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A Developmental Cascade Perspective of Pediatric Obesity: A Systematic Review of Preventive Interventions from Infancy through Late Adolescence

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Abstract

The goals of this systematic review were to identify and describe pediatric obesity prevention interventions from infancy to late adolescence and to provide recommendations for future intervention research in light of a recently proposed developmental cascade (DC) model of pediatric obesity. We conducted an electronic search of randomized controlled trials with a minimum 6-month post-intervention follow-up published between 1995–2019. We included 74 interventions: prenatal/infancy (n=4), early childhood (n=11), childhood (n=38), early-to-mid-adolescence (n=18), and late adolescence (n=3). Infancy and early childhood trials targeted early feeding and positive parenting skills. Half of the childhood and adolescence trials were school-based and used universal prevention strategies; those classified as selective or indicated prevention tended to involve the family for more intensive lifestyle modification. Less than 10% of studies followed participants over long periods of time (≥5 years), and only 16% and 31% of studies assessed intervention mediators and moderators, respectively. We recommend that future interventions focus on early prevention, assess long-term intervention effects, use a standardized taxonomy for defining intervention behavioral strategies, assess underlying mechanisms of action and intervention moderators, target parent and family management strategies across development, and increase scientific equity. We also provide specific recommendations regarding intervention targets for each developmental stage.

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Keywords

cascade; development; pediatric obesity; prevention

Introduction

Pediatric obesity is a global public health problem that threatens the current health and future life expectancy of youth.[1] Obesity results from interactions among multi-level risk factors, has both immediate and long-term physical and mental health consequences, and tends to carry forward across the lifespan.[2–5] A study examining body mass transitions in over 65,000 children ages 3–15 years old showed that those who were in the normal or obese weight range at the age of three tended to maintain their weight status for the next 13 years.[4] Similarly, a systemic review and meta-analysis that examined how well childhood obesity predicted later obesity found that children and adolescents in the obese vs. non-obese weight range were five times more likely to be in the obese weight range as adults.[5] These studies highlight the need to understand how risk factors for obesity (e.g., physical inactivity, poor dietary quality, sedentary behavior) accumulate over time and the importance of strategically leveraging modifiable protective factors (e.g., maternal prenatal health, positive parenting practices) to disrupt disease progression.

Developmental cascades (DCs), defined as “cumulative consequences” occurring over time that result in spreading downstream effects within and across domains,[6,7] offer a perspective from which to view obesity developmentally and ecologically. Cascading effects are also referred to in the literature as “snowball,” “amplification,” “spillover” or “progressive” effects. Importantly, DC models work to elucidate the mechanisms and processes through which early risk factors impact later outcomes across development.[7] They have been successfully used to better understand the progression of a range of youth outcomes including substance use and problem behavior.[8–17] Dishion and colleagues, for example, found that problem behavior, peer marginalization, and poor academic performance between the ages of 11–12 years old significantly predicted gang involvement at the ages of 13–14 years old.[8] Gang involvement, in turn, predicted peer deviancy training between the ages of 16–17 years old, which predicted violence between the ages of 18–19 years old. Despite their utility for understanding complex youth outcomes resulting from dynamic interactions and transactions across multiple domains, however, there is a gap between the developmental science literature on cascades and the state of knowledge about cascades in the development of obesity. DC models have only recently been used to conceptualize pediatric obesity.[18]

Smith and colleagues used a theory-driven model-building approach and scoping review of 310 longitudinal studies to develop the first conceptual DC model of pediatric obesity.[18] This empirically-derived model was intended to inform future hypotheses about the different pathways and constructs that contribute to the outcome of obesity in youth. According to Smith et al. (Figure 1; reprinted figure), risk and protective factors for pediatric obesity with robust empirical support include maternal health and socioeconomic influences (during the prenatal-infants stage), nutrition/dietary intake and rapid weight gain/adiposity rebound

(during the toddlers-preschoolers stage), and nutrition/dietary intake and physical activity/sedentary behaviors (during both the school age children and adolescents-teenagers stages). Beyond these developmentally-specific risk and protective factors, the model identifies processes that may amplify one's risk for obesity from one developmental stage to the next. These include: adverse events/stress, temperament, self-regulation, inhibitory control, and self-esteem. Importantly, the model highlights the relevance of parental influences and family management practices *across development* (i.e., parenting styles, feeding practices, family functioning, relationship quality, and support) that have the ability to inhibit or accelerate the cascade. The model also acknowledges that all these constructs are embedded within distal ecological systems (e.g., neighborhoods, institutions, and communities) but focuses on intra-and inter-individual child processes and mechanisms. Finally, given existing gender differences in pediatric obesity, the model considers the important role of child gender as a potential moderating variable of the DC.

