


REVIEW

Pediatric Body Weight / Intervention

Childhood obesity prevention trials: A systematic review and meta-analysis on trial design and the impact of type 1 error

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Summary

Effect sizes from previously reported trials are often used to determine the meaningful change in weight in childhood obesity prevention interventions because information on clinically meaningful differences is lacking. Estimates from previous trials may be influenced by statistical significance; therefore, it is important that they have a low risk of type 1 error. A systematic review and meta-analysis were conducted to report on the design of child obesity prevention randomized controlled trials and effectiveness according to risk of type 1 error. Eighty-four randomized controlled trials were identified. A large range of assumptions were applied in the sample size calculations. The most common primary outcome was BMI, with detectable effect size differences used in sample size calculations ranging from 0.25 kg/m² (followed up at 2 years) to 1.1 kg/m² (at 9 months) and BMI z-score ranging from 0.1 (at 4 years) to 0.67 (at 3 years). There was no consistent relationship between low risk of type 1 error and reports of higher or lower effectiveness. Further clarity of the size of a meaningful difference in weight in childhood obesity prevention trials is required to support evaluation design and decision-making for intervention and policy. Type 1 error risk does not appear to impact effect sizes in a consistent direction.

KEYWORDS

obesity prevention, randomized controlled trials, trial design, type 1 error

1 | BACKGROUND

Worldwide, 340 million children aged 5–18 years and 38 million children aged up to 5 years are living with overweight or obesity.¹ Rates of childhood obesity have further increased because of lockdown measures during the Covid-19 pandemic.² Obesity in children has been linked to conditions such as diabetes and poor mental health during childhood.^{3,4} Individuals living with overweight or obesity as a child are more likely to have overweight or obesity in adulthood^{5,6} and as a result suffer from obesity-related chronic diseases and, as recently shown,⁷ death from infectious

disease such as Covid-19. This highlights the ongoing importance of tackling childhood obesity including as part of the pandemic recovery.⁸

Recognition of the impact of childhood obesity on the public's health has led to intensive efforts to develop effective prevention programs that can be applied broadly. Evidence from systematic reviews of trials aimed at testing the effectiveness of obesity prevention interventions in children^{9–12} often shows mixed or lack of an effect as evaluated by differences in the prevalence of overweight and obesity or continuous measure of fatness between intervention and control arms.

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Statistics widely used to evaluate differences in prevalence of obesity are *p*-values (using $\alpha < 0.05$ as a decision rule) and 95% confidence intervals that display the interval around the estimate within which the probability of rejecting the null hypothesis when the null hypothesis is true is 5% or less (again assuming $\alpha < 0.05$).¹³ Thus, α , which shows the probability of committing a type I error, has often been deemed as important in the assessment of the success of an obesity prevention intervention. Also of high importance are other statistics that are related to α (or type 1 error) such as the minimal detectable effect, power, sample size, variance of the outcome variable, and other properties that are dependent on the study design.¹⁴ Among these statistics, the minimal detectable effect size is difficult to establish in obesity prevention trials in children because of the lack of consensus on what level of weight change over time constitutes obesity prevention.

In adults, a rule of thumb of a 5% change in body weight has been used for many years¹⁵ to indicate a clinically important effect in obesity treatment, and more recently, a change of less than 3% has been used to define weight maintenance.¹⁶ However, growth as well as multiple other differences make these simple guidelines inappropriate for use in children. Currently, there is little guidance on the amount of change in weight-related measures that constitutes a clinically detrimental change versus a healthy or inconsequential change in children. A population-level reduction in BMI z-score of -0.13 within children aged 2 to 5 years has been suggested to achieve long-term health benefits and healthcare cost savings within obesity prevention trials. This was determined based on obesity-related health impact modeling.⁹ However, determining what a clinically meaningful effect size in childhood obesity prevention trials is challenging. Data from studies that have examined clinical effectiveness is inconsistent with many studies drawing on data of populations with children living with obesity or lacking longer-term follow-up data that are needed to understand if changes in BMI are sustained.¹⁷

To support with trial design, effect sizes seen in previously reported studies are often used as estimates of the minimal detectable effect expected in sample size calculations for new studies.¹⁴ However, the use of previously reported findings based on a reported statistically significant difference does not indicate that the difference is sufficiently large to be clinically meaningful. On the other hand, the use of an unrealistically large minimal detectable effect size in power calculations may lead to a study that has inadequate sample size and power to find smaller effects that may be clinically important.

The aim of this review was to explore the design of childhood obesity prevention randomized controlled trials and their effectiveness according to their risk of type 1 error. We describe the methodologies of trials and the assumptions used within sample size calculations to identify how outcome measures are being decided in the absence of clear guidance of what a clinically important difference is in prevention trials. In addition, we compare the effectiveness of studies deemed high risk of type 1 error to those low risk of type 1 error to explore if there is a difference in the overall effectiveness and if those deemed low risk of type 1 error have a higher or lower overall effectiveness. Exploring if outcomes differ according to risk of

type 1 error can determine whether the risk of type 1 error of a previous study used to support trial design should be considered to ensure the included outcome measure is appropriate to determine if an intervention is effective. The findings of this review can provide guidance to those designing future childhood obesity prevention randomized trials.

2 | METHODS

This systematic review is reported according to PRISMA reporting guidelines¹⁸ and was registered on PROSPERO before the final searches were conducted. The PROSPERO registration can be accessed here https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=131536

The Cochrane Collaboration Handbook¹⁹ was used to provide guidance on the meta-analysis methods, and the eligibility criteria follow similar criteria to the Cochrane Review on “Interventions to prevent obesity in children” published in 2019.⁹ However, as the current review has a focus on trial design and the risk of type 1 error within studies, a more sensitive search was conducted and the eligibility criteria have been developed to reflect the purpose of this review.

2.1 | Search methods

We systematically searched databases including Medline, PsycInfo and Embase (Ovid), CINAHL, Web of Science, Scopus, and the Cochrane Library. The first search was conducted in January 2019 with searches including articles published from any date. Additional updated searches were conducted in February 2020 and January 2021 to identify any new articles published within the previous 12 months. Citations within relevant systematic reviews identified through the search were explored for any additional relevant references. Protocol papers and trial registries referenced in eligible articles were searched to identify any missing information not reported.

The search terms were chosen to identify randomized controlled trials of childhood obesity prevention interventions. Search terms were categorized into five groups: study design (i.e., randomized controlled trials), population (i.e., infant, children, and adolescents), intervention (i.e., obesity prevention), setting (i.e., school and community), and outcome (i.e., BMI) (see [Data S1](#)).

2.2 | Eligibility criteria

2.2.1 | Design

Eligible studies were randomized controlled trials in which an obesity prevention intervention was tested against a comparator. Studies that were described as pilot or feasibility studies were not eligible for inclusion. To account for studies that do not clearly state they are a pilot or feasibility study, a criterion requiring studies to have a

minimum of 100 participants recruited in total was applied. A minimum of 100 participants was decided because of an assumption that studies with a sample size under 100 participants are more likely to be a pilot or feasibility study. However, studies that recruited less than 200 participants were removed in exploratory subgroup analyses to allow the exploration of studies with larger samples. Individual and cluster randomized studies were eligible for inclusion, and no criteria relating to the number of clusters in studies were applied. Follow-up data must have been provided for participants at or later than 6 months from the beginning of the intervention and interventions for women during pregnancy and infancy had to provide follow-up data from children at least 12 months of age. Longer follow-up periods have been specified as they are suited to obesity prevention studies to determine the long-term implications of the intervention, rather than exploring the immediate effect of the intervention that is suited to determining obesity treatment.²⁰ Studies retrieved from any date and in any language were included.

2.2.2 | Population

The review focused on population-based (non-clinical) studies. In order for the study to be eligible, children had to be under the age of 18 years at the commencement of the study. Adults could be included in the study; however, the primary outcome had to relate to the child. Studies that recruited only adults with no child outcomes or did not have child outcomes that were separate from adult outcomes were not eligible for inclusion. Additionally, clinical studies that recruited specialist populations with a condition that could have an impact on a child's weight status (e.g., children with Prader-Willi syndrome, Cushing Syndrome, Hypothyroidism, and Hashimoto's Disease) were ineligible. Studies in which children were specifically recruited based on their weight status or via clinical/medical referral were also not eligible for inclusion as the review aimed to explore study design and outcomes of interventions designed to target the general population.

2.2.3 | Intervention

An eligible intervention must have been designed to bring about behavior changes (e.g., to physical activity levels or energy intake) that contribute toward obesity prevention in children. Interventions must have involved children and/or their parent/care giver. Interventions could take place in the home and out-of-home settings. Treatment interventions that were designed specifically for individuals already living with overweight or obesity were not eligible.

2.2.4 | Outcome measures

A measure of obesity prevention must have been reported as the primary outcome. The primary outcome was assumed based on if the outcome was referred to as a primary or the main outcome measure

within the paper, was the outcome measure included within the sample size calculation, or was confirmed as the primary outcome in a referenced protocol or trial registry. These included weight and height, BMI, BMI z-score, BMI percentile, percent body fat, ponderal index, skin fold thickness and prevalence, or incidence of overweight and obesity. Studies with primary outcomes that were self-reported were not eligible for inclusion.

2.2.5 | Output

Evidence sources were restricted to peer-reviewed journal articles. Conference abstracts, letters to editor, commentaries, and theses were not eligible for inclusion as they would not provide the required information to be included in the review. No publication date criteria were applied to allow the exploration of how child obesity prevention trials have previously been designed. However, studies that were published before the year 2000 have been removed from some analyses to explore the impact of bias of including studies that were conducted at a time when trial protocols and pre-registrations were less common practice.

2.3 | Screening and data extraction

The literature search was conducted by one reviewer (LP) who collated all the articles and removed duplicates. All titles and abstracts were screened by the same reviewer (LP) with members of the review team (HS, WB, LM, ES) second reviewing at least 100 articles each. Disagreements were resolved through a discussion with a third reviewer (MB). In the full-text review, a sample of 150 articles was second reviewed by three reviewers (HS, ES, LM). Disagreements were resolved through discussion with a third reviewer (MB). Kappa scores were generated between each set of reviewers to ensure there was adequate agreement with the screening process prior to the first reviewer conducting the remainder of the screening process. An adequate score was defined as achieving a 0.8 kappa score that equates to a strong inter-rater agreement.²¹ Reasons for exclusion of articles reviewed at the full-text stage were recorded based on the first exclusion criteria identified.

All studies eligible for inclusion had data extracted by one reviewer (LP) with 50% of papers being extracted by a second reviewer (ES). Discrepancies were discussed through discussion with a third reviewer (MB) to reach an agreement. Descriptive data (study and intervention design, sample size calculation, and sample characteristics) were extracted into a purpose-designed Microsoft Access database. Outcome data were extracted directly onto a Microsoft Excel spreadsheet. Authors were contacted to gain access to missing outcome data.

In order to describe how childhood obesity prevention trials have been designed, characteristics of the interventions, population, and study design (including primary outcomes and sample size calculations) were extracted. Information describing the methods and assumptions made during the sample size calculations (i.e., anticipated

effect size) were extracted and were assumed (unless otherwise stated) to have been calculated a priori. Where available, the follow-up point the sample size calculation was based on was extracted.

In addition, data relating to the primary outcomes of studies were extracted to provide details of the reported effectiveness of trials. The primary outcomes of included studies were determined based on the outcome measure authors described as the primary or main outcome of the study or the outcome included in the sample size calculation. Where this was not specified, information within referenced protocols and trial registries was used to clarify the primary outcome of the trial. Primary outcome data were extracted based on the primary outcome follow-up point. This was determined based on the timepoint authors described as the primary or main follow-up point. Where authors did not clearly specify the primary outcome follow-up point, an assumption was made that if follow-up data were only reported at one time point, this was the primary outcome follow-up point. Where multiple follow-up points were reported, information from protocol papers and trial registries were used to identify the primary outcome follow-up point. Where this was not available or did not align with the reporting in the paper, the longest follow-up point was assumed as the primary outcome follow-up point.

To support with the presentation of findings from each trial and the conducting of meta-analysis, missing data were sourced directly from authors where possible. Where baseline and follow-up data for intervention and control arms or between-group differences were not reported, this was requested directly from the authors. Studies with missing data, which were also not provided by authors, or studies that only reported outcomes by subgroups were unable to be included in the meta-analysis, and missing data are highlighted in Table 1.

2.4 | Quality assessment

The quality of included studies was assessed using the Cochrane recommended Risk of Bias 2 (RoB2) tool.¹⁰⁶ This quality appraisal tool is an updated version of the previous risk of bias tool,¹⁰⁷ which now provides separate guidance for appraisal of individually randomized and cluster randomized controlled studies. Each domain was scored either “low risk,” “high risk,” or “some concerns.” When assessing the domain of bias due to missing outcome data, if at least 95% of participants that were randomized were followed up, this was defined as “nearly all participants within clusters.”

Quality appraisal was initially conducted in 50% of papers by the first (LP) and a second reviewer (ES, WB, HS, or LM) with disagreements resolved through discussion with a third reviewer (MB). The first reviewer conducted the remaining 50% of papers following assurance that the quality appraisal tool was being applied consistently.

2.5 | Assessing the risk of type 1 error

All included studies were assessed for the risk of type 1 error. For the purpose of this, we applied predefined criteria including, (1) whether a

protocol or trial registry was referenced and provided detail to confirm the reported primary outcome and follow-up point were predetermined and (2) whether the predetermined primary outcome and follow-up point were reported as the main outcome¹⁰⁸ (i.e., the primary outcome is clearly reported and discussed as the main finding rather than the paper focusing on secondary outcomes that may have had more effect). These criteria were agreed upon by two reviewers (MB and LP) and applied by one reviewer (LP) with discussion with a second reviewer (MB) when support with final decisions was needed. Studies were required to meet both predefined criteria in order to be classified as having a low risk of type 1 error. Otherwise, they were defined as high-risk, though information about whether risk was based on not meeting one or both criteria was collated.

