensitivity: correlation est 0·90	13	2400	-0·01 [-0·08, 0·06]	10%	NA	
Sensitivity: ICC=0	13	2400	0·00 [-0·07, 0·07]	0%	NA	
Subgroup: Intv duration <= 12 months	14	4862	0·01 [-0·07, 0·09]	0%	NA	
Subgroup: Intv duration > 12 months	0	0	NA	-	NA	
Subgroup: Intv type - Diet only	3	1098	-0·04 [-0·16, 0·08]	0%	Chi^2 = 5·80 (P = 0·05)	
Subgroup: Intv type - PA only	3	386	0·22 [0·02, 0·42]	0%	NA	
Subgroup: Intv type - Diet + PA	8	3378	-0·02 [-0·15, 0·11]	0%	NA	
Subgroup: Intv type - Other	0	0	NA	-	NA	
Subgroup: Continent Australia	1	46	-0·19 [-0·81, 0·43]	-	Chi^2 = 0·51 (P = 0·47)	
Subgroup: Continent Europe	2	1206	0·12 [-0·21, 0·45]	83%	NA	
Subgroup: Continent North America	10	1148	-0·01 [-0·12, 0·10]	0%	NA	
Health care service	1	121	-0·48 [-0·95, -0·01]	-	NA	⊕⊕ Low[a,d]
Subgroup: age 6—12 years	0	0	NA	-	NA	
Subgroup: age 13—18 years	1	121	-0·48 [-0·95, -0·01]	-	NA	
Sensitivity: ROB	0	0	NA	-	NA	
Sensitivity: excl change scores	NA	NA	NA	-	NA	
Sensitivity: correlation est 0·80	NA	NA	NA	-	NA	
Sensitivity: correlation est 0·90	NA	NA	NA	-	NA	
Sensitivity: ICC=0	NA	NA	NA	-	NA	
Subgroup: Intv duration <= 12 months	1	121	-0·48 [-0·95, -0·01]	-	NA	
Subgroup: Intv type - Diet + PA	1	121	-0·48 [-0·95, -0·01]	-	NA	

***Table 2*: Results by setting for primary, subgroup and sensitivity meta-analyses.**

*Std. Mean Difference (IV, Random, 95% CI).

[a] downgraded one level for risk of bias: most information from studies at low or unclear risk of bias.

[b] downgraded one level for inconsistency: heterogeneity was not fully explained in subgroup analysis by age, intervention duration or type.

[c] downgraded one level for imprecision: the confidence intervals contained the null value.

[d] downgraded one level for imprecision: total sample size was fewer than 400 participants.

est = estimate, excl = excluded, GRADE = Grading of Recommendations Assessment, Development and Evaluation, intv = intervention, NA = not applicable, PA = physical activity, ROB = risk of bias, SMD = standard mean difference.

Meta-analysis of 13 trials (2,400 participants) comparing home-based childhood obesity prevention interventions to control revealed no overall significant effect on BMI (SMD 0·01, 95% CI -0·07 to 0·09; I^2 = 0%; low certainty evidence; Table 2; Supplementary File Figure S4).

Fifty-six studies were not pooled (no suitable BMI data (n = 38), no assessment of BMI (n = 13), comparative effectiveness study design (n = 4); Table 1) which reported mixed findings. Briefly, of the 39 studies not pooled that measured BMI, 22 (56%) reported an effect in a positive direction (10 of 23 school-bsaed studies; 2

