



OPEN Overview of systematic reviews on behavioral determinants of physical activity and healthy eating in schoolchildren

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Childhood obesity and poor dietary habits represent significant public health challenges globally. Schools provide a crucial environment for interventions promoting physical activity and healthy eating behaviors due to their extensive reach and influential role in child development. This overview aims to synthesize evidence on the effectiveness of school-based interventions promoting physical activity and healthy eating behaviors among school-aged children, examining the role of behavior change techniques (BCTs) and behavioral determinants influencing their success. This study is an overview of systematic reviews and follows the Cochrane Handbook for Systematic Reviews of Interventions as well as the PRIOR (Preferred Reporting Items for Overviews of Reviews) statement. A literature searches until September 30, 2024, was performed in four electronic databases for this Overview: Cochrane database of systematic reviews, MEDLINE via PubMed, Epistemonikos, and PsycINFO. No language restrictions were imposed. Data were included and extracted from all systematic reviews evaluating interventions implemented in school settings targeting physical activity, healthy eating, or both, in children aged 6–11 years. Two reviewers independently screened the identified articles and extracted data related to the study characteristics, intervention components, behavioral outcomes (e.g., moderate-to-vigorous physical activity, dietary quality), cognitive outcomes (e.g., self-efficacy, knowledge, attitudes), and biological outcomes (e.g., BMI, waist circumference), classifying BCTs using standardized classifications whenever available. The AMSTAR-2 tool was used to evaluate the methodological quality of the included studies. Six systematic reviews, encompassing over 230,000 participants, were included. Multicomponent interventions combining physical activity, dietary education, cognitive strategies, and environmental modifications demonstrated consistent positive outcomes. Effective BCTs frequently identified included goal setting, self-monitoring, restructuring the physical environment, and providing feedback on behavior, especially via digital platforms. While significant improvements were consistently noted in behavioral outcomes such as increased physical activity and improved dietary habits, evidence regarding cognitive and biological outcomes like BMI reduction was moderate yet favorable. Methodological quality varied, with most reviews rated critically low, except for one high-quality Cochrane review. School-based interventions integrating multiple BCTs, particularly goal setting, self-monitoring, feedback, and environmental restructuring, are effective in promoting physical activity and healthy eating among school-aged children. Future interventions should emphasize long-term sustainability, technological integration, and address existing methodological limitations to enhance effectiveness and generalizability.

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Abbreviations

AMSTAR-2	A MeaSurement Tool to Assess systematic Reviews 2
BCT	Behavior change technique
BCTTv1	Behavior change technique taxonomy version 1
BMI	Body mass index
CDSR	Cochrane database of systematic reviews
CCA	Corrected covered area
GRADE	Grading of recommendations, assessment, development, and evaluation
MVPA	Moderate-to-vigorous physical activity
OSF	Open science framework
PICOs	Population, intervention, comparison, outcome, study type
RCT	Randomized controlled trial
SAGER	Sex and gender equity in research
SR	Systematic review
TDF	Theoretical domains framework

Childhood obesity and unhealthy dietary habits have emerged as critical global public health issues, requiring action across multiple levels of influence as emphasized by the socio-ecological model^{1,2}. According to the World Health Organization (WHO), the prevalence of childhood overweight and obesity has significantly increased over the past few decades, with an estimated 39 million children under the age of five classified as overweight or obese in 2022³. This rise is associated with numerous health problems, including increased risk of cardiovascular disease, type 2 diabetes, and psychological disorders later in life^{4,5}. Moreover, inadequate physical activity and poor nutrition during childhood can hinder cognitive development and academic performance^{6–8}.

Promoting physical activity and healthy eating from an early age is essential for establishing lifelong healthy habits. Schools provide a unique and influential setting to address these behaviors within a socio-ecological framework, as they encompass individual, interpersonal, organizational, and community influences⁹. Physical activity plays a vital role in maintaining a healthy weight, strengthening bones and muscles, and improving mental health¹⁰. Similarly, a balanced diet—rich in fruits, vegetables, and whole grains, and low in ultra-processed foods—supports optimal growth and reduces the risk of developing chronic diseases¹¹. Schools are key environments for implementing multi-component interventions that integrate educational, behavioral, and structural strategies, and the socio-ecological model provides a robust framework for understanding how multi-level influences interact to shape the effectiveness of school-based interventions¹².

Previous multi-component school-based reviews have examined the effects of such interventions on physical activity, dietary habits, and obesity prevention. For example, Busch et al.¹³ reviewed school-based programs addressing multiple adolescent health behaviors; Amini et al.¹⁴ synthesized reviews on childhood obesity prevention; Love et al.¹⁵ explored the effectiveness and equity of physical activity interventions; and Pflidder et al.¹⁶ compared rural versus urban/suburban contexts. These reviews highlight promising strategies but also reveal variability in effectiveness and a lack of integration between behavioral science frameworks and intervention design. This overview addresses this gap by explicitly linking behavioral determinants to theoretical frameworks, such as the theoretical domains framework (TDF) and the COM-B model, and by identifying effective Behavior Change Techniques (BCTs).

Behavioral determinants—such as motivation, social support, self-efficacy, and environmental factors—play a central role in shaping physical activity and dietary behaviors. These determinants can be systematically mapped to the domains of the TDF (e.g., Social Influences, Beliefs about Capabilities, Environmental Context and Resources)¹⁷ and to the components of the COM-B model (Capability, Opportunity, Motivation)¹⁸, which in turn guide the selection of relevant BCTs¹⁹, such as goal setting, social support, and self-monitoring. This structured linkage provides a practical, evidence-based approach for designing interventions that foster lasting behavior change²⁰.

In the field of nutrition, the theory of planned behavior (TPB)^{21–23}—which examines how attitudes, subjective norms, and perceived behavioral control predict intentions and behaviors—is frequently used to inform intervention strategies. The TPB and related theories, such as the theory of reasoned action, are incorporated into the integrative model of behavioral prediction, which aligns with several TDF domains, including social influences and beliefs about capabilities¹⁷. Similarly, self-determination theory²⁴—which emphasizes the importance of intrinsic motivation—maps onto TDF domains such as reinforcement and motivation. Social support from peers and teachers, another key determinant, is also represented within the TDF Social Influences domain and is operationalized through specific BCTs, such as modeling or facilitating social comparison^{18,25}.

Another key component to consider is the structural conditions within the school environment that support healthier behaviors—such as the built environment, regulatory measures, and the availability of affordable healthy food²⁶. When evaluating regulatory measures and their effectiveness, it is useful to distinguish, as traditionally noted by public administration scholars, between “the carrot, the stick, and the sermon”²⁷.

Despite acknowledging the importance of school-based interventions, the effectiveness of these programs varies widely. This may be due to differences in design, implementation, contextual factors, and the extent to which behavioral determinants, theory-based frameworks, and supportive structural changes are integrated^{28,29}. This article adopts a behavioral science approach^{17,18,30,31}, applying the COM-B model, the TDF, and BCT taxonomy to synthesize evidence from school-based interventions promoting physical activity and healthy eating.

This overview of systematic reviews aims to synthesize evidence on the effectiveness of school-based interventions for promoting physical activity and healthy eating in schoolchildren. Additionally, it explores the role of behavioral determinants in influencing the success of these interventions. By addressing identified gaps

in previous reviews and integrating behavioral science frameworks, this review provides valuable insights for policymakers, educators, and public health professionals in the implementation of strategies aimed at reducing the prevalence of childhood obesity and promoting healthier lifestyles in the school environment³².

Methods
Study design

This study is an overview of systematic reviews and adheres to the Cochrane Handbook for Systematic Reviews of Interventions³³ and the PRIOR (Preferred Reporting Items for Overviews of Reviews) statement³⁴. The PRIOR checklist is reported in Supplementary Material Appendix 1; and sex and gender equity in research (SAGER) guidance³⁵, in Supplementary Material Appendix 2.

Protocol and registration

The protocol for this overview was prospectively registered in PROSPERO (CRD42024587296) on September 16, 2024 (Supplementary Material Appendix 3). In writing and reporting this overview, we followed the Cochrane Handbook for Systematic Reviews of Interventions and the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) guidelines³⁶. The complete protocol can be downloaded from this link in PROSPERO³⁷.