2.6 | Narrative synthesis

A narrative review was conducted to explore the characteristics of included studies. Assumptions made in sample size calculations, including the anticipated intraclass correlation coefficient (ICC), effect size (we also examined the justification of chosen effect sizes), loss to follow-up, and the required sample size, were reported. These findings are reported as ranges, with details of individual studies reported separately.

2.7 | Data synthesis

Meta-analyses were conducted to explore the overall effectiveness of child obesity prevention interventions, in addition to exploring effectiveness according to risk of type 1 error.

A minimum of two studies per analysis were required for a meta-analysis to be conducted. Studies were required to provide participant follow-up numbers, mean differences per arm, and standard deviations (or data necessary to calculate standard deviations) to be included in a meta-analysis. Studies that involved cluster randomization were eligible for inclusion if it was clearly stated that outcomes were adjusted for clustering (see Table 1), or the analysis plan stated that analyses were conducted to account for clustering. Separate meta-analyses were conducted for studies of children aged 0–5 years, children of primary school age (6–11 years), and children of secondary school age (12–18 years).

An analysis was conducted within each age category for both BMI z-score and BMI outcomes combining all intervention designs and primary outcome follow-up points. Meta-analyses were also conducted to compare the effectiveness of studies deemed high or low risk of type 1 error according to the criteria outlined above.

Subgroup analyses were conducted to explore outcomes by follow-up duration (i.e., 6–11 months and subsequent yearly intervals) and intervention type (i.e., nutrition interventions, physical activity interventions, and nutrition and physical activity interventions) when at least two studies had the same intervention design within an analysis. Intervention categories were decided based on the most common

TABLE 1 Sample size details and primary outcomes.

Studies of children aged 0–5 years						
Sample size justification						
Author	Outcome & follow-up point (where reported)	Meaningful change	Required sample	ICC	Participants followed up	
Studies with the primary outcome: BMI z score						
Black, 2021 ²²	BMI z score	0.3	270	NR	Intervention (Mom TOPs): 94 Intervention (Tot Tops): 92 Control: 75	
Davis, 2016 ²³	BMI percentile	Standardized effect sizes of between 0.28 and 0.35	16 Head start centers	0.01 and 0.05	Intervention: 144 Control: 142	
De Coen ²⁴	NR	0.3 effect size	78 per group	NR	Intervention: 670 Control: 442	
Lumeng, 2017 ²⁵	NR	0.16 effect size	450	0.05	HS + POPs: 195 HS + POPs + IYS: 230 Control: 200	
Paul, 2018 ²⁶	BMI z score at 3 years	0.67	276	NA	Intervention: 116 Control: 116	
Reilly, 2006 ²⁷	BMI z score	0.25	400	NR	Intervention: 231 Control: 250	
Taylor, 2018 ²⁸	BMI	0.3	600	NR	Sleep: 147/ FAB: 165/ combination: 143 Control: 161	
Tomayko, 2019 ²⁹	BMI z score	NR	450	NR	NR	
Vlasblom, 2020 ³⁰	BMI	0.4	1250	0.1	Intervention: 663 Control: 766	
Studies with the primary outcome: BMI						
Döring, 2016 ³¹	BMI at child aged 4 years (39-month follow-up)	0.3	950	NR	Intervention: 448 Control: 700	
Haines, 2016 ³²	NR	NR	NR	NR	Intervention: 46 Control: 50	
Kong, 2016 ³³	BMI z score	0.35 effect size	486	NR	Intervention: 286 Control: 263	
Li Ming, 2012 ³⁴	BMI	0.25	630	NR	Intervention: 249 Control: 234	
Mo-suwan, 1998 ³⁵	At child aged 2 years (2-year follow-up)	NR	NR	NR	Intervention: 147 Control: 145	
van Grieken, 2017 ³⁶	NR	NR	NR	NR	Intervention: NR Control: NR	
Studies with the primary outcome: prevalence of overweight and obesity						
Dodd, 2018 ³⁷	Prevalence of overweight and obesity at 18 months	6.4%	1350	NR	Intervention: 1071 Control: 1065	
Morandi, 2019 ³⁸	Prevalence of overweight and obesity	NR	330	NR	Intervention: 252 Control: 216	
Studies with the primary outcome: BMI percentile						
Kobel, 2019 ³⁹	BMI percentile	0.288 to 0.325 effect size	880	NR	Intervention: 318 Control: 240	
Studies with the primary outcome: FMI						
Delisie Nystrom, 2017 ⁴⁰	FMI	10%	200	NR	Intervention: 143 Control: 138	
Studies with the primary outcome: weight for length z-score						
Reifsnider, 2017 ⁴¹	Weight for length z-score	0.59 Effect size	175	NR	Intervention: 61 Control: 58	

TABLE 1 (Continued)

Studies of children aged 0–5 years						
Outcome data						
Author	Primary outcome follow-up point	Intervention mean change	Control mean change	Between arm change	Adjustments	Risk of type 1 error assessment
Studies with the primary outcome: BMIz score						
Black, 2021 ²²	1 year	NR	NR	Mom TOPs 0.07 CI (–0.17 to 0.31) Tot TOPs 0.16 CI (–0.08 to 0.39)	Unadjusted	NR Low
Davis, 2016 ²³	19 months	NR	NR	–0.02 CI (–0.03 to 0.06)	Center race/ethnicity strata, prestudy BMI strata, gender, and whether there were dropouts because of attending prekindergarten	NR High
De Coen ²⁴	19 months	NR	NR	NR	NR	NR High
Lumeng, 2017 ²⁵	8 months	HS + PO Ps 0.002 SD 0.43 HS + PO Ps + IYS: 0.004 SD 0.39	–0.01 SD 0.42	NR	Adjusted for race/ethnicity and age	NR High
Paul, 2018 ²⁶	3 years	–0.13	0.15	–0.28 CI (–0.53 to –0.01)	Unadjusted	NA High
Reilly, 2006 ²⁷	6 months	NR	NR	NR	NR	0.11 High
Taylor, 2018 ²⁸	3.5 years	NR	NR	NR	NR	NR Low
Tomayko, 2019 ²⁹	1 year	NR	NR	NR	NR	NR High
Vlasblom, 2020 ³⁰	36 months	–0.06 SD 1.08	–0.15 SD (1.03)	0.089 CI (–0.07 to 0.247)	Adjusted for cluster	NR High
Studies with the primary outcome: BMI						
Döring, 2016 ³¹	39 months	–1.41 SD 1.14	–1.46 SD 1.28	NR	Unadjusted	Baseline 0.0084 Follow-up 0.0089 NR Low
Haines, 2016 ³²	9 months	–0.13 SD 2.56	0.21 SD 1.57	–0.36 CI–1.23 to 0.51 ITT	Sex and age at baseline	NR High
Kong, 2016 ³³	1 year	0.3 SE 0.08	0.43 SE 0.08	–0.13 SE 0.11	Baseline age	NR High
Li Ming, 2012 ³⁴	2 years	NR	NR	–0.29 CI (–0.55 to –0.02) ITT	Unadjusted	NR Low
Mo-suwan, 1998 ³⁵	8 months	–0.63 SD 1.04	–0.54 SD 1	NR	Baseline BMI of group, sex, and interaction between sex and exercise	Follow-up –0.027 NR High
van Grieken, 2017 ³⁶	36 months	NR	NR	NR	NR	NR High

TABLE 1 (Continued)

Studies of children aged 0–5 years						
Outcome data						
Author	Primary outcome follow-up point	Intervention mean change	Control mean change	Between arm change	Adjustments	Risk of type 1 error assessment
Studies with the primary outcome: prevalence of overweight and obesity						
Dodd, 2018 ³⁷	18 months	NR	NR	1.04 CI (0.94 to 1.16) ITT	Stratification variables BMI category, parity, and center, maternal age, socioeconomic status, and maternal smoking, actual age at assessment, and infant sex.	Low
Morandi, 2019 ³⁸	24 months	23.8%	26.3%	NR	NR	Low
Studies with the primary outcome: BMI percentile						
Kobel, 2019 ³⁹	1 year	−3.372 SD 11.169	−0.782 SD 11.988	NR	Baseline values, gender, age, and migration status	High
Studies with the primary outcome: FMI						
Delisie Nystrom, 2017 ⁴⁰	6 months	−0.23 SD 0.56	−0.2 SD 0.49	NR	Unadjusted	Low
Studies with the primary outcome: weight for length z-score						
Reifsnider, 2017 ⁴¹	1 year	NR	NR	NR	NR	High
Primary school age studies (aged 6–11 years)						
Sample size justification						
Author	Outcome	Meaningful change	Required sample	ICC	Participants followed up	Primary outcome follow-up point
Studies with the primary outcome: BMIZ score						
Adab, 2018 ⁴²	BMIZ score	0.25	1000	0 to 0.04	Intervention: 393 Control: 444	15 months
Breheny, 2020 ⁴³	BMIZ score	0.125	2000	0.04	Intervention: 850 Control: 820	1 year
Dzewaltowski, 2010 ⁴⁴	BMI	0.5 kg/m ²	8 schools	NR	Intervention: 134 Control: 112	3 years
Habib-Mourad, 2020 ⁴⁵	NR	NR	NR	NR	Intervention: 457 Control: 349	3 years
Hull, 2018 ⁴⁶	BMI	0.75 BMI units	272 families	0.10	Intervention: 86 Control: 83	16 months
Johnston, 2013 ⁴⁷	NR	NR	NR	NR	NR	2 years
Kain, 2014 ⁴⁸	BMIZ score at 1 year	0.3 (calculated post hoc)	1500	NR	Intervention: 637 Control: 405	1 year
Li B, 2019 ⁴⁹	BMIZ score	0.17	1640	0.01	Intervention: 804 Control: 777	1 year
Lloyd, 2018 ⁵⁰	BMIZ score at 2 years	0.25	952	0.02	Intervention: 630 Control: 643	2 years
Marcus, 2009 ⁵¹	BMIZ score	0.1	2546	NR	Intervention: 1538 Control: 1300	4 years
Rosario, 2012 ⁵²	BMIZ score	0.5	286	NR	Intervention: 151 Control: 143	6 months

TABLE 1 (Continued)

Primary school age studies (aged 6–11 years)						
Sample size justification			Outcome data			
Author	Outcome	Meaningful change	Required sample	ICC	Participants followed up	Primary outcome follow-up point
Sahota, 2001 ⁵³	Difference in means of a normally distributed outcome measure of >1.8 standard deviations	1.5 SD	10 schools	NR	Intervention: 314 Control: 322	1 year
Waters, 2017 ⁵⁴	BMIz score	0.2	2286	0.017	Intervention: 1318 Control: 1425	4–5 years
Williamson, 2012 ⁵⁵	BMIz score	0.12	1666	NR	PP: 612 PP + PS: 760 Control: 447	28 months
Studies with the primary outcome: BMI						
Akdemir, 2017 ⁵⁶	NR	NR	NR	NR	Intervention: 647 Control: 641	1 year
Angelopoulos, 2009 ⁵⁷	BMI	1 unit	600	NR	Intervention: 321 Control: 325	1 year
Brandstetter, 2012 ⁵⁸	BMI at 1 year	0.1 kg/m ²	616	NR	Intervention: 450 Control: 459	1 year
Donnelly, 2009 ⁵⁹	BMI at 3 years	2 unit increase in control and 1.5 unit increase in intervention	NR	0.1	Intervention: 792 Control: 698	3 year
Elder, 2014 ⁶⁰	BMI at 2 years	0.843 kg/m ²	NR	0.038	Intervention: 237 Control: 252	2 year
Gomez, 2018 ⁶¹	BMI At 1 year	0.6 kg/m ²	2140	NR	Intervention: 974 Control: 1112	15 months (mean follow-up)
Grydeland, 2014 ⁶²	BMI At 2 years	0.72 kg/m ²	1800	NR	Intervention: 465 Control: 859	20 months
Jansen, 2011 ⁶³	BMI	0.22	NR	0.001	Intervention: 1048 Control: 1168	1 school year (8 month)
Lazaar, 2007 ⁶⁴	NR	NR	NR	NR	Intervention: 197 Control: 228	6 months
Li, Y, 2010 ⁶⁵	BMI At 1 year	0.35	4700	0.15	Intervention: 2072 Control: 2115	1 year
Liu, 2019 ⁶⁶	BMI At 1 year	0.8	1800	0.05	Intervention: 900 Control: 939	1 year
Llargues, 2011 ⁶⁷	BMI	0.2	226	NR	Intervention: 272 Control: 236	2 year
Martinez Vizcaino, 2008 ⁶⁸	BMI	0.5 kg/m ²	800	0.009	Intervention: 507 Control: 610	1 school year (9 month)
Puder, 2011 ⁶⁹	NR	NR	NR	NR	Intervention: 333 Control: 292	10 months (1 school year)
Rausch Herscovici, 2013 ⁷⁰	NR	NR	NR	NR	Intervention: 205 Control: 163	6 months
Rush, 2012 ⁷¹	NR	NR	NR	NR	Intervention: 692 Control: 660	2 years
Salmon, 2008 ⁷²	BMI At 6 months	0.5 kg/m ²	350	0.0035	BM: 60 FMS: 69; BM/FMS: 84 Control: 55	1 year
Sevinc, 2011 ⁷³	NR	NR	NR	NR	Intervention 1: 1897 Intervention 2: 1815 Control: 2654	8 months
Sgambato, 2019 ⁷⁴	BMI	1.1	2500	NR	Intervention: 1161 Control: 1109	9 months (1 school year)
Sichieri, 2009 ⁷⁵	BMI	1 unit	280	NR	Intervention: 434 Control: 493	8 months (1 school year)