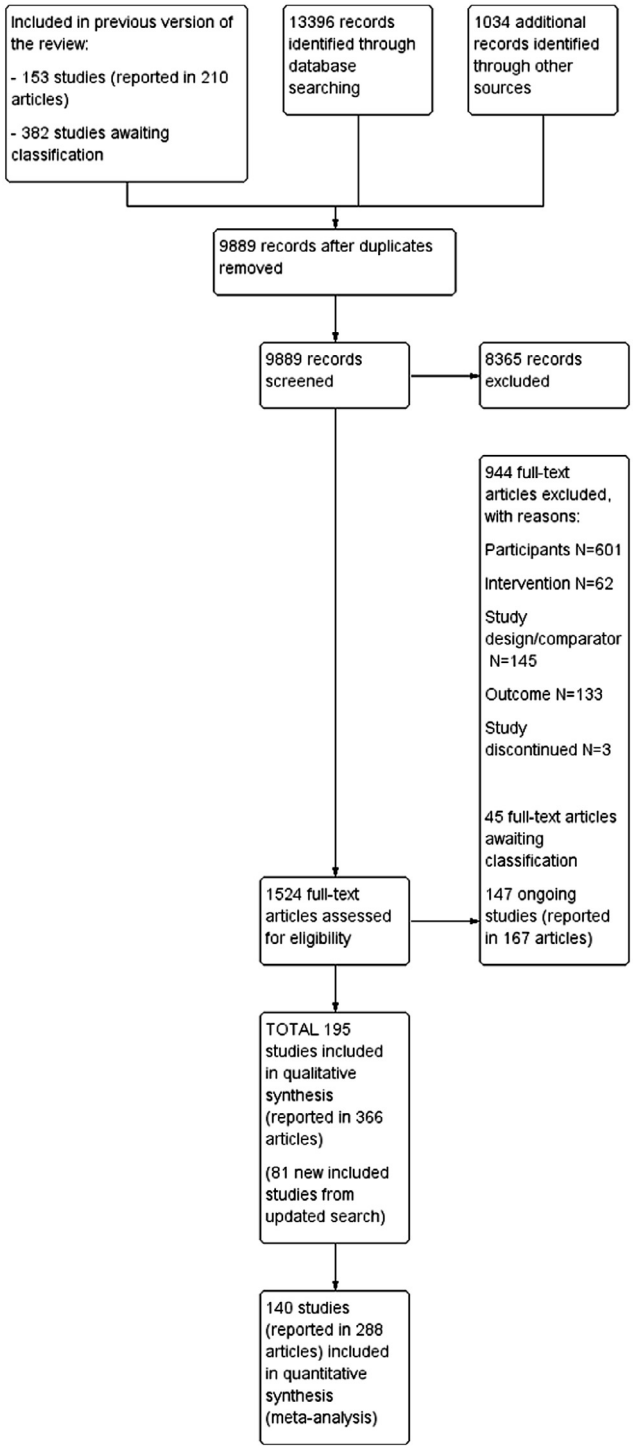
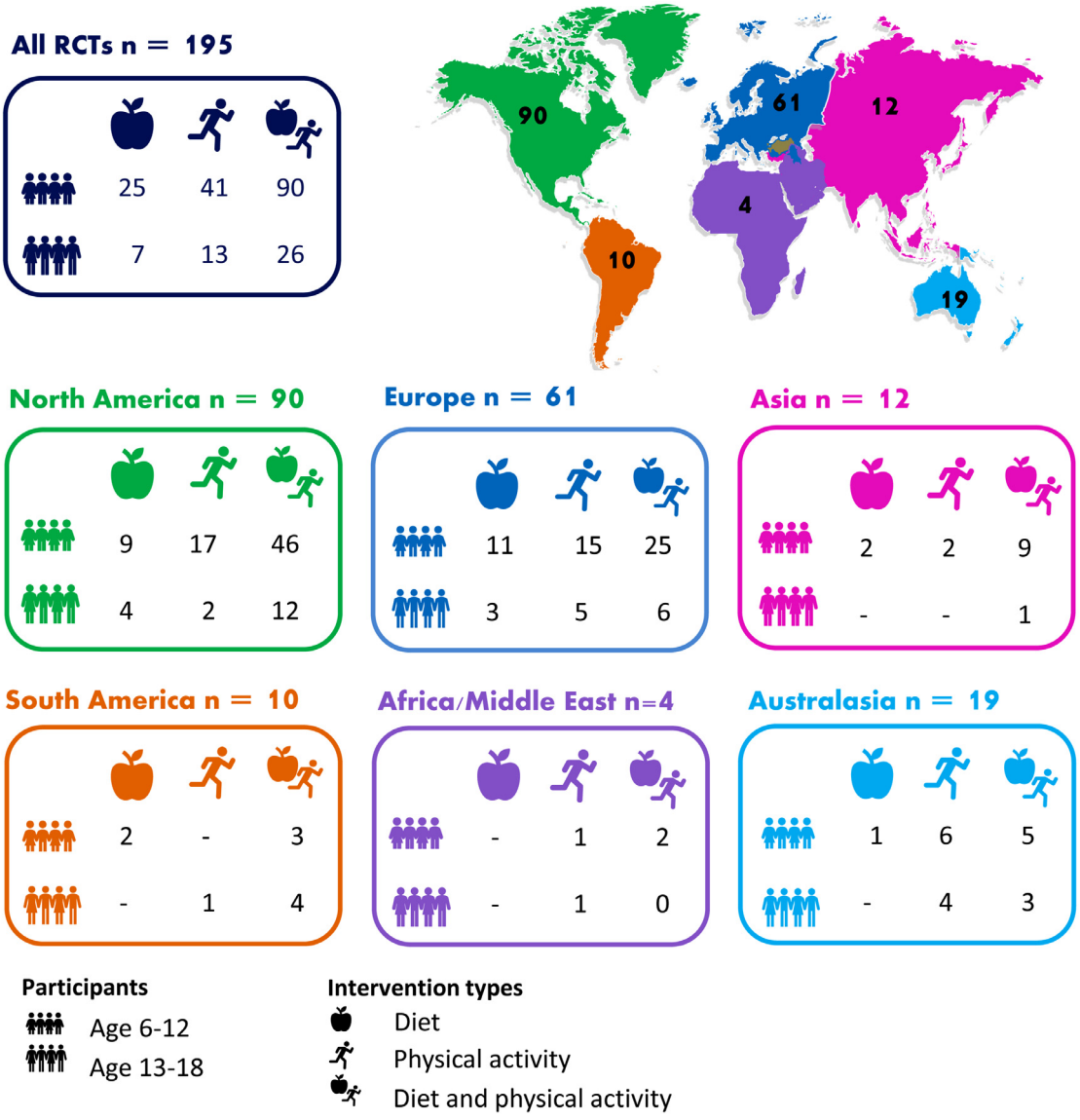