Patient and public involvement

Patients and the public were not involved in the design or conduct of this study. Therefore, no ethical approval was required for this overview.

Eligibility criteria

The eligibility criteria were reported in detail in our protocol (Supplementary Material Appendix 3). The inclusion criteria for this overview were based on the population, intervention, comparison, outcome, and study type (PICOS) framework (Table 1). No restrictions on language or publication status were applied during study selection, ensuring the inclusion of all potentially relevant evidence regardless of the original language of publication.

We included reviews reporting outcomes related to physical activity, healthy eating behaviors, and anthropometric measures (BMI, BMI z-scores, nutritional status categories, waist circumference). Anthropometric measures were eligible whether they were synthesized at the review level (via meta-analysis or narrative synthesis) or reported within individual interventions included in the review, even when no aggregate synthesis was performed for these measures. This approach ensured the inclusion of relevant evidence on body composition and weight-related outcomes across a range of review designs and reporting formats.

All systematic reviews (SRs) were included, operationally defined as any secondary research that included only primary clinical studies, with an explicit search strategy in at least two databases^{33,39}.

Information sources

This overview employed a comprehensive search strategy across MEDLINE (via PubMed), the Cochrane Database of Systematic Reviews (CDSR), Epistemonikos, and PsycINFO. To ensure completeness, reference lists of included reviews were screened, and supplementary searches were conducted, including manual reference checks, citation searching (n=293), and additional records from websites (n=4) and organizations (n=1). All

Element	Inclusion and exclusion criteria
Population	<i>Included:</i> School-aged children up to 6 until 11 years old in school settings. If any study includes a broader age range but also contains the target population, it will be considered for the full-text review stage, and the results pertaining to the target group will be incorporated <i>Excluded:</i> Studies involving children aged 5 years or younger, older than 11 years, or those conducted outside school settings, including laboratory-based or highly controlled environments not representative of real-world school contexts
Intervention	<i>Included:</i> Only prevention-oriented interventions implemented in school settings that aim to promote physical activity and/or healthy eating. This may include single-component (e.g., only educational programmes) or multicomponent interventions (e.g., education combined with environmental or policy changes), such as educational programs, school health initiatives, and strategies applied in the classroom or school environment. The school food environment, as defined by FAO ³⁸ , includes spaces and circumstances within and around the school where students obtain, purchase, or consume food, along with the related information and food promotion. Interventions outside the school setting are excluded <i>Excluded:</i> Interventions outside the school setting, as well as treatment-oriented programs or clinical management of existing conditions (e.g., obesity treatment programs, pharmacological, or surgical interventions)
Comparator	As this is an overview of systematic reviews, a comparator or control group is not required for inclusion. However, considering our interest in the effectiveness of behavioral determinants, we included reviews reporting evidence from experimental studies that assess differences between intervention and control or comparator groups
Outcome	<i>Included:</i> Outcomes related to: (1) <i>Physical activity</i> (e.g., measured by accelerometers, self-reported activity). (2) <i>Healthy eating behavior</i> (e.g., surveys assessing changes in intake of fruits, vegetables, water, sugary beverages, and salt). (3) <i>Anthropometric measures</i> (BMI, BMI z-scores, and BMI percentile) adjusted for age, nutritional status categories (underweight, normal, overweight, obesity), waist circumference). These measures were included whether synthesized at the review level (meta-analysis or narrative synthesis) or reported within individual interventions included in the review, even if not aggregated at the review level <i>Excluded:</i> Studies not reporting specific outcomes related to changes in physical activity, dietary behaviors, or anthropometric measures in children
Study design	<i>Included:</i> Systematic reviews only*, with no language or publication status restrictions, with or without meta-analysis. Systematic reviews reporting evidence from randomized controlled trials (RCTs) alone or in combination with non-randomized or observational studies. When both designs were included, this distinction was recorded, and details were extracted when RCT results were reported separately <i>Excluded:</i> Studies that are not systematic reviews (for example: primary studies, commentary articles, and conferences) were excluded

Table 1. Eligibility criteria for elements of a comprehensive search strategy.

sources were critically evaluated, with search details documented for transparency, and search strategies are available in Supplementary Material Appendix 4.

Search strategy

The electronic search strategy (Supplementary Material Appendices 5 and 6) was conducted from database inception to September 30, 2024, with no restrictions. Additional searches included manual bibliography screening and outreach to authors and experts to identify further eligible studies. Eligibility criteria are detailed in Table 1.

Study selection process

After de-duplication using Rayyan™ software⁴⁰ and pilot testing, two independent reviewers (GD and AB) screened titles and abstracts, followed by full texts, in a blinded manner within Rayyan™. Prior to formal screening, the team conducted a calibration exercise on a random sample of 50 records to harmonize the application of eligibility criteria and establish consensus-based decision rules. Throughout the screening process, a senior reviewer (GF) performed periodic quality checks to ensure adherence to the protocol. Rayyan™ was used to manage the screening workflow, including importing references, automatic de-duplication, applying inclusion/exclusion labels, maintaining an audit trail of decisions, and flagging conflicts for resolution. Disagreements were resolved through discussion and, when necessary, adjudicated by the third reviewer (GF). Reasons for full-text exclusions were recorded in Rayyan™ and are reported in Supplementary Material Appendix 7.

At the title and abstract screening stage, 428 records were excluded because they did not meet one or more eligibility criteria (e.g., wrong population age group, not a school-based setting, non-prevention focus, or not a systematic review). In accordance with Cochrane guidance³³, detailed reasons are reported only for the 39 full-text articles that were assessed but excluded; these are listed in Supplementary Material Appendix 7.

The inter-rater reliability was assessed using Cohen's kappa coefficient⁴¹. Two independent reviewers evaluated the full texts (see Supplementary Material Appendix 8).

Data collection process

We developed a data extraction tool in Microsoft Excel to collect various study data recommended by Cochrane^{42,43}. The data extracted from the included systematic reviews were tested and calibrated within the team (Supplementary Material Appendix 9). For this purpose, one author initially created the spreadsheet and extracted data from a single systematic review. Subsequently, two authors (GD and AB) independently extracted data from three systematic reviews, and all authors provided feedback on whether the data elements were complete and the extracted data unambiguous.

During this calibration phase, inter-rater agreement between GD and AB was 92% across 135 extracted items, with discrepancies ($n = 11$) mainly related to the categorization of BCTs and intervention outcomes. These discrepancies were resolved through discussion, with one case requiring adjudication by a senior reviewer (GF).

Once consensus was reached, one author created a data extraction manual for the spreadsheet, which is available in Supplementary Material Appendix 10.

Data items

Data items included systematic review characteristics; PICOS criteria; and variables related to digital behavior change intervention (Table 2).

Quality appraisal of the included systematic reviews

We performed critical appraisals of systematic reviews using AMSTAR-2⁴⁴, as outlined in our protocol (Supplementary Material Appendix 3). AMSTAR-2 consists of 16 items that evaluate the thoroughness of various elements within the systematic reviews, such as the preparation process, literature search, study selection, data extraction, and analysis, as well as potential biases (e.g., risk of bias, publication bias, or funding sources). Based on the type and number of weaknesses identified (i.e., unmet items), the reviews were assigned a confidence rating: high, moderate, low, or critically low.

Two authors independently (GD and AB) assessed all systematic reviews using an Excel spreadsheet (version 10; Microsoft Inc.), reaching consensus through discussion (Supplementary Material Appendix 11).

Overlap in primary studies included in reviews

To ensure the accuracy of primary study outcome data and prevent double counting, we first evaluated whether the included systematic reviews shared overlapping primary studies. This assessment was conducted by creating a citation matrix and calculating the overall corrected covered area (CCA) using the GROOVE (Graphical Representation of Overlap for Overviews) tool⁴⁵. The GROOVE tool provides a method for interpreting the extent of overlap, where a CCA of 0–5% indicates a slight overlap, 6–10% a moderate overlap, 11–15% a high overlap, and greater than 15% a very high overlap in primary studies cited in multiple systematic reviews.