TABLE 1 (Continued)

Primary school age studies (aged 6–11 years)		Outcome data				Primary outcome follow-up point
Sample size justification						
Author	Outcome	Meaningful change	Required sample	ICC	Participants followed up	Primary outcome follow-up point
Story, 2012 ⁷⁶	NR	NR	NR	NR	NR	2 school years
Wang, 2018 ⁷⁷	BMI After intervention (1 school year–9 months)	0.1	10,000	NR	Intervention: 5275 Control: 4583	1 school year (9 months)
Xu F, 2015 ⁷⁸	BMI	0.5	1200	0.005	Intervention: 605 Control: 504	1 school year (9 months)
Xu H, 2017 ⁷⁹	BMI	0.7 kg/m ²	7500	0.05	Comprehensive intervention: 3476 Nutrition education: 628 Physical activity: 605 No comprehensive intervention: 3398 No nutrition education: 466 No physical activity: 466	1 year
Studies with the primary outcome: Prevalence of overweight and obesity						
Bayer, 2009 ⁸⁰	NR	NR	NR	NR	Intervention: 866 Control: 463	18 months
Cao, 2015 ⁸¹	Obesity prevalence	4% reduction in intervention arm	953	NR	Intervention: 925 Control: 828	3 years
Koch, 2019 ⁸²	Prevalence of overweight and obesity	2%	1800	0.03	Curriculum: 225 Wellness: 167 Curriculum & wellness: 233 Control: 144	10 months
Muckelbauer, 2009 ⁸³	Prevalence of overweight and obesity	4%	3600	<0.005	Intervention: 1641 Control: 1309	10 months (1 school year)
Studies with the primary outcome: percent fat content						
Caballero, 2003 ⁸⁴	NR	0.5 effect size	NR	NR	Intervention: 727 Control: 682	3 school years
Martinez, 2020 ⁸⁵	BMI at end of first (school) year	2%	1600	NR	NR	8 months
Yin, 2012 ⁸⁶	Percent fat content	0.5 SD	540	NR	Intervention: 292 Control: 284	1 year
Studies with the primary outcome: BMI percentile						
Ickovics, 2019 ⁸⁷	BMI	0.3 effect size	558	0.001	Nutrition: 304 Physical activity: 330 No nutrition: 291 No physical activity: 265	3 school years
Wendel, 2016 ⁸⁸	NR	NR	NR	NR	Treatment–Treatment: 62 Treatment–control: 59 Control–treatment: 23 Control–control: 49	2 years
Studies with the primary outcome: incidence of overweight and obesity						
Foster, 2008 ⁸⁹	NR	NR	NR	NR	Intervention: 364 Control: 479	2 years
Polonsky, 2019 ⁹⁰	Incidence of overweight and obesity	Risk ratio of 0.7	1760	0.01	Intervention: 205 Control: 263	2.5 years
Primary outcome: prevalence of obesity						
Tarro, 2014 ⁹¹	Prevalence of obesity	5%	1400	NR	Intervention: 1222 Control: 717	28 months

(Continues)

TABLE 1 (Continued)

Author	Primary school age studies (aged 6–11 years)					Risk of type 1 error assessment
	Intervention mean change	Control mean change	Between arm change	Adjustments	ICC	
Outcome data						
Studies with the primary outcome: BMIz score						
Adab, 2018 ⁴²	NR	NR	-0.077 CI (-0.191 to 0.037) ITT	Baseline outcome, sex, ethnicity, deprivation, 24-h total energy intake, physical activity energy expenditure, and baseline school level covariates (size), % school population South Asian, % school population black African-Caribbean, % free school meal eligibility	NR	High
Breheny, 2020 ⁴³	NR	NR	-0.033 CI (-0.084 to 0.017)	School size, % free school meals, school BMIz, sex, ethnicity, deprivation age, participant baseline outcome, school baseline outcome	Follow-up 0.001	High
Dzewaltowski, 2010 ⁴⁴	-0.1 SE 0.1	0 SE 0.1	NR	School random effect and condition, strata, year, demographic variables, and demographic variable interactions with condition, strata, and year fixed effects. Demographic variables included SES, race/ethnicity, and grade for BMI and BMIz	NR	High
Habib-Mourad, 2020 ⁴⁵	0.134 SE 0.048	0.237 SE 0.054	NR	Adjusted for age, gender, and baseline BMI	NR	Low
Hull, 2018 ⁴⁶	NR	NR	0.023 CI (-0.016 to 0.063)	NR	0.064	High
Johnston, 2013 ⁴⁷	NR	NR	NR	NR	NR	High
Kain, 2014 ⁴⁸	0.02 SD 0.34	0.06 SD 0.34	NR	Baseline value	Follow-up 0.99	High
Li B, 2019 ⁴⁹	-0.35 SD 1.22	-0.23 SD 1.34	-0.13 CI (-0.26 to 0.00)	Clustering and baseline value of the outcome	Follow-up 0.118	Low
Lloyd, 2018 ⁵⁰	0.04 SD 0.87	0.04 SD 0.84	NR	Clustering	NR	High
Marcus, 2009 ⁵¹	NR	NR	NR	Clustering	<1%	High
Rosario, 2012 ⁵²	0.13 SE 0.04	0.34 SE 0.05	-0.176 CI (-0.308 to -0.044)	Gender, age, baseline total energy intake, baseline BMI z-score, and parents' education	NR	Low
Sahota, 2001 ⁵³	NR	NR	NR	NR	NR	High
Waters, 2017 ⁵⁴	NR	NR	NR	NR	NR	High
Williamson, 2012 ⁵⁵	PP: 0.01 SD 0.035 PP + PS: 0.03 SD 0.035	0.07 SD 0.027	NR	NR	0.0005 to 0.026	High

TABLE 1 (Continued)

Primary school age studies (aged 6–11 years)							Risk of type 1 error assessment
Author	Intervention mean change	Control mean change	Between arm change	Adjustments	ICC		
Outcome data							
	Intervention mean change	Control mean change	Between arm change	Adjustments	ICC		
	Studies with the primary outcome: BMI						
Akdemir, 2017 ⁵⁶	0.18 SD 0.82	0.17 SD 0.92	NR	NR	Follow-up 0.985	High	
Angelopoulos, 2009 ⁵⁷	-1.1 CI (-1.2 to -0.9)	0.1 CI (-0.3 to 0.2)	NR	Gender and school region	NA	High	
Brandstetter, 2012 ⁵⁸	NR	NR	-0.06 CI (-0.21 to 0.10)	Baseline value	NR	High	
Donnelly, 2009 ⁵⁹	2 SD 1.9	2 SD 1.9	NR	Clustering and gender	NR	High	
Elder, 2014 ⁶⁰	NR	NR	NR	NR	NR	High	
Gomez, 2018 ⁶¹	0.67 SD 1.18	0.72 SD 1.29	NR	Sex and age and corresponding anthropometric and lifestyle variable at baseline	NR	High	
Grydeland, 2014 ⁶²	NR	NR	NR	NR	NR	High	
Jansen, 2011 ⁶³	NR	NR	NR	NR	Below 0.010	High	
Lazaar, 2007 ⁶⁴	NR	NR	NR	NR	NR	High	
Li, Y, 2010 ⁶⁵	0.56 SD 1.15	0.72 SD 1.2	-0.15 CI (-0.28 to -0.02)	Baseline BMI, age, sex,	NR	High	
Liu, 2019 ⁶⁶	NR	NR	0.7 CI (-0.17 to 0.31)	Baseline outcome value, age, sex, and clustering	NR	High	
Llargues, 2011 ⁶⁷	0.85 SD 1.54	1.74 SD 1.80	NR	Clustering	Follow-up 0.84	High	
Martinez Vizcaino, 2008 ⁶⁸	0.25 SD 0.88	0.23 SD 0.74	NR	Clustering and baseline	NR	High	
Puder, 2011 ⁶⁹	NR	NR	-0.07 CI (-0.19 to 0.06) ITT	Clustering	Follow-up 0.05	Low	
Rausch Herscovici, 2013 ⁷⁰	0.5 SD 0.82	0.56 SD 0.91	NR	NR	Followup 0.967	High	
Rush, 2012 ⁷¹	NR	NR	NR	NR	NR	High	
Salmon, 2008 ⁷²	NR	NR	BM: -0.15 CI (-1.29 to 0.99) FMS: -0.77 CI (-1.80 to 0.26) BM/FMS: -1.53 CI (-2.82 to -0.24)	Clustering	NR	High	
Sevinc, 2011 ⁷³	Intervention 1: 0.37 SD 1.08 Intervention 2: 0.35 SD 1.13	0.51 SD 0.98	NR	NR	NR	High	
Sgambato, 2019 ⁷⁴	0.2	0.3	NR	NR	NR	Low	
Sichieri, 2009 ⁷⁵	0.32 CI (0.19, 0.46)	0.22 CI (0.13, 0.32)	0.1 CI (-0.06, 0.1)	Unadjusted	0.024	High	
Story, 2012 ⁷⁶	NR	NR	0.34 SE 0.17	Age, gender, SES, and school	NR	High	

TABLE 1 (Continued)

Primary school age studies (aged 6–11 years)						
Outcome data						
Author	Intervention mean change 0.22 SE 0.02	Control mean change 0.46 SE 0.02	Between arm change -0.3 CI (-0.5 to -0.1)	Adjustments	ICC	Risk of error assessment type 1
Wang, 2018 ⁷⁷				School-level clustering effects, participants' age, gender, baseline body weight, red meat consumption at baseline	NR	High
Xu F, 2015 ⁷⁸	-0.32	-0.29	-0.03 CI (-0.18 to 0.14)	School-level clustering effects, participants' age, gender, baseline body weight, and parents' education	NR	High
Xu H, 2017 ⁷⁹	Comprehensive intervention: 0.6 SD 1.7 Nutrition education: 0.7 SD 2.2 Physical activity: 0.8 SD 2.2	No comprehensive intervention: 0.8 SD 1.5 No nutrition education: 0.7 SD 2.2 No physical activity: 0.7 SD 2.2	Comprehensive intervention: -0.3 CI (-0.4 to -0.2) Nutrition education: 0 CI (-0.26 to 0.26) Physical activity: 0.07 CI (-0.19 to 0.34)	Sex, age, and intervention types	NR	High
Studies with the primary outcome: Prevalence of overweight and obesity						
Bayer, 2009 ⁸⁰	NR	NR	NR	NR	NR	High
Cao, 2015 ⁸¹	4.1 SD 0.02	0 SD 0.022	NR	Age	NR	High
Koch, 2019 ⁸²	Curriculum: -2.7 Wellness: -2.4 Curriculum & wellness: -0.8	0	NR	NR	NR	High
Muckelbauer, 2009 ⁸³	NR	NR	NR	NR	0.011	Low
Studies with the primary outcome: percent fat content						
Caballero, 2003 ⁸⁴	NR	NR	0.2 CI (-0.84 to 1.31)	NR	NR	High
Martinez, 2020 ⁸⁵	NR	NR	NR	NR	NR	High
Yin, 2012 ⁸⁶	NR	NR	NR	NR	0.94	High
Studies with the primary outcome: BMI percentile						
Ickovics, 2019 ⁸⁷	NR	NR	Nutrition vs. No nutrition 0.9 Physical activity vs. no physical activity -0.45 SE 0.9	Clustering	NR	High
Wendel, 2016 ⁸⁸	Treatment-Treatment: -3.1 SD 14.5 Treatment-control: -1.5 SD 10 Control-treatment: -1.0 SD 10.3	1.8 SD 14.6	Treatment-Treatment -5.24 CI (-10.16 to -0.31) Treatment-control -2.96 (-7.97 to 2.05) Control-Treatment -3.94 CI (-10.56 to 2.68)	Mean change per arm unadjusted Between arm difference adjusted for grade, race/ethnicity, and gender	NR	High
Studies with the primary outcome: incidence of overweight and obesity						
Foster, 2008 ⁸⁹	7.6	14.9	NR	Unadjusted	NR	High
Polonsky, 2019 ⁹⁰	NR	NR	NR	NR	NR	High

TABLE 1 (Continued)