Figure 1. Study flow diagram.



Legend: RCTs – randomised controlled trials

Footnotes [a]. Totals in boxes by age indicate number of different intervention types of each active intervention arm. NB. Two RCTs of 'other' intervention types are not represented (BMI reporting in ages 6-12: Madsen 2021; Mindfulness in ages 13-18: Shomaker 2019), three RCTs tested three treatment arms each (diet, physical activity, diet and physical activity) in ages 6-12 (Ickovics 2019; Warren 2003, Xu 2017), one RCT tested two treatment arms (diet, diet and physical activity) in ages 6-12 (Sevinc 2011), one RCT tested their intervention in children aged 6-12 and 13-18 years; one RCT that tested a diet and physical activity intervention in ages 13-18 years was conducted in both North American and Europe.

Figure 2. Distribution of studies by continent, child age and intervention type.[a]

of 2 after-school program studies; 5 of 6 community-based studies; 2 of 4 home-based studies; 3 of 4 health care service studies). Of the 13 studies that reported other weight outcomes, eight (62%) reported an effect in a positive direction on at least one weight outcome. One of the four comparative effectiveness studies,[52,81,104,159] reported a greater effect on a weight outcome.[104]

Results from all sensitivity analyses were similar to primary analysis results (Table 2).

No differential effects were found in subgroup analyses by age or geographic region for any setting (Table 2).

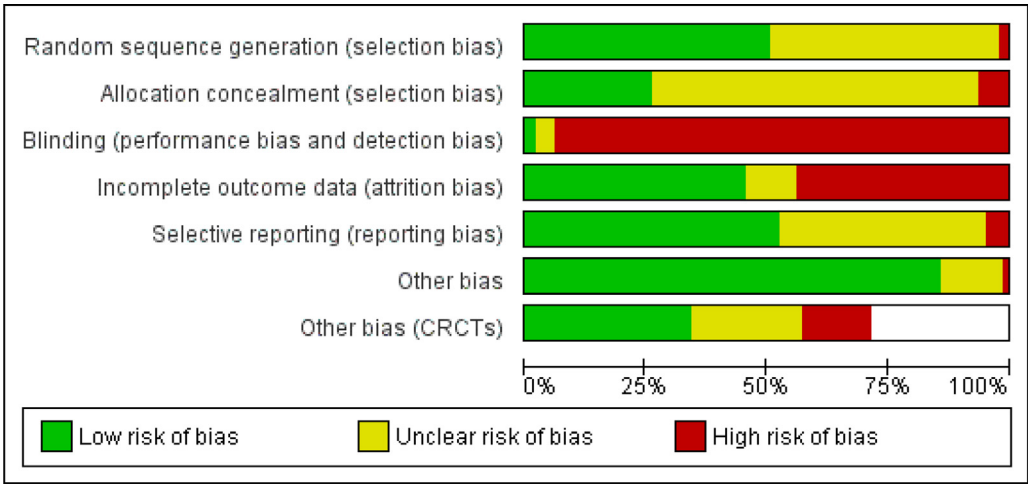


Figure 3. Risk of bias graph of studies included in meta-analysis.