Data synthesis methods

The findings of the included systematic reviews were synthesized narratively and organized into summary tables describing their characteristics, methodological quality, and key outcomes. Data were extracted using a standardized template (Supplementary Material Appendix 9) and structured around core categories: type of intervention and mode of delivery; who provided the intervention and how; where, when, and how much; review period; number and design of included studies; population and sample size; outcomes of interest; intervention effectiveness; effectiveness of BCTs or components; and most frequently used BCTs.

Category	Data items
Bibliographic information	Author and year
	Year of publication
	Title
	Aim of the systematic review
Population characteristics	Participants (total number of participants included)
	Population age
	Specific populations (e.g., children from low socioeconomic backgrounds, gender-specific groups, or adolescents beyond the primary age group)
Study characteristics	Total number of studies included in the review
	Number of randomized controlled trials included
	Type of studies (only RCTs, only non-RCTs, both RCTs and non-RCTs)
	Year of the most recent study included
	Period/date range of the literature search
	Country or geographic location of the studies
Intervention details	<i>Target population</i> group targeted (e.g., schoolchildren aged 6–11)
	<i>Target behavior</i> behaviors addressed (e.g., PA, dietary habits, sugary drinks)
	<i>Theoretical framework</i> whether a theory/model was reported (e.g., SCT, SDT)
	<i>Behavioral outcomes</i> PA levels (MVPA, steps), dietary behaviors (fruit/vegetable consumption, sugary drinks), adherence to healthy behaviors
	<i>Cognitive outcomes</i> self-efficacy, knowledge, attitudes
	<i>Biological outcomes</i> BMI, BMI z-scores, waist circumference, physical fitness
Intervention acceptability and feasibility	Acceptability (engagement, satisfaction)
	Practicability (feasibility in school settings)
	Effectiveness (achievement of objectives)
	Affordability (cost and resources)
	Spill-over effects (unintended outcomes)
	Equity (impact on vulnerable or underserved populations)
Technology delivered	Use of digital technology (mobile devices, computers, wearables, environmental digital objects)
Mode of delivery—digital content type	Websites, apps, video/audio materials, text messages, gamified platforms, virtual environments, AI-based tools (if applicable)
Other characteristics	Number of primary studies included and overlap
	Tools used to assess risk of bias in primary studies
	Whether a meta-analysis was conducted
	Certainty of evidence (GRADE)

Table 2. Data items in this overview of systematic reviews.

Whenever possible, interventions were coded using the Behavior Change Technique Taxonomy version 1 (BCTTv1) and the theoretical domains framework (TDF)^{17,46}. The extraction of BCTs was primarily based on those explicitly reported by the original review authors. In cases where BCTs were not identified in the included reviews, a trained researcher with expertise in BCT coding independently coded the intervention descriptions using the BCT Taxonomy v1 framework^{19,47}. This approach allowed for consistent identification and classification of behavior change mechanisms across studies. Where coding was not feasible due to insufficient detail, the original descriptions provided by the authors were retained.

Outcomes were grouped into three primary domains: (1) behavioral outcomes, including physical activity levels, sedentary time, dietary habits (e.g., fruit/vegetable intake, water consumption), and adherence to healthy routines (e.g., active commuting); (2) cognitive outcomes, such as knowledge, self-efficacy, and attitudes toward healthy behaviors; and (3) biological outcomes, such as BMI or zBMI, waist circumference, nutritional status, and physical fitness.

To assess the effectiveness of BCTs, we developed a matrix mapping the presence and strength of each BCT across outcome types and reviews. A five-level coding system was applied: “▼” for strong evidence of a negative effect, “O” for mixed or null evidence, “O–” and “O+” for limited evidence of a negative or positive effect, respectively, and “▲” for strong evidence of a positive effect. This classification, adapted from Michie et al. approach of Michie et al.^{46,48}, allowed us to compare intervention components across heterogeneous reviews and outcomes.

AMSTAR-2 was used to assess methodological quality, and meta-analysis or GRADE results were recorded when available. Sex and gender were analyzed using the SAGER Guidelines³⁵, to determine whether sex-disaggregated data were reported and whether interventions considered gender-related differences in outcomes or implementation. These guidelines helped ensure a rigorous and equitable analysis of how interventions may differentially impact boys and girls (Supplementary Materials Appendix 12).

Finally, where possible, cross-review comparisons were made to identify converging patterns in effective components (e.g., use of self-monitoring, goal setting, or environmental restructuring) and to examine consistency of effects across settings, populations, and delivery modes.

Results

From a total of 483 identified records, 45 full-text articles were assessed for eligibility. Of these, 39 were excluded, leading to the inclusion of 6 systematic reviews in this overview^{49–54} (Fig. 1). The inter-rater reliability for full-text screening was robust (Kappa = 0.89). Additional studies were identified through supplementary methods, including website searches, and citation searching, ensuring a comprehensive review (Supplementary Material Appendix 4).

Characteristics of systematic reviews

A total of six systematic reviews published between 2018 and 2024 were included. The number of primary studies per review ranged from 13 to 172, covering 230,915 participants combined. The included studies were published between 2004 and 2023 and were conducted mostly in high-income countries such as the United States, United Kingdom, Australia, Canada, and several European nations, based on the World Bank classifications⁵⁵ (Supplementary Material Appendix 13).

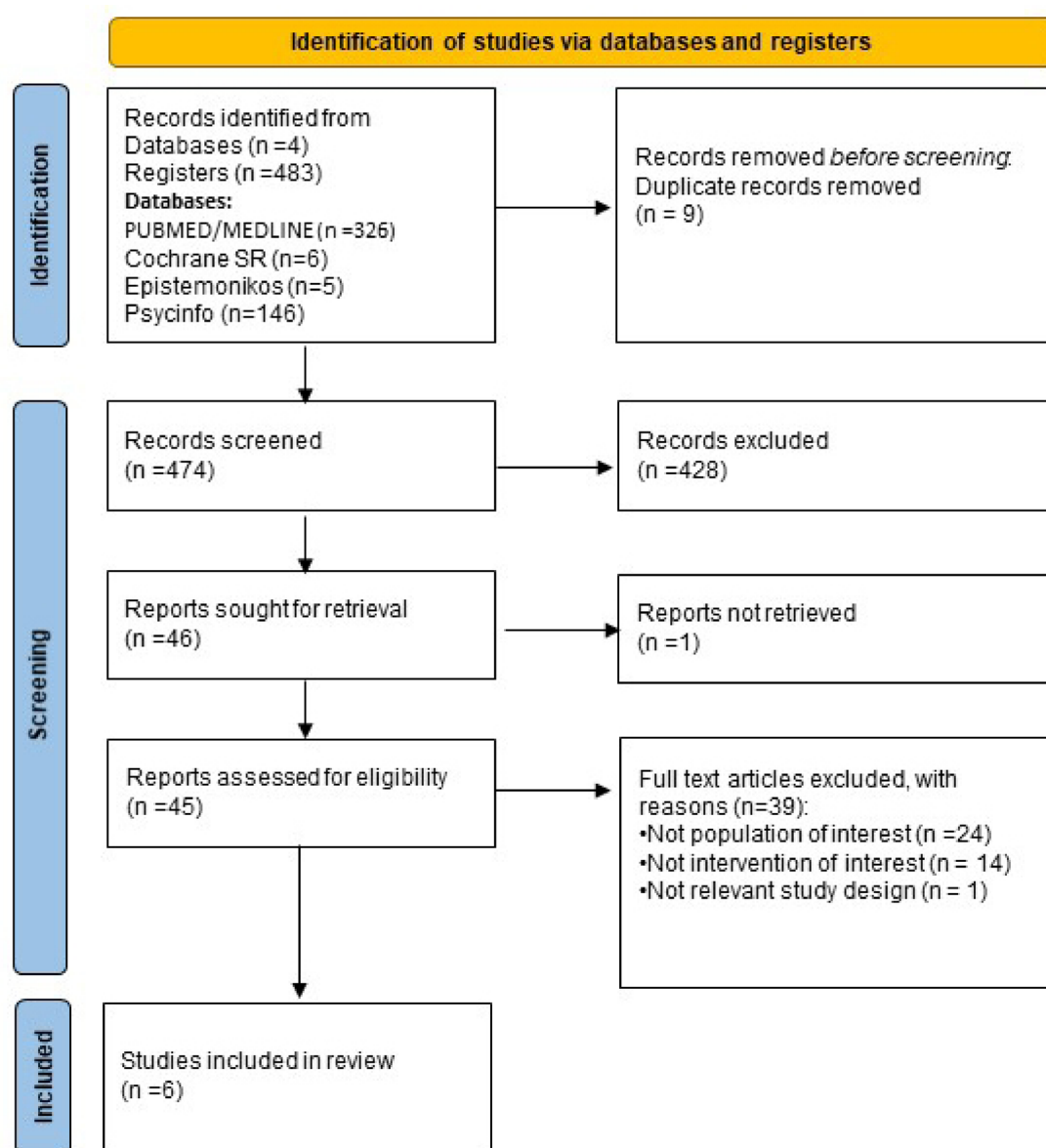


Fig. 1. Flow diagram of study selection based on PRIOR (preferred reporting items for overviews of reviews) guideline. PRISMA 2020 flow diagram from enhancing physical activity and healthy eating in schools: an overview of systematic reviews on behavioral determinants in children aged 11 and under