Primary school age studies (aged 6–11 years)						
Outcome data						
Author	Intervention mean change	Control mean change	Between arm change	Adjustments	ICC	Risk of type 1 error assessment
Tarro, 2014 ⁹¹	Prevalence of obesity -2.02	0.44	NR	NR	NR	High
Secondary school age studies (aged 12–18 years)						
Sample size justification						
Author	Outcome	Meaningful change	Required sample	ICC	Participants followed up	Primary outcome follow-up point
Studies with the primary outcome: BMIz score						
Black, 2010 ⁹²	NR	NR	NR	NR	Intervention: 91 Control: 93	1 year
Viggiano, 2014 ⁹³	BMIz score	0.4	NR	NR	Intervention: 1076 Control: 1080	6 months
Studies with the primary outcome: BMI						
Bonsergent, 2013 ⁹⁴	NR	NR	NR	NR	NR	2 school years
Cunha, 2013 ⁹⁵	BMI At 1 year	0.8 kg/m ²	444	NR	NR	1 school year
Da Silva, 2019 ⁹⁶	BMI	Effect size 0.20	720	NR	Intervention: 286 Control: 317	1 year
Ezendam, 2012 ⁹⁷	NR	NR	NR	NR	Intervention: 391 Control: 337	2 year
Haerens, 2006 ⁹⁸	BMI	0.3	900	NR	NR	2 year
Leme, 2016 ⁹⁹	BMI	0.4 kg/m ²	266	NR	Intervention: 111 Control: 83	6 months
Lubans, 2012 ¹⁰⁰	BMI	1 BMI unit	360	NR	Intervention: 141 Control: 153	1 year
Simon, 2008 ¹⁰¹	BMI	0.4 kg/m ²	960	NR	Intervention: 374 Control: 358	4 years
Singh, 2007 ¹⁰²	Weight	0.5 ± 1.5 kg	500–600	NR	NR	8 months
Smith, 2014 ¹⁰³	BMI	0.4	350	NR	Intervention: 139 Control: 154	8 months
Studies with the primary outcome: BMI percentile						
Bogart, 2016 ¹⁰⁴	NR	NR	NR	NR	Intervention: 829 Control: 539	2 years
Studies with the primary outcome: Prevalence of obesity						
Gortmaker, 1999 ¹⁰⁵	NR	NR	NR	NR	Intervention: 641 Control: 654	18 months
Secondary school age studies (aged 12–18 years)						
Outcome data						
Author	Intervention mean change	Control mean change	Between arm change	Adjustments	ICC	Risk of type 1 error assessment
Studies with the primary outcome: BMIz score						
Black, 2010 ⁹²	NR	NR	NR	NR	NR	High
Viggiano, 2014 ⁹³	NR	NR	NR	NR	0.006	High

(Continues)

TABLE 1 (Continued)

Secondary school age studies (aged 12–18 years)						
Author	Outcome data		Control mean change	Between arm change	Adjustments	Risk of type 1 error assessment
	Intervention mean change	ICC				
Studies with the primary outcome: BMI						
Bonsmergent, 2013 ⁹⁴	Education –0.71 SD 1.49 Environment –0.71 SD 1.47 Screening 0.64 SD 1.44	NR	No education –0.66 SD 1.45 No environment 0.67 SD 1.47 No screening 0.72 SD 1.49	Education –0.05 CI (–0.05 to 0.15) Environment 0.03 CI (–0.07 to 0.13) Screening –0.11 CI (–0.21 to 0.10)	“Adjusted for potential confounders”	NR
Cunha, 2013 ⁹⁵	NR	NR	NR	0.003 ITT	Unadjusted	0.07
Da Silva, 2019 ⁹⁶	0.39	0.39	NR	NR	Age, gender, level of physical activity, household assets score, caregiver education, and pubertal development	NR
Ezendam, 2012 ⁹⁷	NR	NR	NR	NR	NR	NR
Haerens, 2006 ⁹⁸	NR	NR	NR	NR	NR	NR
Leme, 2016 ⁹⁹	NR	NR	NR	–0.26 SE 0.18 ITT	Clustering	0.016
Lubans, 2012 ¹⁰⁰	NR	NR	NR	–0.19 CI (–0.70 to 0.33) ITT	Clustering	NR
Simon, 2008 ¹⁰¹	NR	NR	NR	–0.25 CI (–0.51 to 0.01) ITT	Age and gender	NR
Singh, 2007 ¹⁰²	NR	NR	NR	NR	NR	NR
Smith, 2014 ¹⁰³	0.6 SE 0.09	0.61 SE 0.08	NR	O SE 0.12	School clustering and participant socioeconomic status	NR
Studies with the primary outcome: BMI percentile						
Bogart, 2016 ¹⁰⁴	NR	NR	NR	–0.98 SE 1.01 ITT	Child gender, age in years, Latino race/ethnicity, and US-born status), and NSLP eligibility.	NR
Gortmaker, 1999 ¹⁰⁵	NR	NR	NR	NR	NR	NR
Studies with the primary outcome: Prevalence of obesity						
Gortmaker, 1999 ¹⁰⁵	NR	NR	NR	NR	NR	NR

intervention components identified during data extraction of included studies. When studies had multiple intervention arms that were included in the same analyses, the number of control participants was split evenly across the intervention arms so as not to duplicate participants. Exploratory subgroup analyses were also conducted to exclude studies with recruited samples under 200. Additional subgroup analyses were also conducted to explore the effect of excluding studies that were published before the year 2000 where CONSORT was less likely to have been followed (because of the first CONSORT being published in 1996)¹⁰⁹ and trials less likely to have been pre-registered. The generic inverse variance method by random effect was conducted using Revman 4.2.¹¹⁰ This method was chosen as it allows for the inclusion of studies reporting only the difference between arms as well as studies reporting the mean change from baseline per arm in meta-analyses. When available, adjusted mean data were included in meta-analysis; otherwise, unadjusted data were used.

The quality of evidence provided for each meta-analysis was evaluated using the GRADE toolkit (Grading of Recommendations Assessment, Development, and Evaluation).¹¹¹ Each analysis was ranked either very low, low, moderate, or high quality based on limitations of study design, inconsistency of results, indirectness of evidence, imprecision, and publication bias.

Limitations in the study design of the reviewed papers were evaluated using the RoB2 tools, with a particular focus on biases due to blinding, loss to follow-up, selective reporting, and bias during recruitment in cluster randomized trials. For the purpose of assessing inconsistency, the I² heterogeneity score calculated by Revman was assessed, with results of 40%–60% heterogeneity having moderate inconsistency and any analyses over 60% having substantial inconsistency.¹¹² Publication bias was assessed through visually assessing the asymmetry of funnel plots generated for each analysis through Revman 4.2.

3 | RESULTS

The initial database search (January 2019) retrieved 20,616 articles with an additional five sourced through citation searches (Figure 1¹⁸). Following the removal of duplicates ($n = 9957$) and title and abstract screening, 424 articles were considered for full-text review. Full-text review resulted in 80 articles being eligible for inclusion. The search was updated in February 2020 and January 2021, which resulted in an additional 16 articles^{22,29,30,38,39,43,45,49,66,74,82,85,90,96,113,114} being included. Within the 96 retrieved articles, 12 articles^{113–124} were long-term follow-up articles linked to original studies also included within the review; hence, the review includes data from 84 different randomized controlled trials.

3.1 | Study characteristics

The majority of included studies were cluster randomized ($N = 72/84$) with the most common level of randomization being schools ($N = 56$).

Most studies ($n = 72$) included only one intervention arm, though six^{25,36,55,73,88,98} included two intervention arms, five included three intervention arms,^{28,72,79,82,87} and one study included five intervention arms.⁹⁴

Half the included studies ($N = 47$) examined an intervention based within a school setting with a further 15 studies having interventions based in the school and home. The remaining studies were based in the home, community settings, early years settings, and maternity settings. Nutrition education ($N = 65$) and physical activity ($N = 65$) were the most common components of interventions, with less common components focused on parenting, sleep routines, and food environments. Almost all studies examined both male and female children ($N = 81$) with two studies recruiting females only^{99,100} and one study recruiting males only.¹⁰³ Twenty studies recruited children aged from 0 to 5 years of age, over half of studies recruited children of primary school age ($N = 50$), and 14 studies recruited children of secondary school age (11–18 years). Four studies^{24, 75, 45,93} recruited children with age ranges that spanned the age categories used here (i.e., 3–6 years) and were categorized based on the average mean age of children at baseline.

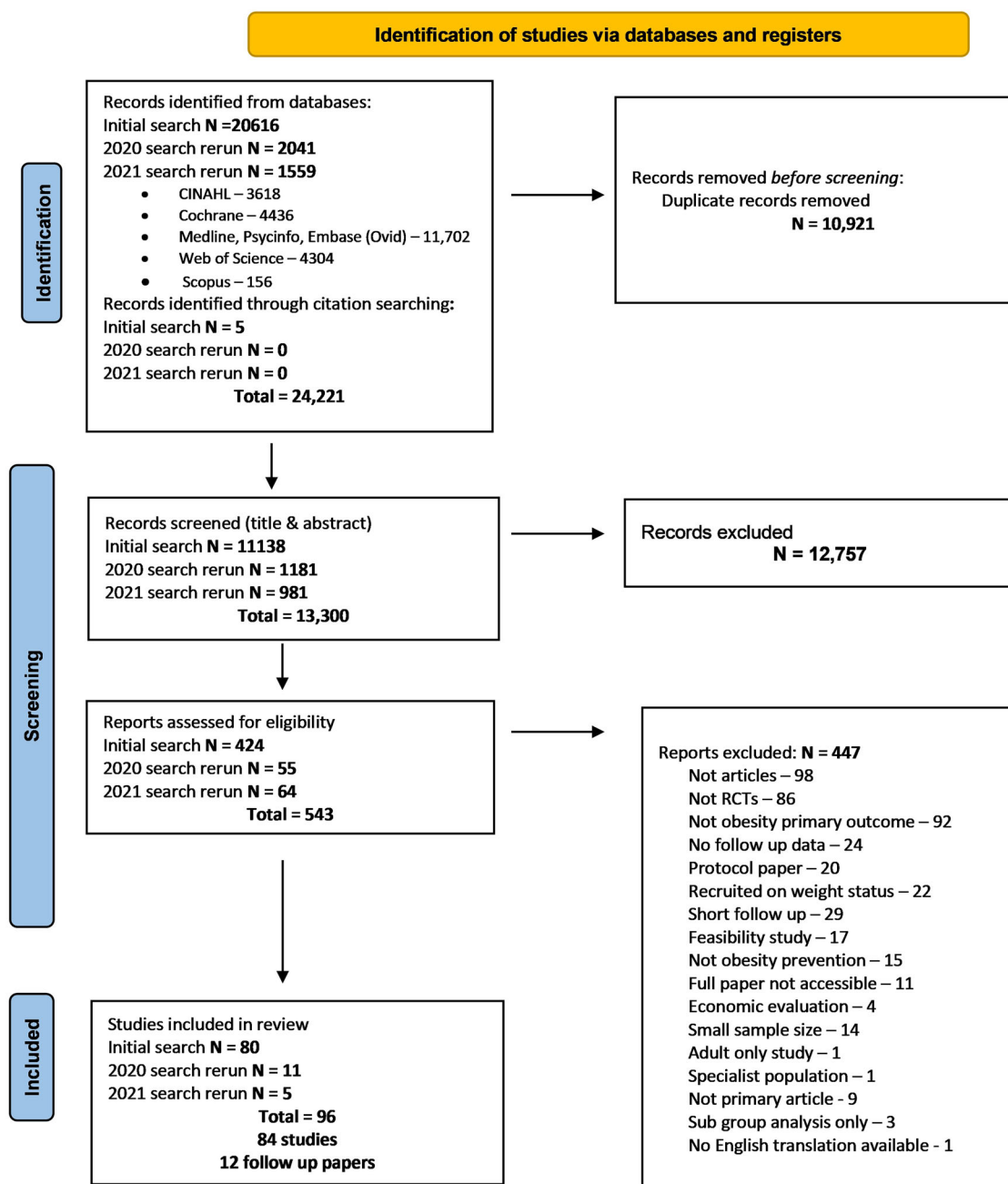
The characteristics of the 84 included studies are displayed in Data S2, with details of the 12 follow-up papers reported within the original study's information.

3.2 | Risk of bias of included studies

Figure 2 reports the overall risk of bias in included studies, with 12 studies assessed using the individually randomized risk of bias tool and 72 assessed using the cluster randomized tool. “Missing information” was a common reason for studies receiving judgments of “some concerns” for multiple domains. All domains of bias had more studies assessed to be of low risk of bias rather than high risk of bias; however, the overall quality of the majority of studies was reduced because of the large number of domains being labeled as “some concerns” by the tool. Only two studies^{25,49} received scores indicating that they were at low risk for all domains, though seven studies were low risk for all but one domain indicating “some concerns.”^{28,40,42,43,50,52,77} The risk of bias of each study by domain can be viewed in Data S3.

3.3 | Risk of type 1 error

Of the 84 studies, 20 studies met both criteria and were considered as low risk of type I error.^{22,28,31,32,34,37,38,40,45,49,50,52,69,74,83,94,95,97,99,101} The most common criterion that studies did not meet that contributed to them being classified as high risk of type 1 error was not including a reference to a protocol or trial registry, making it unclear if reported findings were based on a predetermined primary outcome ($N = 35$). A further 10 studies did not provide details of the primary outcome timepoint, and one study⁸⁶ did not provide details of the primary outcome or timepoint on the referenced trial register. Fifteen



From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71. doi: 10.1136/bmj.n71

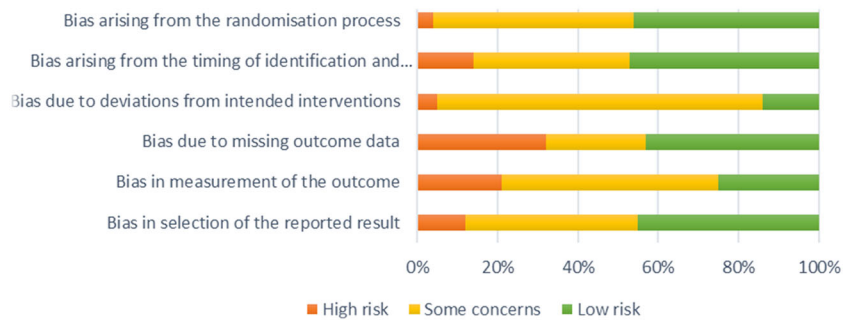
FIGURE 1 PRISMA flow diagram.

studies were classified as high risk because of the primary outcome ($n = 6$) or timepoint ($n = 9$) reported in the paper not matching the prespecified primary outcome and timepoint on the referenced trial registry. Four studies were at high risk of type 1 error because of the prespecified primary outcome measure not being reported as the main outcome of the study. The risk of type 1 error of each study is reported in Table 1.