DC models can offer unique insights for prevention by identifying timely opportunities to target specific risk and/or protective factors and elucidating mediating processes that may either promote positive or interrupt negative cascades. Such an approach has been used successfully in the prevention of child problem behaviors and later delinquency-related outcomes.[19–21] However, it is unclear how consistent existing obesity prevention interventions, which we defined as those that prevent *and/or* reduce obesity/excess weight gain, are with the DC model of pediatric obesity in terms of targeting relevant risk and protective factors and cascade processes (i.e., all those listed in bold in Figure 1).

Systematic reviews and/or meta-analyses of pediatric obesity prevention interventions published in the last five years[22–29] have followed rigorous review methodology (e.g., comprehensive search strategies across several databases) and have found that although effect sizes are generally small,[23,25,27,29] interventions with the most promise are those delivered in school settings that additionally include a home-based component (e.g., parent outreach).[22,29] Limitations of these reviews include the tendency to focus on one or two specific developmental stages[24,26,28] and no systematic reporting of potential differences in intervention strategies and effects by developmental stage.[22,25,27,29] These reviews have also included studies with varying designs (e.g., quasi-experimental, natural experiments, randomized controlled trials (RCTs))[22,26,27,29] and cite study heterogeneity as a barrier to determining features that contribute to intervention efficacy.[22,25] Notably, none of the reviews that include RCTs specifically report information related to testing and reporting of interventions' mechanisms of action (i.e., mediators) and moderators of intervention effects. As such, little is known about the pathways by which these interventions exert their effects or for whom they work best across and within developmental stages.

Using the DC model as an organizing framework to present the results, this study aims to inform future obesity prevention efforts by conducting a systematic review to (1) identify and describe preventive interventions from infancy through late adolescence reporting immediate and sustained effects on weight status and/or related health behaviors (physical activity, sedentary behavior, diet), and (2) provide recommendations for pediatric obesity prevention in light of the DC model.

Methods

Search Strategy and Eligibility Criteria

In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[30], we conducted a thorough search of the electronic databases PubMed, PsycINFO, and SCOPUS using the following medical subject headings or keywords: overweight/obese, nutrition, physical activity, sedentary behavior, prevention, and intervention. See Table 1 for the detailed search strategy used for PubMed. Author YA ran searches on March 25, 2015 (for articles published between January 1995-February 2015), September 28, 2016 (for articles published between March 2015-September 2016), February 7, 2018 (for articles published between October 2016-December 2017), February 5, 2019 (for articles published between January 2018-January 2019), and April 4, 2019 (for articles published between February 2019-April 2019). Authors exported search results from each database to the citation management software EndNote (Desktop version X7 and EndNote Web) to eliminate duplicates and facilitate ease of shared access to full-text articles by the study team.

Before conducting the search, we specified study inclusion and exclusion criteria and developed an internal protocol and standardized Microsoft Excel document to guide the extraction of relevant information from each intervention. We included interventions in this review if they: (1) were RCTs, (2) had outcome papers published in peer-reviewed journals between January 1995 and April 2019, (3) were written in the English language, (4) targeted youth from the prenatal stage through late adolescence (0–18 years old), and (5) reported effects on youth weight status, physical activity, sedentary behavior, or dietary variables (e.g., fruit and vegetable intake, sugar-sweetened beverage intake) as primary or secondary outcomes. We excluded pilot studies, review papers, and RCTs solely involving participants with chronic medical conditions (e.g., cancer, type 2 diabetes) or serious mental illness (e.g., psychosis). Because the purpose of this review was to examine interventions using the DC model as an organizing framework, we decided to exclude those with only pre-and immediate post-intervention assessments or with a post-intervention follow-up period less than six months from the end of intervention delivery. We additionally sought out published baseline/protocol papers to gather details on each of the included interventions that were not found in the original article.

Study Selection and Data Collection

We conducted the review in three phases: (1) title and abstract screening, (2) full text review and data extraction, and (3) cross-checking. See Figure 2 for the PRISMA flow diagram of selected studies, which contains the combined results across all five searches and lists reasons why studies were excluded at each of the aforementioned phases. After removal of 373 duplicates, the search yielded a total of 2,692 potentially eligible articles.