All reviews included randomized controlled trials (RCTs), with five also incorporating non-randomized or observational studies. One review⁵⁴ included only RCTs. All six reviews included children under 11 years of age, although some also included adolescents. The interventions were implemented primarily in school or school-related settings (e.g., after-school programs, active school transport initiatives). All data are reported, and the detailed characteristics of the individual systematic reviews are presented in Supplementary Material Appendices 13 and 14. The synthesis of study characteristics across all six systematic reviews is shown in Table 3. Additionally, to provide a quick reference, Table 4 presents a condensed summary of each included review, focusing on the author, population, intervention, number of studies, study designs, and main findings.

Characteristics of the interventions

Scope and focus of interventions

The characteristics of interventions reviewed consistently underscore schools as critical environments for promoting physical activity and healthy eating behaviors among children. Four reviews specifically addressed physical activity promotion^{50,51,53,54}, while five reviews targeted combined interventions incorporating both physical activity and healthy eating^{49,51–54} as detailed in Table 3. Comprehensive interventions addressing both behaviors generally showed greater effectiveness compared to interventions targeting single domains alone.

Structural and environmental modifications

Structural and environmental changes emerged as integral to effective intervention strategies. Five reviews emphasized specific environmental modifications, such as upgrading playground facilities, improving walking

Characteristics	Results (n = 6 SRs)	Details and sources
Systematic review design		
Number of studies included	301 (total)	Ranged from 13 ⁵¹ to 172 ⁵⁴
Participants (total number)	230,915	Spiga et al. ⁵⁴ alone included 189,707 participants
Range year of the study included	(2004–2023)	Based on search periods reported
Place (country-geographic location)	Mostly high-income countries	UK, USA, Australia ^{50,52,54}
Only RCT	1/6	Spiga et al. ⁵⁴
RCT and non RCT	5/6	Allcott-Watson et al. ⁴⁹ , Casado-Robles et al. ⁵⁰ , Dai ⁵¹ , Klein et al. ⁵² and Larouche et al. ⁵³
Number RCT	213/301	Most from Klein et al. ⁵² , Larouche et al. ⁵³ and Spiga et al. ⁵⁴
Target population		
Included children under 11 years	6/6	All reviews included this age group; some extended to adolescents up to 19 years
Reported sex/gender differences	5/6	Allcott-Watson et al. ⁴⁹ , Casado-Robles et al. ⁵⁰ , Dai ⁵¹ , Klein et al. ⁵² and Spiga et al. ⁵⁴
Intervention type		
Physical activity promotion	3/6	Casado-Robles et al. ⁵⁰ , Dai ⁵¹ and Larouche et al. ⁵³
Only healthy eating education	0/6	None reported
Combined interventions (PA + nutrition)	3/6	Allcott-Watson et al. ⁴⁹ , Klein et al. ⁵² and Spiga et al. ⁵⁴
Intervention settings	6/6	All reviews focused on schools or related settings (community/home)
Structural/environmental changes	5/6	Allcott-Watson et al. ⁴⁹ , Casado-Robles et al. ⁵⁰ , Klein et al. ⁵² , Larouche et al. ⁵³ and Spiga et al. ⁵⁴
Explicit theoretical framework	5/6	Social cognitive theory, self-determination theory, etc., though inconsistently applied
BCT described via BCTTv1 or TDF	1/6	Allcott-Watson et al. ⁴⁹
Technology-delivered interventions	2/6	Casado-Robles et al. ⁵⁰ and Spiga et al. ⁵⁴
Behavioral outcomes		
Increased physical activity	6/6	All reviews reported improvements (e.g., MVPA, steps, active transport)
Improved dietary habits	5/6	Allcott-Watson et al. ⁴⁹ , Casado-Robles et al. ⁵⁰ , Dai ⁵¹ , Klein et al. ⁵² and Spiga et al. ⁵⁴
Adherence to healthy behaviors	5/6	Reported inconsistently
Cognitive outcomes		
Improved self-efficacy	3/6	Allcott-Watson et al. ⁴⁹ , Dai ⁵¹ and Klein et al. ⁵²
Increased knowledge	3/6	Dai ⁵¹ , Klein et al. ⁵² and Spiga et al. ⁵⁴
Positive attitudes toward healthy behaviors	3/6	Reported qualitatively; not always with validated scales
Biological outcomes		
BMI or zBMI reduction	6/6	Most consistent indicator; strongest in Spiga et al. ⁵⁴
Waist circumference, body composition, fitness	4/6	Dai ⁵¹ , Klein et al. ⁵² , Larouche et al. ⁵³ and Spiga et al. ⁵⁴
Other biomarkers (cholesterol, glucose)	2/6	Klein et al. ⁵² and Spiga et al. ⁵⁴
Meta-analysis and certainty of evidence		
Meta-analysis	2/6	Casado-Robles et al. ⁵⁰ and Spiga et al. ⁵⁴
Certainty of evidence (GRADE)	2/6	Reported in Casado-Robles et al. ⁵⁰ and Spiga et al. ⁵⁴

Table 3. Main characteristics of systematic reviews (SRs). Results are presented as n/N, where n is the number of systematic reviews reporting the characteristic and N is the total number of reviews included (N = 6).

Author and review type	Population and setting	Intervention	N studies included	Study designs	Main effectiveness findings
Allcott-Watson et al. ⁴⁹ (Systematic review)	Adolescents 10–19 years; schools and community	School/community multicomponent (PA + HE)	14	Mostly RCTs	Promising for behavior maintenance; mixed short-term effects
Casado-Robles et al. ⁵⁰ (Systematic review and meta-analysis)	Children and adolescents (5–18 years); school/home/community	Wearable trackers + counseling	45	RCTs, quasi-experimental	Moderate favorable effects on steps/MVPA; stronger in females
Dai ⁵¹ (Systematic review)	Disadvantaged students (5–19 years); schools	PA school-based	13	RCTs, quasi-experimental	Moderate PA effects; stronger if culturally tailored/parental involvement
Klein et al. ⁵² (Systematic review)	Children & adolescents (6–18 years); schools	Obesity prevention (PA + HE + behavior)	27	RCTs, quasi-experimental, and observational studies	Significant BMI/waist reduction with combined PA + HE
Larouche et al. ⁵³ (Systematic review)	Children & adolescents (6–18 years); schools/neighborhoods	Active school transport (SRTS, WSB)	30	RCTs, quasi-experimental, and observational studies	Limited improvements; multi-level & long-term more promising
Spiga et al. ⁵⁴ (Systematic review and meta-analysis)	Children (5–11 years); schools and community	Obesity prevention (diet, PA, both)	172	RCTs only	Small BMI/zBMI reductions; strongest in combined diet + PA

Table 4. Overview of included systematic reviews.

and cycling infrastructure, cafeteria enhancements, and the introduction of school gardens^{49,51–54}. These structural approaches were consistently linked to positive behavioral outcomes and were usually implemented as part of broader multi-component interventions. They contributed to increased availability of, and access to, spaces for physical activity and healthy food options.