3.4 | Assumptions used to develop study sample size calculations

Studies reporting a sample size calculation applied a range of assumptions and are presented according to the different age categories (i.e., children aged 0–5 years, primary school-aged children, and secondary school-aged children) in Table 1. The most commonly reported

FIGURE 2 Risk of bias of included studies by domain.



primary outcomes across studies of all population age groups were BMI ($N = 30$) and BMI z-score ($N = 15$). Few studies ($N = 15$) reported the specific follow-up point their sample size calculation was based on. Information on the follow-up point considered within sample size calculations are included in Table 1.

The detectable effect size differences used in sample size calculations in trials of children aged 0–5 years ranged from 0.25²⁷ (no specified timepoint) to 0.67²⁶ (at 3-year follow-up) BMI z-score and BMI ranging from 0.25 kg/m²³⁴ (at 2 years follow-up) to 0.35 kg/m²³³ (no timepoint specified). For trials including primary school-aged children, the detectable differences used in sample size calculations ranged from 0.1⁵¹ (no timepoint specified) to 0.5⁵² (no timepoint specified) BMI z-score and BMI ranged from 0.1 kg/m²⁵⁸ (at 1 year) to 1.1 kg/m²⁷⁴ (no timepoint specified). Only one trial that included secondary school-aged children considered BMI z-score in their sample size calculations, and they considered a detectable difference of 0.4⁹³ (no timepoint specified). Detectable difference in BMI ranged from 0.2 effect size⁹⁶ (no timepoint specified) to a difference of 1.0 BMI unit¹⁰⁰ (no timepoint specified).

Twenty-one studies provided justification of the expected difference (used to develop effect sizes) specified in their sample size calculations. The most commonly used data used to estimate a detectable difference came from previous studies ($N = 8$)^{38,52,62,72,90} and pilot studies.^{65,100,103} Some authors used data from their own previously conducted studies,⁴¹ or from outcome data collected at earlier stages of their trial.^{37,60} In addition, two studies stated their detectable difference in their sample size calculation was based on data sets from national databases. Two studies based their expected difference on the difference between growth chart major percentile lines.^{23,31} Five studies stated they used “clinically important differences.” Two of these studies referenced childhood obesity treatment intervention studies rather than prevention studies and both stated clinically important differences of 0.25 BMI z-score.^{42,43} The remaining three studies did not provide a reference or explanation for what they stated was clinically meaningful difference used in their sample size calculation and stated a clinically important difference of 0.1, 0.75, and 0.5 kg/m².^{46,77,78}

Of the 51 studies reporting the sample size α significance level, all but one study used an assumption of a p level of 0.05. Of the 57 studies that reported the sample size β power, 41 based their sample size calculation on 80% power. The most common estimated dropout rate was 20% ($N = 8$), and the range ($N = 21$) was 10%–30%. Twenty-two of the 75 cluster randomized trials reported assumed intraclass

correlation coefficient that ranged from 0.001^{63,87} to 0.15,⁶⁵ and the most commonly used ICC was 0.05^{25,66,79} or 0.01^{30,46,59}. Four studies used an ICC based on research in a similar setting^{49,68,78} or with a similar population.⁷²

3.5 | Meta-analyses

Details and outcomes for individual study's primary outcome and meta-analysis can be found in Tables 1 and 2, respectively. Forest plots and funnel plots for each analysis can be seen in Data S4. Meta-analyses showing the effectiveness for BMI and BMI z-score outcomes for each age category are reported below with studies of all primary outcome follow-up points combined. Within each forest plot figure, subgroup analyses by follow-up point (i.e., 6–11 months, 12–23 months, and 24–36 months) are also presented.

All meta-analyses were scored at either low or very low quality based on the GRADE quality assessment. The most common reasons were “risk of biases in individual studies” and “differences in follow up time and intervention designs of combined studies.” Potential publication bias was detected in the analyses of the overall effectiveness of interventions aimed at children of primary school age with BMI outcome as a primary outcome and primary school age interventions with BMI as primary outcome deemed high risk of type 1 error.

3.6 | BMI z-score effect size in children aged 0 to 5 years

The overall difference between intervention and control of studies examining BMI z-score of children aged 0 to 5 years reporting BMI z-score as a primary outcome was -0.00 (CI $-0.05, 0.05$). Of these, only one study with two intervention arms had a low risk of type 1 error²² and had a pooled mean difference of 0.12 (CI $-0.05, 0.28$). Four studies,^{23,25,26,30} classified as high risk, had a combined mean difference of -0.01 (CI $-0.06, 0.04$).

3.7 | BMI effect size in children aged 0 to 5 years

Five studies that were eligible for meta-analysis reported BMI as the primary outcome and had a combined mean difference of

TABLE 2 Summary of findings.

Comparison	Outcome	No. intervention arms	Total participants	Mean difference (confidence interval)	GRADE quality	
0–5 years obesity prevention interventions vs. control						
1.1	Overall effectiveness	BMIz score	7	2834	–0.00 (–0.05, 0.05)	Very low
	1.1.1 6–11 month follow-up		2	625	0.01 (–0.06, 0.08)	
	1.1.2 12–23 month follow-up		3	548	0.01 (–0.08, 0.10)	
	1.1.3 24–36 month follow-up		2	1,661	–0.08 (–0.44, 0.28)	
1.2.1	Studies low risk of type 1 error	BMIz score	2	262	0.12 (–0.05, 0.28)	Very low
1.2.2	Studies high risk of type 1 error	BMIz score	5	2,572	–0.01 (–0.06, 0.04)	Very low
1.3	Update on effectiveness	BMI	5	2,568	–0.09 (–0.23, 0.04)	Low
	1.3.1 6–11 month follow-up		2	388	–0.11 (–0.33, 0.12)	
	1.3.2 12–23 month follow-up		1	549	–0.13 (–0.35, 0.09)	
	1.3.3 24–35 month follow-up		1	483	–0.29 (–0.55, –0.03)	
	1.3.4 36–48 month follow-up		1	1,148	0.05 (–0.09, 0.19)	
1.4.1	Studies low risk of type 1 error	BMI	3	1727	–0.12 (–0.41, 0.17)	Low
1.4.2	Studies high risk of type 1 error	BMI	2	841	–0.11 (–0.27, 0.05)	Low
0–5 years obesity prevention intervention vs. control: exploratory subgroup analysis						
1.5	Update on effectiveness (exploratory analysis of studies with recruited samples over 200)	BMI	4	2,472	–0.09 (–0.23, 0.05)	Very Low
			1	292	–0.09 (–0.32, 0.14)	
			1	549	–0.13 (–0.35, 0.09)	
	1.5.1 6–11 month follow-up		1	483	–0.29 (–0.55, –0.03)	
	1.5.2 12–23 month follow-up		1	1,148	0.05 (–0.09, 0.19)	
	1.5.3 24–35 month follow-up					
	1.5.4 36–48 month follow-up					
1.6.1	Studies low risk of type 1 error (exploratory analysis of studies with recruited samples over 200)	BMI	2	1,631	–0.10 (–0.43, 0.23)	Very low
1.6.2	Studies high risk of type 1 error (exploratory analysis of studies with recruited samples over 200)	BMI	2	841	–0.11 (–0.27, 0.05)	Low
1.7	Update on effectiveness (exploratory analysis of studies with referenced protocols or trial registrations)	BMI	4	2,276	–0.11 (–0.29, 0.07)	Very Low
			1	96	–0.36 (–1.23, 0.51)	
			1	549	–0.13 (–0.35, 0.09)	
	1.7.1 6–11 months		1	483	–0.29 (–0.55, –0.03)	
	1.7.2 12–23 month follow-up		1	1,148	0.05 (–0.09, 0.19)	
	1.7.3 24–35 month follow-up					
	1.7.4 36–48 month follow-up					
1.8.1	Studies low risk of type 1 error (exploratory analysis of studies with referenced protocols or trial registrations)	BMI	3	1727	–0.12 (–0.41, 0.17)	Very low
1.8.2	Studies high risk of type 1 error (exploratory analysis of studies with referenced protocols or trial registrations)	BMI	1	549	–0.13 (–0.35, 0.09)	NA
Primary school age (6–11 years) obesity prevention interventions vs. control						
2.1	Update on effectiveness	BMIz score	10	8,705	–0.04 (–0.06, –0.03)	Very low
	2.2.1 6–11 month follow-up		1	294	–0.18 (–0.31, –0.04)	
	2.2.2 12–23 month follow-up		4	4,257	–0.03 (–0.09, 0.03)	
	2.1.3 24–43 month follow-up		5	4,154	–0.05 (–0.07, –0.03)	
2.2.1	Studies low risk of type 1 error	BMIz score	3	3,148	–0.10 (–0.19, –0.01)	Very low
2.2.2	Studies high risk of type 1 error	BMIz score	7	5,557	–0.04 (–0.06, –0.02)	Very low
2.3	Update on effectiveness	BMI	18	34,608	–0.16 (–0.27, –0.05)	Very low
	2.3.1 6–11 month follow-up		5	13,636	–0.04 (–0.15, 0.06)	
	2.3.2 12–23 month follow-up		11	18,508	–0.19 (–0.34, –0.03)	

TABLE 2 (Continued)

Comparison	Outcome	No. intervention arms	Total participants	Mean difference (confidence interval)	GRADE quality
2.3.3 24–36 month follow-up		1	508	−0.89 (−1.18, −0.60)	
2.3.4 36–48 month follow-up		1	1,490	0.00 (−0.19, 0.19)	
2.4.1 Studies low risk of type 1 error	BMI	1	625	−0.07 (−0.19, 0.05)	NA
2.4.2 Studies high risk of type 1 error	BMI	17	33,517	−0.17 (−0.29, −0.05)	Very low
Primary school age obesity prevention intervention vs. control: exploratory subgroup analysis					
3.1 Update on effectiveness by intervention design	BMIz score	1	1,670	−0.03 (−0.08, 0.02)	NA
3.1.1 Physical activity		1	294	−0.18 (−0.31, −0.04)	NA
3.1.2 Nutrition education		4	3,480	−0.10 (−0.17, −0.03)	Low
3.1.3 Nutrition education and physical activity					
3.2 Update on effectiveness by intervention design	BMI	3	6,375	−0.03 (−0.17, 0.10)	Low
3.2.1 Physical activity		1	1,094	0.00 (−0.26, 0.26)	NA
3.2.2 Nutrition education		4	9,867	−0.55 (−0.98, −0.12)	Very low
3.2.3 Nutrition education and physical activity					
Secondary school age obesity prevention interventions vs. control					
4.1 Update on effectiveness	BMI	4	1,513	−0.15 (−0.30, 0.00)	Low
4.1.1 6–11 month follow-up		2	487	−0.10 (0.34, 0.15)	
4.1.2 12–23 month follow-up		1	294	−0.19 (−0.70, 0.32)	
4.1.3 48 month follow-up		1	732	−0.25 (−0.51, 0.01)	
4.2.1 Studies low risk of type 1 error	BMI	1	194	−0.26 (−0.61, 0.09)	NA
4.2.2 Studies high risk of type 1 error	BMI	3	1,319	−0.12 (−0.29, 0.05)	Very low

−0.09 kg/m² (CI −0.23, 0.04). Subgroup analysis that removed one study with a sample smaller than 200³² found a similar combined mean difference of −0.09 kg/m² (CI −0.23, 0.05), and the subgroup analysis removing the study with no referenced protocol or trial registration found a combined mean difference of −0.11 kg/m² (CI −0.29, 0.07). Three of these studies^{25,31,32} were at low risk of type 1 error, with a combined mean difference of −0.12 (−0.41, 0.17) compared with two studies^{33,35} at high risk of type 1 error with a mean difference of −0.11 (CI −0.27, 0.05). A subgroup analysis found a slightly smaller effect (−0.10 kg/m² [−0.43, 0.23]) within studies of low risk of type 1 error following the removal of the study with less than 200 participants but a slightly higher effect in studies of low risk of type 1 error when the study with no referenced protocol or trial registration (published in 1998)³⁵ was removed (−0.13 kg/m² [CI −0.35, 0.09]).

3.8 | BMI z-score effect size in primary school-aged children (6–11 years)

Studies of primary school-aged children that reported BMI z-score as a primary outcome had a combined mean difference of −0.04 (CI −0.06, −0.03). Subgroup analysis was conducted based on intervention design. Interventions that included both a nutrition and physical activity

component ($n = 4$) had a combined mean difference of −0.10 (CI −0.17, −0.3) compared with the physical activity-only intervention that had a mean difference between intervention and control arm of −0.03 (CI −0.08, 0.02)⁴³ and the nutrition education only intervention that had a mean difference of −0.18 (CI −0.31, −0.04).⁵²

Three studies^{49,50,52} that reported BMI z-score as a primary outcome within 6–11-year-olds had a low risk of type 1 error and had a combined mean difference of −0.10 (CI −0.19, −0.01) compared with six studies that had a high risk of type 1 error and had a mean difference of −0.04 (CI −0.06, −0.02).

3.9 | BMI effect size in primary school-aged children (6–11 years)

Studies of primary school-aged participants that reported BMI as the primary outcome reported a combined mean difference of −0.16 (CI −0.27, −0.05)^{61,65,66,69,77–79} exploratory subgroup analysis found that studies with a physical activity component only ($N = 3$)^{65,68,79} had a mean difference of −0.03 (CI −0.17, 0.10), those with a nutrition education component only ($N = 1$)⁷⁹ had a mean difference of 0.00 (−0.26, 0.26), and those ($N = 4$)^{57,66,67,79} with both nutrition education and physical activity component have a combined mean difference of −0.55 (CI −0.98, −0.12).