Two authors conducted the title and abstract screening and five authors participated in the extraction and cross-checking of information across the various searchers in the study. Percentage agreement was calculated on a subset of 50 studies from the initial search, and because it was high (94%), authors proceeded independently with the remainder of the title

and abstract screening. We organized reasons for excluding studies into the following categories and screened them accordingly: 1) not an RCT, 2) not outcomes of interest, 3) demographic criteria (e.g., age) not met, 4) pilot/feasibility study, 5) no post-intervention follow-up or follow-up < six months. We decided that once a study fit into one of the aforementioned categories, it would be documented as the reason for exclusion (e.g., a study that was an RCT and reported outcomes of interest in adults > 18 years was excluded for reason #3, even if it was also a pilot study with no follow-up period). We resolved discrepancies through discussions at scheduled study team meetings, where authors who had uncertainty regarding the inclusion or exclusion of any particular study sought input from the lead authors. We contacted five study authors to request full text versions of papers we were unable to access or to clarify study inclusion; three responded. In the instances that the authors did not respond, we determined eligibility based on the abstract only.

We included 704 articles in the full text review phase. During this phase, we excluded another 630 articles due to not meeting study inclusion criteria. We subsequently extracted data from 74 interventions reported across 141 articles.

The lead authors created an electronic data extraction file in Microsoft Excel, and together with the study team, developed a list of decision rules to guide the extraction process (e.g., report study sample size and participant characteristics from baseline; determine youth developmental stage using the mean age of study participants). We extracted data on the following from each study: 1) general study information (i.e., authors, publication year, journal, country); 2) participant characteristics (i.e., sample size, developmental stage/age, demographics (sex, race/ethnicity, weight status)); 3) intervention characteristics (i.e., name, duration, theoretical framework, strategies, and outcomes of interest assessed); 4) between-group effects for outcomes of interest at post-intervention and follow-up assessment points (coded as either “+” (indicating a significant between-group difference in favor of the experimental condition), “-” (indicating a significant between-group difference in favor of the comparison condition), or “0” (indicating no significant between-group difference)); and 5) presence of formal mediation analyses, moderation analyses, or analyses examining effects of the intervention on theoretically-relevant potential mediating variables. We classified each study by type of prevention intervention using the Institute of Medicine’s protractor model.[31] This model places prevention on a continuum based on a population’s risk for a condition and identifies three subtypes of prevention (i.e., universal, selective, or indicated). We classified studies as “universal” if they included participants regardless of weight status or applied the intervention broadly (e.g., school-based), “selective” if the majority of youth fell into the overweight category at baseline or were specifically recruited due to being at-risk for obesity (e.g., ethnic minority, low income), or “indicated” if the majority of youth fell into the obese category at baseline or the intervention specifically targeted reductions in weight. We also assessed risk of bias for all included studies across five domains (i.e., sequence generation, allocation concealment, blinding of study personnel, incomplete outcome data, and selective outcome reporting) using the Cochrane Collaboration’s tool for assessing risk of bias in randomized trials.[32] Specifically, each intervention received an indication of “yes,” (low risk of bias), “no” (high risk of bias) or “unclear” (insufficient detail provided) for each of the five domains. Once the initial round of data extraction was complete, we randomly assigned each included study to a different

author, who cross-checked all extracted information for accuracy. We resolved discrepancies through discussions at study team meetings and/or through consulting the lead authors.

Results

We included 74 distinct interventions reported across 141 published articles in this review. We organized interventions into five categories based on the child's age at baseline: prenatal/infancy (< 2 years; n = 4), early childhood (2–5 years; n = 11), childhood (6–11 years; n = 38), early adolescence (12–15 years; n = 18), and late adolescence (16–18 years; n = 3). Table 2 summarizes general study characteristics and Table 3 the intervention characteristics and effects.

Prenatal/Infancy (< 2 yrs)

General study characteristics.—We reviewed four distinct interventions reported across 13 published articles for the prenatal/infancy developmental stage.[33–45] Three of these, classified as universal prevention, had moderate (n = 454 and 698) to large (n = 17,046 mother-infant dyads) sample sizes while the other, Healthy Moms (n = 114), was smaller.[43–45] Because this study targeted women who were pregnant and in the obese weight range (the intervention was delivered prenatally), we classified it as selective prevention (in reference to the child). Across the four studies, infant age at baseline ranged from 15 weeks gestation to 4.3 months old, and each study included a fairly even ratio of females to males. Length of follow-up ranged from 1–11.5 years.

Intervention characteristics.—The duration of prenatal/infancy interventions ranged from 12 weekly group sessions to four sessions delivered across an 18-month period. Mothers were the primary recipients of each of these interventions.