Duration and frequency of activities

Duration and frequency of intervention activities were identified as critical determinants of effectiveness. While intervention periods varied significantly from 6 weeks to 2 years, interventions exceeding 6 months with extended follow-up periods of at least 12 months generally demonstrated greater success in establishing sustained healthy behaviors^{49,52,54}. Effective interventions also employed regular engagement strategies, with activities occurring daily or weekly.

Use of theory

Explicit theoretical grounding was noted in three reviews, which referenced the use of Social Cognitive Theory and Self-Determination Theory^{49,52,54}. Only one study reported the use of specific BCTs, such as goal setting, self-monitoring, and feedback⁴⁹.

The inclusion of technological components was relatively limited but demonstrated moderate effectiveness. Specifically, two reviews evaluating wearable activity trackers and mobile feedback systems highlighted their potential utility in increasing children's physical activity levels^{50,54}.

Technological components

In summary, interventions combining physical activity and healthy eating, supported by structural modifications, sustained durations, and regular participant engagement, consistently yielded significant positive outcomes. These findings, explicitly detailed in Table 5, emphasize the necessity for comprehensive, theoretically-informed, and strategically integrated interventions within educational settings (Table 5 and Supplementary Material Appendices 13 and 14).

Effectiveness of interventions

Effectiveness according to behavior change techniques (BCTs)

The most frequently reported BCTs identified in the included systematic reviews were goal setting (BCT 1.1), self-monitoring of behavior (BCT 2.3), and restructuring the physical environment (BCT 12.1). These techniques demonstrated robust evidence regarding their effectiveness in improving both physical activity levels and healthy eating behaviors. For instance, Klein et al.⁵² highlighted that interventions combining physical activity and nutritional components significantly improved body mass index (BMI), waist circumference, and body fat percentage. In this context, BCTs such as goal setting and self-monitoring were explicitly identified as effective components supporting adherence to healthy behaviors among school-aged children (see Tables 5 and 6).

The use of feedback on behavior (BCT 2.2) showed moderate yet consistent effects, particularly when provided through digital devices such as wearable trackers or mobile apps. Casado-Robles et al.⁵⁰, through their systematic review and meta-analysis, found that wearable device-based interventions significantly increased daily physical activity (mean increase of 1692 steps/day; $p < 0.001$; $d = 0.220$ for moderate-to-vigorous physical activity), along with modest reductions in sedentary time ($d = 0.172$; $p = 0.011$). These effects appeared particularly beneficial among less active adolescents and female participants, who typically exhibit lower baseline activity levels (see Tables 5 and 6).

Regarding the technique information about health consequences (BCT 5.1), findings were mixed. However, this BCT was notably effective for sustaining long-term behavior change. Allcott-Watson et al.⁴⁹ specifically identified this technique as promising, especially for maintaining healthy dietary behaviors beyond the intervention period. Complementary techniques such as problem-solving (BCT 1.2) and action planning (BCT

Reference and review type	Type of intervention and mode of delivery	Who provided, how	Where, when, and how much	Review period	N primary studies and study designs	Population and sample size	Outcomes of interest	Intervention effectiveness	Effectiveness of BCTs or components	Most frequently used BCTs and components	Statistical significance and effect size (p value, Cohens' d , r)	Certainty of evidence reported	AMSTAR 2 rating
Allcott-Watson et al. ⁴⁹ (Systematic review)	School- and community-based interventions delivered via workshops, group activities, and environmental changes	Researchers and school staff, peer mentors	School settings, community spaces; duration varied across studies (3 months to 2 years)	Up to 2021	14 studies (7 PA, 3 HE, 4 PA + HE; mostly RCTs)	13,243 participants aged 10–19 years, 47% female	PA: MVPA levels, sedentary behavior HE: Dietary quality, fruit/veg consumption	Promising outcomes for behavior maintenance post-intervention. Mixed evidence for immediate behavior change	PA: Promising BCTs for maintenance: 5.1 Information on health consequences, 3.2 Social support (practical) HE: Promising BCTs for maintenance: 1.2 Problem-solving, 1.4 Action planning, 2.3 Self-monitoring of behavior, 5.1 Information on health consequences	PA: 1.1 Goal setting, 1.2 Problem solving, 3.1 Social support (unspecified) HE: 4.1 Instruction, 5.1 Health consequences, 8.1 Behavioral rehearsal	Some studies reported small to moderate improvements ($p < 0.05$, Cohens' $d = 0.2-0.5$). No meta-analysis	Not reported	Critically low
Casado-Robles et al. ⁵⁰ (Systematic review and meta-analysis)	Programs incorporating consumer-wearable activity trackers for PA promotion and SB reduction. Delivered with goal-setting, counseling, reminders, motivational strategies, and exercise routines	Researchers or trained facilitators, with support from schools and communities. Delivery varied by study, including in-person workshops and tracker-provided feedback	Conducted across schools, homes, and community settings. Duration: Minimum 3 weeks (Mean: 11.78 weeks)	Up to December 2020	44 publications (45 studies): including RCTs, quasi-experimental designs, and pre-experimental trials	5620 participants (mean age: 12.85 ± 2.84 years, range 5–18). Studies included boys and girls; 32 studies had mixed-gender groups, 8 only girls, 5 only boys	Daily total steps MVPA levels Total PA SB	Moderate favorable effects on daily total steps and MVPA. Limited for total PA and SB. Greater effect observed in females and less active participants	Goal-setting, educational counseling, reminders, motivational strategies, and wrist-worn trackers showed the highest impact	1.1 Goal setting (behavior) 2.3 Self-monitoring of behavior 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behavior 12.1 Restructuring the physical environment	Steps/day: Mean Difference (MD) = +1692.79 (95% CI 1322.52–2063.06), $p < 0.001$ MVPA: $d = 0.220$ (95% CI 0.134–0.307), $p < 0.001$ Sedentary behavior: $d = 0.172$, $p = 0.011$	Low to moderate	Critically low
Continued													

Reference and review type	Type of intervention and mode of delivery	Who provided, how	Where, when, and how much	Review period	N primary studies and study designs	Population and sample size	Outcomes of interest	Intervention effectiveness	Effectiveness of BCIs or components	Most frequently used BCIs and components	Statistical significance and effect size (p value, Cohens' d , r)	Certainty of evidence reported	AMSTAR 2 rating
Dai ⁵¹ (Systematic review)	School-based physical activity programs for disadvantaged students	Teachers, program-specific staff. Delivered in-school and after-school	Conducted across schools in disadvantaged socio-economic settings. Average duration of interventions ranged from 6 weeks to 2 years depending on the study	2011–2017	13 studies (RCTs, quasi-experimental)	Total: ~ 5000 students; majority were low-income, urban, ethnically diverse children, aged 5–19 years	Increased physical activity levels, changes in MVPA (moderate-to-vigorous physical activity)	Moderate effects on PA, with higher effectiveness for programs involving culturally tailored activities and parental involvement	Culturally tailored activities, parent involvement, student-led decision-making, behavior modification components like goal-setting	1.1 Goal setting (behavior) 3.1 Social support (unspecified) 5.1 Information about health consequences	Several studies showed statistically significant improvements in MVPA and self-efficacy ($p < 0.05$). No effect sizes reported	Not reported	Critically low
Continued													
Klein et al. ⁵² (Systematic review)	School-based interventions focused on pediatric obesity prevention and management. Interventions included physical activity, nutritional changes, and behavioral strategies	Teachers, health educators, or external facilitators provided interventions. Involvement of community and family components was noted in some cases	Conducted in schools, with interventions lasting from 9 weeks to 3 years. Sessions ranged from 30 to 90 min. Follow-ups varied from immediate to 3 years post-intervention	January 2018–December 2022	27 studies (mixed designs: RCTs, cluster RCTs, quasi-experimental, and observational studies)	Total: 28,774 participants (aged 6–18 years)	BMI, body fat percentage, waist circumference Physical activity and nutritional behaviors Psychosocial factors, including motivation and self-efficacy	Significant improvements in BMI and waist circumference when physical activity and nutritional changes were combined. Positive but non-significant effects for isolated physical activity or behavioral change interventions	Goal setting, self-monitoring, social support, and environmental modifications were identified as effective components	1.1 Goal Setting (Behavior) 2.3 Self-monitoring of behavior 3.1 Social support (unspecified) 4.1 Instruction on how to perform the behavior	Significant reductions in zBMI, BMI, and body fat percentage ($p < 0.05$); no meta-analysis or effect size reported	Not reported	Critically low
Continued													