Only one study reporting BMI as a primary outcome had a low risk of type 1 error with a mean difference of -0.07 (CI $-0.19, 0.05$)⁶⁹ compared with 13 studies that had a combined mean difference of -0.17 ($-0.29, -0.05$) and had a high risk of type 1 error.

3.10 | BMI z-score effect size in secondary school-aged children (12–18 years)

No studies of secondary school-aged children that were eligible for inclusion in the meta-analysis reported BMI z-score as a primary outcome.

3.11 | BMI effect size in secondary school-aged children (12–18 years)

Four studies reported BMI as the primary outcome, with a mean difference of -0.15 ($-0.30, 0.00$). Of these, one study⁹⁹ was rated as being of low risk of type 1 error and had a mean difference of -0.26 (CI $-0.61, 0.09$) compared with three studies^{100,101,103} rated as high risk of type 1 error that had a combined mean difference of -0.12 (CI $-0.29, 0.05$).

4 | DISCUSSION

4.1 | Summary and interpretation of findings

This review has provided readers with details of how previous studies have designed child obesity prevention trials (particularly related to assumptions applied in sample size calculations). Additionally, the quality of studies was appraised, based on both the risk of bias and risk of type 1 error, with only two studies being deemed low risk of bias for all domains of risk and 19 studies being deemed low risk of type 1 error. We also provide an update on the overall effectiveness of childhood obesity prevention interventions including the most recently published studies.

A large range in the assumptions have been used to develop sample size calculations, including the predicted effect sizes. The variability in predicted effect size within sample size calculations could in part be attributed to logical differences based on intervention design, follow-up duration, and/or participant age; all of which could influence the predicted reduction in BMI or BMI z-score.⁹ One difficulty faced was a high level of uncertainty regarding the amount of change that would constitute a “meaningful change” in child obesity prevention trials. There was a limited justification of the authors' primary outcome measure; however, where detail was provided, authors often reported using data from previous trials considered to have generated a “successful” outcome to guide sample size calculations. In some studies, these appeared to be based on the size of statistically significant differences rather than clinical or meaningful significance, and the implications for obesity prevention were not discussed.

The review has highlighted that many studies previously conducted in the field may be at risk of type 1 error. However, rather than consistently observing a greater effect in those at greatest risk of type 1 error, our analyses for primary school-aged studies with BMI z-score and secondary school-aged studies with BMI as primary outcomes identified larger effect sizes in those at low risk of type I error. Although there was no consistency in whether studies deemed high or low risk of type 1 error were reporting greater effectiveness across the different analyses, the analyses identified that when analyzing outcomes of studies that are high and low risk of type 1 error separately different results were generated. This suggests risk of type 1 error may have an impact on findings and should be considered both when interpreting study results and when using previous evidence to support future trial design.

Direct comparisons cannot be made with outcomes of previous reviews because of differences in eligibility of included studies and how populations and interventions have been categorized and also because of no previous meta-analyses having explored studies with high or low risk of type 1 error. However, findings of the overall effectiveness of obesity prevention interventions within this systematic review appear to have commonalities with recent reviews, generally showing small reductions in both BMI and BMI z-score in favor of the intervention. For example, the effects demonstrated in this review were -0.10 for BMI z-score and -0.55 for BMI (for combined diet and physical activity interventions in primary school-aged children) and -0.15 for BMI (for secondary school-aged children). Other similar recent meta-analysis had BMI z-score effect sizes ranging from -0.02 to -0.20 and -0.05 to -1.53 for BMI.^{9,10,125} Although this review found interventions to have bigger effects in older children, the most recent Cochrane review⁹ found interventions to have a larger effect in children aged 0 to 5 years compared with primary school children. However, this could be explained by different studies being included in the analyses because of different eligibility criteria of the two reviews.

In obesity prevention research, it is hypothesized that “multiple small changes within a system can make a difference” to weight management.^{126,127} This hypothesis is plausible and is based on economic modeling.^{17,128,129} Although there is little debate that multiple changes are needed across the whole system to impact on obesity prevalence at a population level, it is not yet known how individual interventions contribute to prevention within the system. This is further complicated by our need to design evaluations that, rather than looking for a measurable impact of obesity reduction at an individual level (i.e. with treatment), seek to find smaller alterations to energy imbalance that over time reduce excess weight gain.^{9,130,131}

4.2 | Strengths and limitations of the study

The review included a broad search strategy that identified a large number of papers. Missing evidence was sought through referenced protocols and through contacting authors to ensure a maximum number of studies could be included in the meta-analyses and studies

were appraised based on as much information as possible. However, only 40 of the retrieved studies were eligible for inclusion for the meta-analyses, either because of missing outcome data or not reporting BMI or BMI z-score as a primary outcome. Additionally, the criteria for determining the risk of type 1 error were based on assumed criteria that were not further explored or validated. For example, some studies classed as high risk for not providing a protocol or registration may have been published before CONSORT guidance in this area.¹³² Further, some studies simply had missing information on trial registration or did not reference a protocol, perhaps indicating a reporting error rather than a bias. Although a validated tool was not used to categorize studies at high or low risk of type 1 error, our approach has allowed an exploration and comparison of studies considered most and least likely to be at risk of type 1 error.

The confidence of findings from all meta-analyses was assessed to be either low or very low. This suggests that findings should be interpreted with caution. The large amount of missing information to assess the risk of bias of individual studies included in the meta-analyses was a common reason for the downgrading of the quality of evidence. The updated version of the RoB2 tool used in the review required more detail on study design to be reported than the previous version, and as some studies included in the review were published before CONSORT guidelines were available, some studies did not report information required to support decision making.

5 | CONCLUSION

This review has found there is broad variation in the design of child obesity prevention trials and that the effectiveness of obesity prevention interventions is being determined according to a range of expected effect sizes. It has provided readers with details of how previous studies have designed obesity prevention trials, which, in the absence of a defined “clinically meaningful difference” in child obesity prevention, can provide guidance for future study design. The design of individual studies is reported alongside information of the study’s quality in relation to its risk of bias and risk of type 1 error. Where new studies are designed based on outcomes of previous RCTs, this review suggests that study quality and risk of type 1 error should be considered to ensure the sample size is based around a realistic outcome that has not been over or underestimated because of errors in trial conduct.

We also provide an update on the overall effectiveness of childhood obesity prevention interventions including the most recently published studies, highlighting greater BMI differences when interventions combine diet and physical activity components. Further clarity is required to determine what a meaningful difference is in population prevention trials in order to support decision-making in trial design.

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CONFLICT OF INTEREST STATEMENT

No conflicts of interest.

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REFERENCES

1. Organisation WH. Obesity and Overweight. Accessed 01.10.2020, 2020. <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>
2. The Lancet D, amp, Endocrinology. Childhood obesity: a growing pandemic. *Lancet Diabetes Endocrinol.* 2022;10(1):1. doi:10.1016/S2213-8587(21)00314-4
3. Sharma V, Coleman S, Nixon J, et al. A systematic review and meta-analysis estimating the population prevalence of comorbidities in children and adolescents aged 5 to 18 years. *Obes Rev.* 2019;20(10):1341-1349. doi:10.1111/obr.12904
4. Morrison KM, Shin S, Tarnopolsky M, Taylor VH. Association of depression & health related quality of life with body composition in children and youth with obesity. *J Affect Disord.* 2015;172:18-23. doi:10.1016/j.jad.2014.09.014
5. Simmonds M, Llewellyn A, Owen CG, Woolcott N. Predicting adult obesity from childhood obesity: a systematic review and meta-analysis. *Obes Rev.* 2016;17(2):95-107. doi:10.1111/obr.12334
6. Singh AS, Mulder C, Twisk JW, van Mechelen W, Chinapaw MJ. Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obes Rev.* 2008;9(5):474-488.
7. Gardiner J, Oben J, Sutcliffe A. Obesity as a driver of international differences in COVID-19 death rates. *Diabetes Obes Metab.* 2021;23(7):1463-1470. doi:10.1111/dom.14357
8. The Lancet Public H. Childhood obesity beyond COVID-19. *Lancet Public Health.* 2021;6(8):e534. doi:10.1016/S2468-2667(21)00168-7
9. Brown T, Moore THM, Hooper L, et al. Interventions for preventing obesity in children. *Cochrane Database Syst Rev.* 2019;2019(7):CD001871. doi:10.1002/14651858.CD001871.pub4
10. Liu Z, Xu H-M, Wen L-M, et al. A systematic review and meta-analysis of the overall effects of school-based obesity prevention interventions and effect differences by intervention components. *Int J Behav Nutr Phys Act.* 2019;16:95. doi:10.1186/s12966-019-0848-8
11. Redsell SA, Edmonds B, Swift JA, et al. Systematic review of randomised controlled trials of interventions that aim to reduce the risk, either directly or indirectly, of overweight and obesity in infancy and early childhood. *Matern Child Nutr.* 2016;12(1):24-38. doi:10.1111/mcn.12184
12. Flynn AC, Suleiman F, Windsor-Aubrey H, et al. Preventing and treating childhood overweight and obesity in children up to 5 years old: a systematic review by intervention setting. *Matern Child Nutr.* 2022;e13354. doi:10.1111/mcn.13354
13. du Prel J-B, Hommel G, Röhrig B, Blettner M. Confidence interval or p-value?: part 4 of a series on evaluation of scientific publications. *Deutsches Arzteblatt International.* 2009;106(19):335-339. doi:10.3238/arztebl.2009.0335
14. Kadam P, Bhalerao S. Sample size calculation. *Int J Ayurveda Res.* 2010;1(1):55-57. doi:10.4103/0974-7788.59946
15. Williamson DA, Bray GA, Ryan DH. Is 5% weight loss a satisfactory criterion to define clinically significant weight loss? *Obesity (Silver Spring).* 2015;23(12):2319-2320. doi:10.1002/oby.21358
16. Stevens J, Truesdale KP, McClain JE, Cai J. The definition of weight maintenance. *Int J Obes (Lond).* 2006;30(3):391-399. doi:10.1038/sj.ijo.0803175
17. Brown V, Ananthapavan J, Sonntag D, Tan EJ, Hayes A, Moodie M. The potential for long-term cost-effectiveness of obesity prevention interventions in the early years of life. *Pediatr Obes.* 2019;14(8):e12517. doi:10.1111/ijpo.12517
18. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ.* 2021;372:n71. doi:10.1136/bmj.n71