Heterogeneity was evident for school-based (I^2 = 56%) and after-school program interventions (I^2 = 76%), which subgroup analysis by age, intervention duration and type did not entirely explain (Table 2).

Results from the meta-regression identified no association between any covariates assessed and the overall SMD for BMI ($F(df1 = 11, df2 = 128) = 0{\cdot}77$; $p = 0{\cdot}6645$; $R^2 = 0$; Supplementary File Table S3), with the I^2 indicating 54% of the variability was attributable to between study variation (with similar results from the Knapp-Hartung and permutation tests).

Fifty-three studies reported assessing potential adverse events, including unhealthy weight control behaviours, change in prevalence of underweight, adverse body image-related consequences, and quality of life (Supplementary File Table S1). The majority (43/53) reported no evidence of an adverse effect (low quality evidence). Eight studies reported one or more unintended adverse effects on an outcome other than weight. Three school-based studies reported an increase in unhealthy weight control or weight concern behaviours,[139,208,226] and one school, after-school program or home study each reported increased peer weight talk,[147] minor ankle sprains,[33] bruises and strained muscles/tendons,[203] depressive symptom score,[151] overexercising,[139] or increase food intake,[195] in intervention compared to control participants. Two studies reported dizziness in both intervention and control groups due to medical procedures (blood drawing,[33,106] venipuncture).[105] One study reported adverse effects were observed but did not report what they were.[72]

Ten studies reported findings from cost effectiveness analyses and 28 reported absolute costs (Supplementary File Table S1). Pooling of cost effectiveness data was not possible due to the heterogeneity of interventions and outcomes, however nine reported the intervention to be cost effective (low quality evidence).[38,53,65,92,109,124,135,138,186,229]

Inspection of funnels plots (Supplementary File Appendix B) suggested potential reporting bias for only ASP interventions, which may have led to an overestimation of the magnitude of effect. However, given the overall null effect for ASPs such assessment does not change the conclusions. Eggers tests to investigate publication bias did not identify any evidence of publication bias in any setting, including ASPs (Supplementary File Appendix C).

Discussion

This review, which represents the most comprehensive synthesis of childhood obesity prevention interventions for school-aged children to date, found an effect for school-based obesity prevention interventions, albeit it modest, equivalent to a 0·11 improvement in BMI. These findings are consistent with those from the previous Cochrane review on this topic and other reviews in the field.[17] No overall effect was found for after-school programs, community or home interventions. However, while the confidence intervals included zero, the point estimate for after-school programs was more than twice that of school-based studies. Presence of adverse effects were uncommon (10/53 studies) and not severe, including minor sprains and increases in unhealthy weight control in small proportions of children. No conclusions could be drawn regarding cost effectiveness due to limited reporting (10/195), and meta-regression analyses across all settings found none of the examined study characteristics were associated with an effect on BMI.

The distribution of characteristics of the 81 new studies were similar to the existing Cochrane review,[17] with studies primarily conducted in high (85% v 84%) and upper middle-income countries (15% v 15%), schools

(67% v 70%), targeting younger school-aged children (76% v 74%), testing diet plus physical activity interventions (59% v 61%), and were interventions of less than or equal to 12 months in duration (77% v 73%). The update did not identify any new studies in low- or lower middle-income countries. Two new obesity prevention studies were identified that did not include an explicit diet or physical activity component indicating some diversification in intervention content, although neither reported a positive effect. The limited effects from such a large number of RCTs targeting diet and physical activity suggests a better understanding of how these interventions work, or do not work, is needed prior to development of new interventions.

While comparison between this update and the existing Cochrane review[17] is limited given differential approaches to synthesis, both similarly concluded childhood obesity prevention interventions have modest to no effect on child weight. These findings are also generally consistent with other systematic reviews of childhood obesity prevention interventions.[20,232]

Some limitations and potential biases of the review methods should be noted. The selection criteria of an explicit obesity prevention aim and RCT design may have excluded, and may explain the lack of studies, in low/low-middle countries. In such countries, obesity prevention studies are frequently integrated more broadly with related issues of the double burden of malnutrition, undernutrition and food insecurity, and randomized designs are less common.[16] While the income level of countries in which studies were tested was considered in meta-regression analyses, and there were no differential effects identified in subgroup analyses by continent, the specific impact of how the different contexts in each country impacts on the effectiveness of interventions is unknown. Additionally, the RCT design selection criteria may have excluded population-wide or system level intervention studies including those that combine interventions across multiple settings which may have considerable potential for population level impact. RCT designs for these types of studies are often not appropriate or feasible, and are more frequently tested in quasi-experimental or implementation research designs which were not included in this review.