Reference and review type	Type of intervention and mode of delivery	Who provided, how	Where, when, and how much	Review period	N primary studies and study designs	Population and sample size	Outcomes of interest	Intervention effectiveness	Effectiveness of BCTs or components	Most frequently used BCTs and components	Statistical significance and effect size (p value, Cohen's d , r)	Certainty of evidence reported	AMSTAR 2 rating
Larouche et al. ⁵³ (Systematic review)	Active school transport (AST) interventions. Delivered via educational programs, safe routes to school (SRTS), walking school buses (WSB), and environmental changes	Programs were provided by school staff, community organizations, or policymakers. Delivery methods varied widely, including workshops, supervised walking routes, and infrastructure modifications	Conducted in schools, neighborhoods, and urban areas. Duration ranged from 1 day to 3 years	Feb 1, 2010–Oct 15, 2016	27 papers reporting 30 interventions. Mixed designs including RCTs, quasi-experimental, and observational studies	School-aged children and adolescents (6–18 years). Sample sizes ranged from small groups to over 13,000 participants	AST behaviors, mode of school transport, physical activity levels, parental attitudes, and environmental impacts	Limited improvements in AST behaviors with most interventions reporting “trivial” to small effect sizes. Multi-level and long-term interventions showed more promising results	Interventions incorporating education, encouragement, and environmental modifications were more effective	Education: 4.1 Instruction on behavior. Encouragement: 1.1 Goal-setting and 2.3 Self-monitoring. Infrastructure: 12.1 Restructuring the environment	13 out of 30 interventions showed significant effects; Cohen's d ranged from -0.61 to 0.75 (mostly trivial to small effects)	Low to moderate	Critically low
Spiga et al. ⁵⁴ (Systematic review and meta-analysis)	Interventions to prevent obesity through dietary changes, physical activity, or both. Delivered in schools, homes, and communities	Teachers, parents, health professionals, community leaders; methods varied across settings	Conducted in schools, homes, and community centers; duration ranged from one day to four years	Up to February 2023	172 studies (RCTs only)	189,707 children aged 5–11 years, with a mix of socioeconomic backgrounds and geographical locations	Body mass index (BMI), zBMI, percentiles of BMI, dietary intake, physical activity levels, sedentary behavior, adverse events	Small reductions in BMI for combined dietary and physical activity interventions. Activity-focused interventions showed slight BMI reductions in the medium term; dietary-only showed minimal effects	Goal-setting, feedback on behavior, restructuring physical environments, and credible social support, source information showed varied effectiveness	1.1 Goal setting (behavior), 2.3 Self-monitoring of behavior, 12.1 Restructuring physical environment, 3.1 Social support (practical), 5.1 Information on health consequences	zBMI: MD = -0.05 (95% CI -0.09 to -0.02), $p < 0.05$; $n = 20,998$. Effect size considered small	Moderate	High

Table 5. Summary of Included systematic reviews: interventions, delivery characteristics, outcomes, and effectiveness of behavior change techniques (BCTs). This table summarizes the key characteristics and findings from six systematic reviews evaluating school- and community-based interventions for improving health behaviors among children and adolescents. Interventions targeted physical activity (PA), healthy eating (HE), and related outcomes such as moderate-to-vigorous physical activity (MVPA), sedentary behavior (SB), and body mass index (BMI), including standardized zBMI). The coding of behavior change techniques (BCTs) follows the Behavior Change Technique Taxonomy v1 (BCTTv1). AST refers to active school transport programs, including strategies such as Safe Routes to School (SRTS) and Walking School Buses (WSB). RCTs are randomized controlled trials. “Intervention Effectiveness” reflects authors’ overall conclusions, while “Statistical Significance and Effect Size” reports quantitative outcomes (e.g., p values, Cohen's d) when available. “Certainty of Evidence” and “AMSTAR 2 Rating” indicate the methodological quality and trustworthiness of the included reviews.

1.4) were also reported to be effective in promoting medium- and long-term dietary behavior changes, notably improving the consumption of fruits and vegetables (see Tables 5 and 6).

Behavioral outcomes

All six systematic reviews reported improvements in physical activity and dietary behaviors. There were consistent increases in moderate-to-vigorous physical activity (MVPA), daily step counts, and reductions in sedentary time. Dai⁵¹ reported that culturally tailored interventions involving family participation significantly improved MVPA among children from disadvantaged settings. Spiga et al.⁵⁴ demonstrated small yet statistically significant BMI z-score reductions (-0.05 ; 95% CI -0.09 to -0.02 ; $p < 0.05$), emphasizing the combined effectiveness of dietary and physical activity interventions compared to diet-only approaches (see Tables 5 and 6).

Adherence to healthy behaviors, such as increased water consumption and healthier snack choices, was notably higher in interventions explicitly using the aforementioned BCTs (e.g., Klein et al.⁵²; Larouche et al.⁵³; see Table 5).

Cognitive outcomes

Four systematic reviews^{50–52,54} reported improvements in self-efficacy, frequently associated with educational and motivational components, such as goal-setting, counseling sessions, and personalized feedback. Three reviews^{51,52,54} documented significant increases in knowledge about healthy eating and positive shifts in attitudes toward physical activity. However, these outcomes were often assessed through self-report measures, somewhat limiting the certainty of these results (see Tables 5 and 6).

Biological outcomes

All systematic reviews reported biological measures such as BMI, zBMI, waist circumference, and physical fitness levels. The strongest evidence was provided by Spiga et al.⁵⁴, which reported moderate-certainty evidence for BMI reductions at medium-term follow-up, clinically relevant for childhood obesity prevention (mean difference zBMI: -0.05 ; 95% CI -0.09 to -0.02 ; $p < 0.05$; see Tables 5 and 6).

Additional clinical biomarkers such as blood glucose or cholesterol levels were rarely reported. Klein et al.⁵² was one of the few reviews mentioning these biomarkers, although not systematically analyzed (see Table 5).

Sex and gender equity in research (SAGER) application

The application of the sex and gender equity in research (SAGER) guidelines revealed that most of the reviewed studies included sex- or gender-disaggregated data, although in some cases, this information was limited. In general, significant differences between boys and girls were observed, with boys typically exhibiting higher levels of physical activity, while girls demonstrated greater adherence to dietary interventions. One study, Dai⁵¹, specifically reported that girls had lower baseline physical activity levels but showed greater improvements post-intervention. Nevertheless, the absence of explicit gender-specific analyses in some studies restricts the depth of conclusions related to equity (Supplementary Material Appendices 15 and 16).

Quality appraisal of the included systematic reviews

Overall, confidence in the results of the systematic reviews was high in 17% (1/6) of the reviews, moderate in 0%, low in 0%, and critically low in 83% (5/6). The most frequent methodological weaknesses identified were lack of a complete list of excluded studies (5/6 reviews, 83%^{49–53}), no reporting of funding sources for primary studies (5/6 reviews, 83%; same five as above), and absence of a registered or published review protocol (2/6 reviews, 33%^{51,52}).

By contrast, the Cochrane review by Spiga et al.⁵⁴ was rated as high quality, fulfilling all AMSTAR-2 critical domains (see Table 7; For full details, see Supplementary Material Appendix 17).

Overlap in primary studies included in reviews

The overlap assessment revealed that most primary studies were cited only once across the systematic reviews. Overall, there was a minimal overlap in the 293 primary studies included in the 6 systematic reviews, with a Corrected Covered Area (CCA) of 0.82. Comparisons between pairs of systematic reviews indicated that 93% (14 out of 15) had a low overlap ($< 5\%$), 6% (1 out of 15) had a moderate overlap (5% to $< 10\%$), and none of the comparisons showed high (10% to $< 15\%$) or very high ($\geq 15\%$) overlap. These findings are illustrated in Fig. 2 and detailed in Supplementary Material Appendices 18 and 19.