19. Higgins JPT, Thomas J, Chandler J, et al. *Cochrane Handbook for Systematic Reviews of Interventions version 6.1 (updated September 2020)*. Cochrane Database Syst Rev Accessed 23 January 2021; 2020. www.training.cochrane.org/handbook
20. Jones RA, Sinn N, Campbell KJ, et al. The importance of long-term follow-up in child and adolescent obesity prevention interventions. *Int J Pediatr Obes*. 2011;6(3-4):178-181. doi:10.3109/17477166.2011.575155
21. McHugh ML. Interrater reliability: the kappa statistic. *Biochem Med (Zagreb)*. 2012;22(3):276-282. doi:10.11613/BM.2012.031
22. Black MM, Hager ER, Wang Y, et al. Toddler obesity prevention: a two-generation randomized attention-controlled trial. *Matern Child Nutr*. 2021;17(1):1-16. doi:10.1111/mcn.13075
23. Davis SM, Myers OB, Cruz TH, et al. CHILE: outcomes of a group randomized controlled trial of an intervention to prevent obesity in preschool Hispanic and American Indian children. *Prev Med*. 2016; 89:162-168. doi:10.1016/j.ypmed.2016.05.018
24. De Coen V, De Bourdeaudhuij I, Vereecken C, et al. Effects of a 2-year healthy eating and physical activity intervention for 3-6-year-olds in communities of high and low socio-economic status: the POP (prevention of overweight among pre-school and school children) project. *Public Health Nutr*. 2012;15(9):1737-1745. doi:10.1017/S1368980012000687
25. Lumeng JC, Miller AL, Horodyski MA, et al. Improving self-regulation for obesity prevention in head start: a randomized controlled trial. Randomized controlled trial. *Pediatrics*. 2017;139(5): e20162047. doi:10.1542/peds.2016-2047
26. Paul IM, Savage JS, Anzman-Frasca S, et al. Effect of a responsive parenting educational intervention on childhood weight outcomes at 3 years of age: the INSIGHT randomized clinical trial. *Jama*. 2018; 320(5):461-468. doi:10.1001/jama.2018.9432
27. Reilly JJ, Kelly L, Montgomery C, et al. Physical activity to prevent obesity in young children: cluster randomised controlled trial. *Br Med J*. 2006;333(7577):1041-1043. doi:10.1136/bmj.38979.623773.55
28. Taylor RW, Gray AR, Heath A-LM, et al. Sleep, nutrition, and physical activity interventions to prevent obesity in infancy: follow-up of the prevention of overweight in infancy (POI) randomized controlled trial at ages 3.5 and 5 y. *Am J Clin Nutr*. 2018;108(1):228-236. doi:10.1093/ajcn/nqy090
29. Tomayko EJ, Prince RJ, Cronin KA, Kim K, Parker T, Adams AK. The healthy children, strong families 2 (HCSF2) randomized controlled trial improved healthy behaviors in American Indian families with young children. *Curr Dev Nutr*. 2019;3(Suppl 2):53-62. doi:10.1093/cdn/nzy087
30. Vlasblom E, van Grieken A, Beltman M, L'Hoir MP, Raat H, Boere-Boonekamp MM. Parenting support to prevent overweight during regular well-child visits in 0-3 year old children (BBOFT+ program), a cluster randomized trial on the effectiveness on child BMI and health behaviors and parenting. *PLoS ONE*. 2020;15(8):e0237564. doi:10.1371/journal.pone.0237564
31. Döring N, Ghaderi A, Bohman B, et al. Motivational interviewing to prevent childhood obesity: a cluster RCT. *Pediatrics*. 2016;137(5):1-10. doi:10.1542/peds.2015-3104
32. Haines J, Rifas-Shiman SL, Gross D, McDonald J, Kleinman K, Gillman MW. Randomized trial of a prevention intervention that embeds weight-related messages within a general parenting program. *Obesity*. 2016;24(1):191-199. doi:10.1002/oby.21314
33. Kong A, Buscemi J, Stolley MR, et al. Hip-Hop to Health Jr. randomized effectiveness trial: 1-year follow-up results. *Am J Prev Med*. 2016;50(2):136-144. doi:10.1016/j.amepre.2015.07.008
34. Li Ming W, Baur LA, Simpson JM, Rissel C, Wardle K, Flood VM. Effectiveness of home based early intervention on children's BMI at age 2: randomised controlled trial. *BMJ: Br Med J*. 2012;345(7865): 17-17. doi:10.1136/bmj.e3732
35. Mo-suwan L, Pongprapai S, Junjana C, Puetpaiboon A. Effects of a controlled trial of a school-based exercise program on the obesity indexes of preschool children. *Am J Clin Nutr*. 1998;68(5):1006-1011. doi:10.1093/ajcn/68.5.1006
36. van Grieken A, Vlasblom E, Lu W, et al. Personalized web-based advice in combination with well-child visits to prevent overweight in young children: cluster randomized controlled trial. *J Med Internet Res*. 2017;19(7):e268. doi:10.2196/jmir.7115
37. Dodd JM, Louise J, Deussen AR, McPhee AJ, Owens JA, Robinson JS. Prenatal diet and child growth at 18 months. *Pediatrics*. 2018;142(3):e20180035. doi:10.1542/peds.2018-0035
38. Morandi A, Tommasi M, Soffiati F, et al. Prevention of obesity in toddlers (PROBIT): a randomised clinical trial of responsive feeding promotion from birth to 24 months. Journal Article; Randomized Controlled Trial; Research Support, Non-U.S. Gov't. *Int J Obes (Lond)*. 2019;43(10):1961-1966. doi:10.1038/s41366-019-0406-0
39. Kobel S, Wartha O, Lammle C, Dreyhaupt J, Steinacker JM. Intervention effects of a kindergarten-based health promotion programme on obesity related behavioural outcomes and BMI percentiles. *Prev Med Rep*. 2019;15:100931. doi:10.1016/j.pmedr.2019.100931
40. Delisle Nyström C, Sandin S, Henriksson P, et al. Mobile-based intervention intended to stop obesity in preschool-aged children: the MINISTOP randomized controlled trial. *Am J Clin Nutr*. 2017;105(6): 1327-1335. doi:10.3945/ajcn.116.150995
41. Reifsnider E, McCormick D, Cullen K, et al. Randomized controlled trial to prevent infant overweight in a high-risk population. *Acad Pediatr*. 2017;18(3):324-333. doi:10.1016/j.jacp.2017.12.007
42. Adab P, Pallan MJ, Lancashire ER, et al. Effectiveness of a childhood obesity prevention programme delivered through schools, targeting 6 and 7 year olds: cluster randomised controlled trial (WAVES study). *BMJ (Clinical Research Ed)*. 2018;360:k211. doi:10.1136/bmj.k211
43. Breheny K, Passmore S, Adab P, et al. Effectiveness and cost-effectiveness of The Daily Mile on childhood weight outcomes and wellbeing: a cluster randomised controlled trial. *Int J Obes (Lond)*. 2020;44(4):812-822. doi:10.1038/s41366-019-0511-0
44. Dziewaltowski DA, Rosenkranz RR, Geller KS, et al. HOP'N after-school project: an obesity prevention randomized controlled trial. *Int J Behav Nutr Phys Act*. 2010;7(1):90. doi:10.1186/1479-5868-7-90
45. Habib-Mourad C, Ghandour LA, Maliha C, Dagher M, Kharroubi S, Hwalla N. Impact of a three-year obesity prevention study on healthy behaviors and BMI among Lebanese schoolchildren: findings from Ajjal Salima program. *Nutrients*. 2020;12(9):2687. doi:10.3390/nu12092687
46. Hull PC, Buchowski M, Canedo JR, et al. Childhood obesity prevention cluster randomized trial for Hispanic families: outcomes of the healthy families study. *Pediatr Obes*. 2018;13:686-696.
47. Johnston CA, Moreno JP, El-Mubasher A, Gallagher M, Tyler C, Woehler D. Impact of a school-based pediatric obesity prevention program facilitated by health professionals. *J Sch Health*. 2013;83(3): 171-181. doi:10.1111/josh.12013
48. Kain J, Concha F, Moreno L, Leyton B. School-based obesity prevention intervention in Chilean children: effective in controlling, but not reducing obesity. *J Obes*. 2014;2014:618293.
49. Li B, Pallan M, Liu WJ, et al. The CHIRPY DRAGON intervention in preventing obesity in Chinese primary-school-aged children: a cluster-randomised controlled trial. *PLoS Med*. 2019;16(11): e1002971. doi:10.1371/journal.pmed.1002971
50. Lloyd J, Creanor S, Logan S, et al. Effectiveness of the Healthy Life-styles Programme (HeLP) to prevent obesity in UK primary-school children: a cluster randomised controlled trial. *Lancet Child Adolesc Health*. 2018;2(1):35-45. doi:10.1016/S2352-4642(17)30151-7
51. Marcus C, Nyberg G, Nordenfelt A, et al. A 4-year, cluster-randomized, controlled childhood obesity prevention study: STOPP. *Int J Obes (Lond)*. 2009;33(4):408-417. doi:10.1038/ijo.2009.38

52. Rosário R, Oliveira B, Araújo A, et al. The impact of an intervention taught by trained teachers on childhood overweight. *Int J Environ Res Public Health*. 2012;9(4):1355-1367. doi:10.3390/ijerph9041355
53. Sahota P, Rudolf MCJ, Dixey R, Hill AJ, Barth JH, Cade J. Randomised controlled trial of primary school based intervention to reduce risk factors for obesity. *Br Med J*. 2001;323(7320):1029-1032. doi:10.1136/bmj.323.7320.1029
54. Waters E, Gibbs L, Tadic M, et al. Cluster randomised trial of a school-community child health promotion and obesity prevention intervention: findings from the evaluation of fun 'n healthy in Moreland! Journal Article; Randomized Controlled Trial. *BMC Public Health*. 2017;18(1):92. doi:10.1186/s12889-017-4625-9
55. Williamson DA, Champagne CM, Harsha DW, et al. Effect of an environmental school-based obesity prevention program on changes in body fat and body weight: a randomized trial. *Obesity*. 2012;20(8):1653-1661. doi:10.1038/oby.2012.60
56. Akdemir M, Donmez L, Polat H. The effect of nutritional and physical activity interventions on nutritional status and obesity in primary school children: a cluster randomized controlled study. *Kuwait Med J*. 2017;49(2):105-113.
57. Angelopoulos PD, Milionis HJ, Grammatikaki E, Moschonis G, Manios Y. Changes in BMI and blood pressure after a school based intervention: the CHILDREN study. *Eur J Public Health*. 2009;19(3):319-325. doi:10.1093/eurpub/ckp004
58. Brandstetter S, Klenk J, Berg S, et al. Overweight prevention implemented by primary school teachers: a randomised controlled trial. *Obes Facts*. 2012;5(1):1-11. doi:10.1159/000336255
59. Donnelly JE, Greene JL, Gibson CA, et al. Physical Activity Across the Curriculum (PAAC): a randomized controlled trial to promote physical activity and diminish overweight and obesity in elementary school children. *Prev Med*. 2009;49(4):336-341. doi:10.1016/j.ypmed.2009.07.022
60. Elder JP, Crespo NC, Corder K, et al. Childhood obesity prevention and control in city recreation centres and family homes: the MOVE/me Nuevo project. *Pediatr Obes*. 2014;9(3):218-231. doi:10.1111/j.2047-6310.2013.00164.x
61. Gomez SF, Esteve RC, Subirana I, et al. Effect of a community-based childhood obesity intervention program on changes in anthropometric variables, incidence of obesity, and lifestyle choices in Spanish children aged 8 to 10 years. *Eur J Pediatr*. 2018;177(10):1531-1539. doi:10.1007/s00431-018-3207-x
62. Grydeland M, Bjelland M, Anderssen SA, et al. Effects of a 20-month cluster randomised controlled school-based intervention trial on BMI of school-aged boys and girls: the HEIA study. *Br J Sports Med*. 2014;48(9):768-773. doi:10.1136/bjsports-2013-092284
63. Jansen W, Borsboom G, Meima A, et al. Effectiveness of a primary school-based intervention to reduce overweight. *Int J Pediatr Obes*. 2011;6(2-2):e70-e77. doi:10.3109/17477166.2011.575151
64. Lazaar N, Aucouturier J, Ratel S, Rance M, Meyer M, Duch'e P. Effect of physical activity intervention on body composition in young children: influence of body mass index status and gender. *Acta Paediatr*. 2007;96(9):1321-1325. doi:10.1111/j.1651-2227.2007.00426.x
65. Li YP, Hu XQ, Schouten EG, et al. Report on childhood obesity in China (8): effects and sustainability of physical activity intervention on body composition of Chinese youth. *Biomed Environ Sci*. 2010;23(3):180-187. doi:10.1016/S0895-3988(10)60050-5
66. Liu Z, Li Q, Maddison R, et al. A school-based comprehensive intervention for childhood obesity in China: a cluster randomized controlled trial. Journal Article; Randomized Controlled Trial; Research Support, Non-U.S. Gov't. *Childhood Obes*. 2019;15(2):105-115. doi:10.1089/chi.2018.0251
67. Llargues E, Franco R, Recasens A, et al. Assessment of a school-based intervention in eating habits and physical activity in school children: the AVall study. *J Epidemiol Community Health*. 2011;65(10):896-901. doi:10.1136/jech.2009.102319
68. Martínez Vizcaíno V, Salcedo Aguilar F, Franquelo Gutiérrez R, et al. Assessment of an after-school physical activity program to prevent obesity among 9- to 10-year-old children: a cluster randomized trial. *Int J Obes (Lond)*. 2008;32(1):12-22. doi:10.1038/sj.jco.0803738
69. Puder JJ, Marques-Vidal P, Schindler C, et al. Effect of multidimensional lifestyle intervention on fitness and adiposity in predominantly migrant preschool children (Ballabeina): cluster randomised controlled trial. *BMJ (Clinical Research Ed)*. 2011;343(oct13 2):d6195. doi:10.1136/bmj.d6195
70. Rausch Herscovici C, Kovalskys I, De Gregorio MJ. Gender differences and a school-based obesity prevention program in Argentina: a randomized trial. *Rev Panam Salud Publica*. 2013;34(2):75-82.
71. Rush E, Reed P, McLennan S, Coppinger T, Simmons D, Graham D. A school-based obesity control programme: project energize. Two-year outcomes. *Br J Nutr*. 2012;107(4):581-587. doi:10.1017/S0007114511003151
72. Salmon J, Ball K, Hume C, Booth M, Crawford D. Outcomes of a group-randomized trial to prevent excess weight gain, reduce screen behaviours and promote physical activity in 10-year-old children: switch-play. *Int J Obes (Lond)*. 2008;32(4):601-612. doi:10.1038/sj.jco.0803805
73. Sevinc O, Bozkurt AI, Gundogdu M, et al. Evaluation of the effectiveness of an intervention program on preventing childhood obesity in Denizli, Turkey. Denizli'de cocukluk cag{i}ndeki obezitesinin onlenmesine yonelik bir mudahale programi{dotless}ni{dotless}n etkinliginin degerlendirilmesi. *Turk J Med Sci*. 2011;41(6):1097-1105.
74. Sgambato MR, Cunha DB, Souza BSN, et al. Effectiveness of school-home intervention for adolescent obesity prevention: parallel school randomised study. *Br J Nutr*. 2019;122(9):1073-1080. doi:10.1017/S0007114519001818
75. Sichieri R, Trotte AP, de Souza RA, Veiga GV. School randomised trial on prevention of excessive weight gain by discouraging students from drinking sodas. *Public Health Nutr*. 2009;12(2):197-202. doi:10.1017/s1368980008002644
76. Story M, Hannan PJ, Fulkerson JA, et al. Bright start: description and main outcomes from a group-randomized obesity prevention trial in American Indian children. *Obesity*. 2012;20(11):2241-2249. doi:10.1038/oby.2012.89
77. Wang Z, Xu F, Ye Q, et al. Childhood obesity prevention through a community-based cluster randomized controlled physical activity intervention among schools in China: the health legacy project of the 2nd world summer youth olympic games (YOG-Obesity study). *Int J Obes (Lond)*. 2018;42(4):625-633. doi:10.1038/ijo.2017.243
78. Xu F, Ware RS, Leslie E, et al. Effectiveness of a randomized controlled lifestyle intervention to prevent obesity among Chinese primary school students: CLICK-obesity study. *PLoS ONE*. 2015;10(10):e0141421. doi:10.1371/journal.pone.0141421
79. Xu HQ, Li YP, Zhang Q, et al. Comprehensive school-based intervention to control overweight and obesity in China: a cluster randomized controlled trial. *Asia Pac J Clin Nutr*. 2017;26(6):1139-1151. doi:10.6133/apjcn.112016.05
80. Bayer O, von Kries R, Strauss A, et al. Short- and mid-term effects of a setting based prevention program to reduce obesity risk factors in children: a cluster-randomized trial. *Clin Nutr*. 2009;28(2):122-128. doi:10.1016/j.clnu.2009.01.001
81. Cao Z-J, Wang S-M, Chen Y. A randomized trial of multiple interventions for childhood obesity in China. *Am J Prev Med*. 2015;48(5):552-560. doi:10.1016/j.amepre.2014.12.014
82. Koch PA, Contento IR, Gray HL, et al. Food, health, & choices: curriculum and wellness interventions to decrease childhood obesity in fifth-graders. *J Nutr Educ Behav*. 2019;51(4):440-455. doi:10.1016/j.jneb.2018.12.001