Studies were restricted to those reporting an intervention and first follow-up of 12 weeks or greater, which may have excluded brief interventions with short-term follow up (e.g. [233–235]). Such approaches may be more easily implemented at scale, less costly and, if effective at longer-term follow-up, more appealing to policymakers and health decision makers, and may warrant separate synthesis. Additionally, studies that targeted diet and physical activity but did not measure a weight outcome were excluded from the review. This may have excluded studies with a meaningful positive impact on a proximal outcome of obesity, such as diet or physical activity. Additionally, the review did not synthesize any outcome data related to diet, physical activity or other potential co-benefits of obesity prevention interventions (e.g. mental health status). Finally, the findings of the review are limited to those studies published up to 30 June 2021. Whilst additional eligible studies may have been published since this date, it is unlikely their inclusion would make substantial difference to the point estimates, nor key conclusions of the review due the large number of studies included in the review to date, especially in the school setting.

In terms of implications for policy and practice, there is moderate certainty evidence, as assessed by the GRADE approach, for the continued implementation and ongoing investment of school-based obesity prevention interventions, which appear unlikely to cause serious harm. While observed pooled effects were small, small improvements in obesity can have a meaningful effect when implemented at a population level and has likely contributed to the reduced trajectory of overweight and obesity that has been observed in some high-income countries.[236] The potential public health benefits of such interventions however likely depend on consideration of their cost, and government capacity to deliver at scale given their relatively small effects on BMI.

The lack of effects of primary analyses pooling childhood obesity prevention interventions in after-school program, home and community settings need to be interpreted with caution given the considerable variability of interventions, the low to very low-certainty evidence, and identification of some high-quality studies in these settings with positive effects. This is echoed by the sensitivity analysis results for after-school programs excluding studies at high risk of bias, which may suggest the potential benefit of high-quality studies in this setting. Additionally, findings for studies conducted in health care settings were limited due to their scarcity.

Surprisingly none of the hypothesized variables included in the meta-regression accounted for any of the observed heterogeneity in the final model. This suggests that other intervention or population characteristics may need to be explored to advance the childhood obesity field. This could include a comprehensive examination of the effectiveness of intervention components and the behavior change techniques that underpin them; or the wider determinants of health that interventions target.[237] Similarly, a better understanding may be required of the impact of factors that likely impact on effectiveness of interventions such as consumer co-production, differential effectiveness between population groups that may widen health inequities,[238] or the duration of investment required for population-wide impact. Given the distal nature of weight status, synthesis of proximal outcomes such as diet and physical activity may be important to identify additional promising obesity prevention interventions that warrant

implementation. Synthesis of published and unpublished adverse, cost and other co-benefit outcomes assessed in obesity prevention interventions may also provide a more complete picture of obesity prevention intervention impact. Finally, synthesis of large-scale community-based interventions, 'upstream' interventions based on the wider determinants of health that target system or environmental changes,[237] and other interventions that have adopted non-RCT designs, may be important to guide childhood obesity prevention policymaking, particularly for low- and middle-income countries where the evidence is scant.

Contributors

All review authors contributed to the conception of the research and were involved in the preparation of the review including providing critical comment on drafts. RKH led the review update and manuscript drafting. RKH and KMO screened titles and abstracts and full texts to determine trial eligibility. THMM managed data access from the Brown and Moore et al review to this review team. THMM/CS was 3rd reviewer to determine trial eligibility. KMO, SL and RKH extracted data from eligible trials. RKH and KMO conducted and verified the meta-analyses. AH conducted the meta-regression. KMO, THMM, CS, SY and SL assessed risk of bias, and RKH was 3rd reviewer where consensus was not achieved. RKH, KMO and LW assessed quality of trials (GRADE). All review authors contributed to, critically reviewed and approved the final manuscript; had full access to all the data in the study; and final responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.eclinm.2022.101635.

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