Discussion

Principal results

This overview of systematic reviews synthesized evidence from six comprehensive reviews evaluating the effectiveness of school-based interventions aimed at promoting physical activity and healthy eating. The findings confirm that BCTs—such as goal setting (1.1), self-monitoring of behavior (2.3), and restructuring the physical environment (12.1), including spaces for healthier food consumption—consistently show strong evidence of effectiveness in improving PA levels and dietary behaviors in school settings. Framed within the COM-B model¹⁸, these BCTs influence behavior by enhancing capability (e.g., self-monitoring increases self-awareness and goal-directed behavior), opportunity (e.g., environmental restructuring provides supportive contexts for behavior), and motivation (e.g., goal setting promotes clear intentions and intrinsic motivation).

Additionally, techniques such as feedback on behavior (2.2) and information about health consequences (5.1) exhibited moderate effectiveness, particularly through digital platforms, likely due to their capacity to deliver timely, personalized feedback that enhances reflective motivation. Importantly, social support techniques, including unspecified (3.1), practical (3.2), emotional (3.3) support, social reward (10.4), and social incentives

	Author	AMSTAR-2 Rating	1.1 Goal setting (behavior)	1.2 Problem solving	1.4 Action planning	2.2 Feedback on behavior	2.3 Self-monitoring of behavior	3.1 Social support (unspecified)	3.2 Social support (practical)	4.1 Instruction on how to perform the behavior	5.1 Information about health consequences	7.1 Prompts/Cues	8.1 Behavioral practice/rehearsal	9.1 Credible source	10.4 Social reward	10.5 Self-Incentive	12.1 Restructuring the physical environment
Overall effect			▲	O+	O+	▲	▲	▲	▲	▲	▲	▲	O+	▲	O+	O+	▲
Behavioral outcomes																	
Physical activity (↑ MVPA)	Casado-Robles et al. ⁵⁰	●	▲			▲	▲	O		▲	O	▲			O	O	▲
	Dai ⁵¹	●	▲			O+	O+	▲		▲	O+	O		O	O	O	O+
	Larouche et al. ⁵³	●	O+			O+	▲	O		▲	O	▲			O	O	▲
	Spiga et al. ⁵⁴	●	▲			▲	▲		▲	▲	▲	▲		▲			▲
Sedentary behavior (↓)	Casado-Robles et al. ⁵⁰	●	O			O+	▲			O	O	O		O	O	O	O+
	Allcott-Watson et al. ⁴⁹	●	▲	▲		▲	▲	O	▲	▲	▲	▲	▲	▲	O+	O+	▲
Healthy eating (↑ Diet quality)	Klein et al. ⁵²	●	▲	O+	O+	O+	▲	▲		▲	▲	O	O		O+	O+	▲
Cognitive outcomes																	
Knowledge (↑)	Klein et al. ⁵²	●	▲	O+		▲	▲	▲		▲	▲	▲			O	O	▲
	Allcott-Watson et al. ⁴⁹	●	O+	O+		O+	O+	O	▲	O+	▲	O	▲	O+	O+	O+	O+
Attitudes (↑)	Spiga et al. ⁵⁴	●	▲			▲	▲			▲	▲	O		▲	O	O	▲
Biological outcomes																	
BMI/zBMI (↓)	Spiga et al. ⁵⁴	●	▲			▲	▲		▲	▲	▲	O		▲	O	O	▲
	Klein et al. ⁵²	●	▲	O+		O+	▲	O+		▲	▲	O+	O		O+	O+	▲

Table 6. Summary of the effectiveness of behavior change techniques in interventions for enhancing physical activity and healthy eating in schools. ↑ indicates improvement (increase) in physical activity, dietary quality, knowledge, or positive health-related attitudes; ↓ indicates reduction in sedentary behaviors or biological indicators such as body mass index (BMI). Abbreviations: AMSTAR-2 (A Measurement Tool to Assess Systematic Reviews), BCT (Behavior Change Techniques), MVPA (Moderate-to-Vigorous Physical Activity), BMI (Body Mass Index), zBMI (BMI standardized by age and sex; z-score), PA (Physical Activity), SB (Sedentary Behavior), HE (Healthy Eating). AMSTAR-2 quality ratings are indicated by colored circles as follows: ● = High, ● = Moderate, ● = Low, ● = Critical low. Classification of effectiveness from current systematic reviews and meta-analyses: ▲ = Positive effect of BCT based on good evidence such as subgroup or regression analyses, O+ = Positive effect of BCT based on low evidence such as frequency of individual BCTs within effective interventions, O = Mixed evidence or no effect, O- = Negative effect of BCT based on low level of evidence such as frequency of individual BCTs within effective interventions, ▼ = Negative effect of BCT based on good evidence such as subgroup or regression analyses.

Author-year/criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Rating overall confidence in the results of the review
Allcott-Watson et al. ⁴⁹	YES	YES	YES	YES	PARTIAL YES	YES	NO	YES	YES	NO	NO META-ANALYSIS	NO META-ANALYSIS	PARTIAL YES	YES	NO	YES	Critically low
Casado-Robles et al. ⁵⁰	YES	YES	YES	YES	YES	YES	NO	YES	YES	NO	NO META-ANALYSIS	NO META-ANALYSIS	YES	YES	NO	YES	Critically low
Dal ⁵¹	YES	NO	PARTIAL YES	YES	NO	NO	NO	YES	NO	NO	NO META-ANALYSIS	NO META-ANALYSIS	NO	PARTIAL YES	NO	YES	Critically low
Klein et al. ⁵²	YES	NO	YES	YES	PARTIAL YES	PARTIAL YES	NO	YES	PARTIAL YES	NO	NO META-ANALYSIS	NO META-ANALYSIS	NO	YES	NO	YES	Critically low
Larouche et al. ⁵³	YES	YES	YES	YES	YES	PARTIAL YES	NO	YES	YES	NO	NO META-ANALYSIS	NO META-ANALYSIS	YES	YES	NO	YES	Critically low
Spiga et al. ⁵⁴	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	High
Rating overall confidence in the results of the review	High		No or one non-critical weakness: the systematic review provides an accurate and comprehensive summary of the results of the available studies that address the question of interest														
	Moderate		More than one non-critical weakness*: the systematic review has more than one weakness but no critical flaws. It may provide an accurate summary of the results of the available studies that were included in the review														
	Low		One critical flaw with or without non-critical weaknesses: the review has a critical flaw and may not provide an accurate and comprehensive summary of the available studies that address the question of interest														
	Critically low		More than one critical flaw with or without non-critical weaknesses: the review has more than one critical flaw and should not be relied on to provide an accurate and comprehensive summary of the available studies														
			*Multiple non-critical weaknesses may diminish confidence in the review and it may be appropriate to move the overall appraisal down from moderate to low confidence														

Table 7. Critical assessment outcomes based on the AMSTAR 2 (a measurement tool to assess systematic reviews) tool. Below is a brief summary of the aspects evaluated in each of the 16 items of the AMSTAR-2 tool: (1) clear definition of research question and inclusion criteria (PICO); (2) **protocol registered before starting the review**; (3) justification for included study designs; (4) **adequate literature search strategy**; (5) study selection conducted in duplicate; (6) data extraction conducted in duplicate; (7) **clear justification for excluded studies**; (8) detailed description of included studies; (9) **appropriate assessment of risk of bias in individual studies**; (10) adequate reporting of funding sources; (11) **appropriate use of meta-analytical methods**; (12) assessment of the impact of risk of bias on results; (13) **interpretation of the risk of bias in discussing results**; (14) discussion of heterogeneity in results; (15) **assessment of potential publication bias**; and (16) reporting of conflicts of interest by review authors. (Critical domains highlighted in bold.)