83. Muckelbauer R, Libuda L, Clausen K, Toschke AM, Reinehr T, Kersting M. Promotion and provision of drinking water in schools for overweight prevention: randomized, controlled cluster trial. *Pediatrics*. 2009;123(4):e661-e667. doi:10.1542/peds.2008-2186
84. Caballero B, Clay T, Davis SM, et al. Pathways: a school-based, randomized controlled trial for the prevention of obesity in American Indian schoolchildren. *Am J Clin Nutr*. 2003;78(5):1030-1038. doi:10.1093/ajcn/78.5.1030
85. Martinez-Vizcaino V, Pozuelo-Carrascosa DP, Garcia-Prieto JC, et al. Effectiveness of a school-based physical activity intervention on adiposity, fitness and blood pressure: MOVI-KIDS study. *Br J Sports Med*. 2020;54(5):279-285. doi:10.1136/bjsports-2018-099655
86. Yin Z, Moore JB, Johnson MH, Vernon MM, Gutin B. The impact of a 3-year after-school obesity prevention program in elementary school children. *Child Obes*. 2012;8(1):60-70. doi:10.1089/chi.2011.0085
87. Ickovics JR, Duffany KOC, Shebl FM, et al. Implementing school-based policies to prevent obesity: cluster randomized trial. *Am J Prev Med*. 2019;56(1):e1-e11. doi:10.1016/j.amepre.2018.08.026
88. Wendel ML, Benden ME, Zhao H, Jeffrey C. Stand-biased versus seated classrooms and childhood obesity: a randomized experiment in Texas. *Journal Article; Randomized Controlled Trial. Am J Public Health*. 2016;106(10):1849-1854. doi:10.2105/AJPH.2016.303323
89. Foster GD, Sherman S, Borradaile KE, et al. A policy-based school intervention to prevent overweight and obesity. *Pediatrics*. 2008;121(4):E794-E802. doi:10.1542/peds.2007-1365
90. Polonsky HM, Bauer KW, Fisher JO, et al. Effect of a breakfast in the classroom initiative on obesity in urban school-aged children a cluster randomized clinical trial. *JAMA Pediatr*. 2019;173(4):326-333. doi:10.1001/jamapediatrics.2018.5531
91. Tarro L, Llauradó E, Albaladejo R, et al. A primary-school-based study to reduce the prevalence of childhood obesity—the EdAl (Educació en Alimentació) study: a randomized controlled trial. *Trials*. 2014;15(1):58-58. doi:10.1186/1745-6215-15-58
92. Black MM, Hager ER, Le K, et al. Challenge! Health promotion/obesity prevention mentorship model among urban, black adolescents. *Pediatrics*. 2010;126(2):280-288. doi:10.1542/peds.2009-1832
93. Viggiano A, Viggiano E, Di Costanzo A, et al. Kaledo, a board game for nutrition education of children and adolescents at school: cluster randomized controlled trial of healthy lifestyle promotion. *Eur J Pediatr*. 2014;174:217-228.
94. Bonsergent E, Agrinier N, Thilly N, et al. Overweight and obesity prevention for adolescents: a cluster randomized controlled trial in a school setting. *Am J Prev Med*. 2013;44(1):30-39. doi:10.1016/j.amepre.2012.09.055
95. Cunha DB, Souza B, Pereira RA, Sichieri R. Effectiveness of a randomized school-based intervention involving families and teachers to prevent excessive weight gain among adolescents in Brazil. *PLoS ONE*. 2013;8(2):e57498.
96. da Silva KBB, Ortelan N, Murta SG, et al. Evaluation of the computer-based intervention program Stayingfit Brazil to promote healthy eating habits: the results from a school cluster-randomized controlled trial. *Int J Environ Res Public Health*. 2019;16(10):1674. doi:10.3390/ijerph16101674
97. Ezendam NPM, Brug J, Oenema A. Evaluation of the web-based computer-tailored FATaintPHAT intervention to promote energy balance among adolescents: results from a school cluster randomized trial. *Arch Pediatr Adolesc Med*. 2012;166(3):248-255. doi:10.1001/archpediatrics.2011.204
98. Haerens L, Deforche B, Maes L, Stevens V, Cardon G, De Bourdeaudhuij I. Body mass effects of a physical activity and healthy food intervention in middle schools. *Obesity (Silver Spring, Md)*. 2006;14(5):847-854. doi:10.1038/oby.2006.98
99. Leme AC, Lubans DR, Guerra PH, Dewar D, Toassa EC, Philippi ST. Preventing obesity among Brazilian adolescent girls: six-month outcomes of the Healthy Habits, Healthy Girls-Brazil school-based randomized controlled trial. *Randomized Controlled Trial. Prev Med*. 2016;86:77-83. doi:10.1016/j.ypmed.2016.01.020
100. Lubans DR, Morgan PJ, Okely AD, et al. Preventing obesity among adolescent girls. *Arch Pediatr Adolesc Med*. 2012;166(9):821-827. doi:10.1001/archpediatrics.2012.41
101. Simon C, Schweitzer B, Oujaa M, et al. Successful overweight prevention in adolescents by increasing physical activity: a 4-year randomized controlled intervention. *Int J Obes (Lond)*. 2008;32(10):1489-1498. doi:10.1038/ijo.2008.99
102. Singh AS, Paw MJMCA, Brug J, Van Mechelen W. Short-term effects of school-based weight gain prevention among adolescents. *Arch Pediatr Adolesc Med*. 2007;161(6):565-571. doi:10.1001/archpedi.161.6.565
103. Smith JJ, Morgan PJ, Plotnikoff RC, et al. Smart-phone obesity prevention trial for adolescent boys in low-income communities: the ATLAS RCT. *Pediatrics*. 2014;134(3):e723-e731. doi:10.1542/peds.2014-1012
104. Bogart LM, Elliott MN, Cowgill BO, et al. Two-year BMI outcomes from a school-based intervention for nutrition and exercise: a randomized trial. *Pediatrics*. 2016;137(5):e20152493. doi:10.1542/peds.2015-2493
105. Gortmaker SL, Peterson K, Wiecha J, et al. Reducing obesity via a school-based interdisciplinary intervention among youth—Planet health. *Arch Pediatr Adolesc Med*. 1999;153(4):409-418. doi:10.1001/archpedi.153.4.409
106. Sterne JACSJ, Page MJ, Elbers RG, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*. 2019;366:l4898. doi:10.1136/bmj.l4898
107. Higgins JPT, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ*. 2011;343(oct18 2):d5928. doi:10.1136/bmj.d5928
108. Andrade C. The primary outcome measure and its importance in clinical trials. *J Clin Psychiatry*. 2015;76(10):e1320-e1323. doi:10.4088/JCP.15f10377
109. David M, Sally H, Kenneth FS, et al. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. *BMJ*. 2010;340(mar23 1):c869. doi:10.1136/bmj.c869
110. Review Manager (RevMan) [Computer program] Version 4.2, 2019.
111. Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008;336(7650):924-926. doi:10.1136/bmj.39489.470347.AD
112. Deeks JJ, Higgins JPT, Deeks JJ, Higgins JPT, Altman DG. In: Higgins JPT, Thomas J, Chandler J, et al., eds. *Cochrane Handbook for Systematic Reviews of Interventions version 62 (updated February 2021)*. Cochrane; 2021.
113. Dodd JM, Deussen AR, Louise J. Effects of an antenatal dietary intervention in women with obesity or overweight on child outcomes at 3-5 years of age: LIMIT randomised trial follow-up. *Journal: Article in Press. Int J Obes (Lond)*. 2020;44(7):1531-1535. doi:10.1038/s41366-020-0560-4
114. Recasens MA, Xicola-Coromina E, Manresa JM, et al. Impact of school-based nutrition and physical activity intervention on body mass index eight years after cessation of randomized controlled trial (AVall study). *Clin Nutr*. 2019;38(6):2592-2598. doi:10.1016/j.clnu.2018.12.029
115. Delisle Nyström C, Sandin S, Henriksson P, Henriksson H, Maddison R, Löf M. A 12-month follow-up of a mobile-based (mHealth) obesity prevention intervention in pre-school children: the MINISTOP randomized controlled trial. *BMC Public Health*. 2018;18(1):658. doi:10.1186/s12889-018-5569-4
116. Dewar DL, Morgan PJ, Plotnikoff RC, et al. The nutrition and enjoyable activity for teen girls study: a cluster randomized controlled

- trial. *Am J Prev Med.* 2013;45(3):313-317. doi:10.1016/j.amepre.2013.04.014
117. Leme ACB, Baranowski T, Thompson D, Nicklas T, Philippi ST. Sustained impact of the "Healthy Habits, Healthy Girls - Brazil" school-based randomized controlled trial for adolescents living in low-income communities. *Prev Med Rep.* 2018;10:346-352. doi:10.1016/j.pmedr.2018.04.013
 118. Llargués E, Recasens MA, Manresa J-M, et al. Four-year outcomes of an educational intervention in healthy habits in schoolchildren: the Avall 3 trial. *Eur J Public Health.* 2017;27(1):42-47. doi:10.1093/eurpub/ckw199
 119. Llauradó E, Tarro L, Moriña D, Aceves-Martins M, Giralt M, Solà R. Follow-up of a healthy lifestyle education program (the EdAI study): four years after cessation of randomized controlled trial intervention. *BMC Public Health.* 2018;18(1):104. doi:10.1186/s12889-017-5006-0
 120. Lubans DR, Smith JJ, Plotnikoff RC, et al. Assessing the sustained impact of a school-based obesity prevention program for adolescent boys: the ATLAS cluster randomized controlled trial. *Int J Behav Nutr Phys Act.* 2016;13(1):92. doi:10.1186/s12966-016-0420-8
 121. Rush E, McLennan S, Obolonkin V, et al. Project Energize: whole-region primary school nutrition and physical activity programme; evaluation of body size and fitness 5 years after the randomised controlled trial. *Br J Nutr.* 2014;111(2):363-371. doi:10.1017/s0007114513002316
 122. Salcedo Aguilar F, Martínez-Vizcaíno V, Sánchez López M, et al. Impact of an after-school physical activity program on obesity in children. *J Pediatr.* 2010;157(1):36-42.e3. doi:10.1016/j.jpeds.2009.12.046
 123. Singh AS, Paw M, Brug J, van Mechelen W. Dutch obesity intervention in teenagers effectiveness of a school-based program on body composition and behavior. *Arch Pediatr Adolesc Med.* 2009;163(4):309-317. doi:10.1001/archpediatrics.2009.2
 124. Tarro L, Llauradó E, Moriña D, Solà R, Giralt M. Follow-up of a healthy lifestyle education program (the Educació en Alimentació study): 2 years after cessation of intervention. *J Adolesc Health.* 2014;55(6):782-789. doi:10.1016/j.jadohealth.2014.06.020
 125. Taghizadeh S, Farhangi MA. The effectiveness of pediatric obesity prevention policies: a comprehensive systematic review and dose-response meta-analysis of controlled clinical trials. *J Transl Med.* 2020;18(1):480. doi:10.1186/s12967-020-02640-1
 126. World Health Organization. Population-based approaches to childhood obesity prevention. 2012.
 127. Graham HE, Madigan CD, Daley AJ. Is a small change approach for weight management effective? A systematic review and meta-analysis of randomized controlled trials. *Obes Rev.* 2022;23(2):e13357. doi:10.1111/obr.13357
 128. Wright DR, Kenney EL, Giles CM, et al. Modeling the cost effectiveness of child care policy changes in the U.S. *Am J Prev Med.* 2015;49(1):135-147. doi:10.1016/j.amepre.2015.03.016
 129. Hollingworth W, Hawkins J, Lawlor DA, Brown M, Marsh T, Kipping RR. Economic evaluation of lifestyle interventions to treat overweight or obesity in children. *Int J Obes (Lond).* 2012;36(4):559-566. doi:10.1038/ijo.2011.272
 130. Institute of Medicine Committee on an Evidence Framework for Obesity Prevention Decision M. In: Kumanyika SK, Parker L, Sim LJ, eds. *Bridging the Evidence Gap in Obesity Prevention: A Framework to Inform Decision Making.* National Academies Press (US) Copyright 2010 by the National Academy of Sciences. All rights reserved; 2010.
 131. Griffin N, Phillips SM, Hillier-Brown F, et al. A critique of the English national policy from a social determinants of health perspective using a realist and problem representation approach: the 'Childhood Obesity: a plan for action' (2016, 2018, 2019). *BMC Public Health.* 2021;21(1):2284. doi:10.1186/s12889-021-12364-6
 132. Schulz KF, Altman DG, Moher D. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. *BMJ.* 2010;340(mar23 1):c332. doi:10.1136/bmj.c332

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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