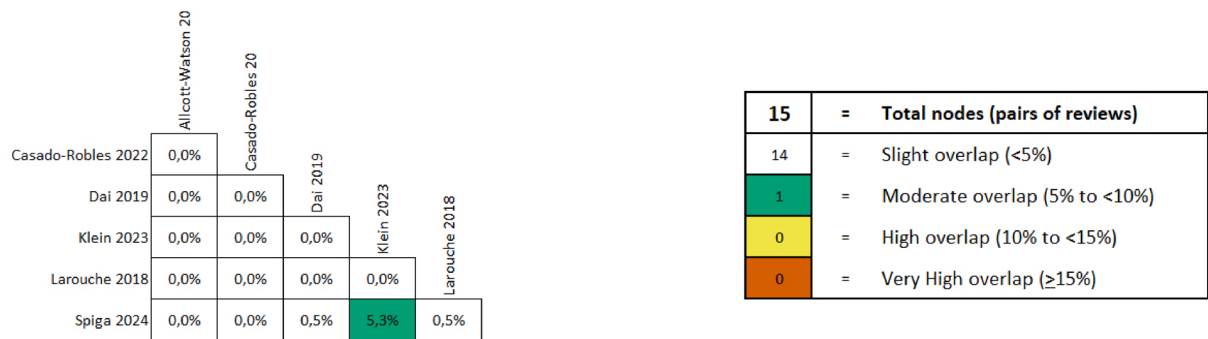


Fig. 2. Overlap in the primary studies among review pairs based on the GROOVE (graphical representation of overlap for overviews) tool.

(10.5), were identified as essential in facilitating healthy behaviors in school settings. The involvement of parents, teachers, teaching assistants, and the broader social environment within schools provides critical emotional encouragement, practical assistance, and reinforcement, significantly bolstering children’s adherence and engagement in physical activity and healthy eating interventions. Biological outcomes, notably BMI reductions, showed modest but clinically relevant improvements, reinforcing the utility of comprehensive, multicomponent interventions.

Comparison with prior work

Our findings align with previous overviews and systematic reviews suggesting that multicomponent school-based interventions integrating physical, dietary, cognitive, and environmental elements are more effective than single-domain interventions. Consistent with the existing literature, goal setting and self-monitoring were repeatedly identified as effective BCTs in promoting sustained behavioral change. Additionally, similar to earlier studies, we found that feedback mechanisms, particularly those utilizing digital tools, significantly enhance intervention effectiveness. Moreover, our results regarding modest but significant BMI reductions align with previous evidence, underscoring the importance of sustained, integrated interventions for childhood obesity prevention.

Importantly, recent evidence from Imad et al.⁵⁶ provides a complementary perspective. Their umbrella review mapped components of obesity prevention interventions and highlighted that not all multicomponent strategies yield favorable BMI outcomes. For instance, diet-only interventions in primary school settings and some broad school-based programs were frequently classified as likely ineffective for BMI/zBMI. In contrast, curriculum modifications in physical education and policies targeting the school food environment were identified as the most consistently effective components. Our overview complements these findings by expanding the focus beyond anthropometric indicators to include behavioral and cognitive outcomes, and by systematically coding intervention content using BCTTv1 and the TDF. This approach clarifies how effective components—such as goal setting, self-monitoring, and social support—operate within school contexts, providing insights into mechanisms of change that can inform the design of future interventions.

Taken together, these findings not only reinforce the theoretical and methodological evidence base but also have direct implications for public health practice.

Public health implications

Beyond theoretical and methodological advances, these findings have direct public health relevance. Schools represent one of the most equitable and scalable platforms for influencing children's health trajectories, reaching diverse populations during critical developmental stages. Embedding evidence-based strategies—such as goal setting, self-monitoring, and supportive school food and physical activity environments—into school health policies and curricula can strengthen long-term obesity prevention efforts, help reduce inequities, and ensure a sustainable impact at the population level.

Sex and gender equity in research (SAGER)

A notable strength of this synthesis is the explicit incorporation of sex and gender equity in research (SAGER) guidelines, which facilitated the identification of important gender-specific differences in intervention effectiveness. The majority of reviewed studies included sex- or gender-disaggregated data, though with some limitations in detail. Notably, boys generally exhibited higher baseline levels of physical activity, while girls demonstrated greater adherence and improvement in dietary interventions. For instance, Dai⁵¹ reported that girls, despite lower initial physical activity levels, showed substantial improvements following interventions, emphasizing the critical need for tailored strategies addressing gender-specific behaviors and barriers. Nonetheless, the absence of detailed gender-specific analyses in some reviews limits the depth of conclusions related to equity, underscoring a vital area for future research.

Evidence gaps

Despite the comprehensive nature of the included reviews, several important evidence gaps were identified. First, few reviews systematically assessed or explicitly reported long-term adherence to healthy behaviors beyond the immediate post-intervention period. Additionally, most reviews focused on studies conducted in high-income countries, which may limit the generalizability of findings to low- and middle-income settings, where different behavioral determinants could influence the effectiveness of interventions.

There was also limited evidence regarding the effectiveness of BCTs that target emotional and motivational components, such as reducing negative emotions (BCT 11.2) or using self-incentives (BCT 10.7). This highlights a need for further research into strategies that address these dimensions of behavior.

Another notable limitation across studies was the selection of outcome indicators. For instance, using changes in zBMI scores to evaluate interventions targeting both healthy eating and physical activity may fail to capture meaningful behavioral improvements. In some cases, positive changes in dietary habits or physical activity levels may occur without being reflected in anthropometric indicators, suggesting the need for broader and more sensitive outcome measures.

Finally, conducting a meta-meta-analysis or meta-regression was not feasible due to substantial methodological and statistical heterogeneity across the included reviews (e.g., population age ranges, intervention types, outcome measures, and analytic strategies). Furthermore, the critically low methodological quality of most included reviews (per AMSTAR-2) limited the appropriateness of higher-level quantitative pooling. Instead, this overview synthesized the evidence qualitatively and systematically mapped intervention strategies and BCTs, providing actionable insights that complement prior meta-analytic evidence.

Strengths and limitations

This overview benefits from rigorous methodology, including adherence to PRISMA guidelines, comprehensive searches across multiple databases, and systematic methodological quality assessments using AMSTAR-2. Furthermore, applying the BCTTv1 allowed systematic identification and comparison of effective components. However, limitations include potential bias due to the critical low methodological quality ratings of most included systematic reviews. Additionally, significant heterogeneity in intervention duration, delivery modes, and measurement methods across primary studies limits precise comparative analyses.

A notable strength of this overview is the minimal overlap of primary studies across the included systematic reviews. Specifically, the corrected covered area (CCA) was very low (0.82%), indicating a highly efficient and complementary coverage of the literature. This minimal overlap ensures that the synthesized evidence provides a comprehensive representation of existing interventions, thus enhancing confidence in the robustness and breadth of our conclusions.

Conclusions

This overview highlights that multicomponent, school-based interventions are effective in improving physical activity, dietary behaviors, and related biological outcomes in children. Key BCTs—such as goal setting, self-monitoring, environmental restructuring, and the use of digital feedback mechanisms—consistently yield positive results.

For successful implementation, educational institutions should invest in teacher training programs focused on BCTs, enhance school infrastructure to support active environments, increase the availability of healthy food options, and incorporate digital tools for behavior monitoring and feedback. Additionally, it is essential to examine the environmental conditions that support physical activity and healthy eating. These include the availability of infrastructure and equipment, access to affordable healthy food options, the presence of healthy foods in school cafeterias, internal school policies that limit access to unhealthy foods, and broader regulatory measures in surrounding areas that promote healthy environments. This calls for an intervention approach grounded in a socio-ecological model.

Addressing the identified evidence gaps—particularly those related to the long-term sustainability of behavior change and the limited use of BCTs targeting emotional and motivational aspects—is critical. Future research should prioritize methodological rigor, incorporate explicit theoretical frameworks, apply gender-sensitive approaches, and promote equity in intervention design. Above all, it should assess the structural conditions that enable the adoption and maintenance of healthy behaviors.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Author contributions

The study was conceptualized by GD, AP, TP and AB. Methodology: GD, AB, and GF. The literature search strategy was developed by GD, AP and AB. Articles were located, identified, and evaluated by GD and AB. Data were extracted and checked by these same authors. The initial dimension and criteria list was composed and discussed by all the authors. Supervision: AP, JA and TP. Writing—original draft: The manuscript was drafted and edited by GD, AB y GF. with close revision and feedback from AP and TP as well as review and feedback from all other coauthors. Validation: TP and AP. Writing—review and editing: GD, AB, GF, AP, DA, JA and TP.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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