Two of the universal prevention interventions, NOURISH RCT and Baby Teeth Talk, targeted infant feeding practices at the family level. NOURISH aimed to promote healthy infant feeding in first-time Australian mothers through goal-setting, identifying barriers/facilitators, self-monitoring, and problem-solving.[33–38] Baby Teeth Talk was an oral health intervention that aimed to reduce sugar intake and improve nutrition in disadvantaged Aboriginal families.[42] Mothers received anticipatory guidance on child health-related behaviors and participated in a series of motivational interviewing sessions from pregnancy until the child was 18 months of age. Although PROBIT was also a universal prevention intervention that targeted infant feeding practices, it was delivered at the hospital level.[39–41] Healthcare providers in Belarussian maternity hospitals and clinics randomized to the intervention condition received an 18-hour lactation management training course that focused on methods to maintain lactation, promote exclusive and prolonged breastfeeding, and resolve common breastfeeding problems. Finally, Healthy Moms was a selective intervention that aimed to limit pregnancy weight gain to within 3% of randomization weight. The intervention was based on behavioral self-management principles and consisted of a combination of two individual dietary counseling sessions and 16 weekly group sessions for expecting mothers.[43–45]

Intervention effects.—Of the prenatal/infancy interventions, all four assessed weight-related outcomes and three assessed dietary outcomes. The three interventions classified as universal prevention reported significant between-group differences in either weight-related or dietary outcomes.

Intervention mediators and moderators.—None of the studies in this developmental stage tested for mediated or moderated effects of the intervention.

Early Childhood (2–5 years)

General study characteristics.—We reviewed 11 distinct interventions reported across 20 published articles for the early childhood developmental stage.[46–65] We classified seven of these as universal prevention, three as selective, and one as indicated. Sample sizes ranged from 57–731 participants, and most participants were in the normal weight range at baseline. Of the five studies that reported participant race and ethnicity, three had predominantly non-Hispanic White samples. Length of follow-up ranged from 6 months to 9.5 years.

Intervention characteristics.—The duration and intensity of early childhood interventions ranged from a single 10-minue session to weekly sessions for six months. Eight of these 11 interventions were delivered exclusively at the family level.

The seven universal early childhood interventions were grounded in either SCT or a social contextual framework. These interventions generally targeted parenting and behavioral constructs such as parental modeling of healthy behaviors and restructuring of the home environment to encourage healthy behaviors.

The selective (n=3) and indicated (n=1) early childhood interventions were primarily grounded in a social contextual framework. Half of these interventions were delivered exclusively at the family level (with parents and children participating in some separate and some joint activities) and included components such as dietary counseling, structured physical activity sessions, and parent training (e.g., reinforcement, behavior management, changing family attitudes towards healthy lifestyle behaviors). Interventions delivered at schools included strategies for increasing active play and teacher-led nutrition education sessions.

Intervention effects.—Ten of the 11 interventions assessed multiple outcomes of interest for this review. Eight studies assessed weight-related outcomes, physical activity, and sedentary behavior, while nine assessed dietary outcomes. Two interventions reported significant between-group differences (in favor of the experimental condition) for weight-related outcomes, one for sedentary behavior, and eight for diet at one or more of the post-intervention and follow-up assessment time points. Six interventions had null effects (i.e., those coded with a “0” across all assessment time points) on weight-related and sedentary behavior outcomes, and one on dietary outcomes. All of the interventions that assessed physical activity reported null effects.

Of the seven early childhood interventions classified as universal, six reported significant between-group differences in diet at one or more of the post-intervention and follow-up assessment time points.

Of the four selective and indicated early childhood interventions, two reported no significant between-group differences in any of the outcomes assessed; the other two reported significant between-group differences in child diet and one other outcome (either weight-related or sedentary behavior).

Intervention mediators and moderators.—Two studies in this developmental stage reported formally testing for mediation effects and one tested for both mediation and moderation effects (referred to as either "Med✓" and/or "Mod✓" in Table 3). In the Healthy Habits study, a telephone-based intervention targeting the home food environment in preschoolers, child access to junk food (e.g., sugary snacks and beverages) in the home and parents' use of restrictive child feeding strategies independently mediated the effects of the intervention on child junk food intake at the 2-month follow-up.[51] Similarly, parent fruit and vegetable intake and provision of these foods at both 2- and 12-month follow-ups were significant mediators of this intervention on child fruit and vegetable intake.[55] The EMPOWER intervention assessed maternal-facilitated constructs of SCT including environment, emotional coping, expectations, self-control, and self-efficacy. A home environment conducive to healthy nutritional choices was found to significantly predict 13% of the change in child fruit and vegetable intake from baseline to follow-up.[59] Key mediators in the Family Check-Up were parents' use of positive behavior support strategies and nutritional quality of meals served at home. Moderators examined in this study included child race/ethnicity, geographic region, and poverty status; however, none of these were found to be significant.

Childhood (6–11 years)

General study characteristics.—We reviewed 38 distinct interventions across 69 published articles for the childhood developmental stage.[66–134] We classified 37% of these as universal prevention, 26% as selective, and the remaining 37% as indicated. Sample sizes ranged from 30–2,350 participants. Fifty percent of the studies reported information regarding participant race and ethnicity; of those, 12 consisted of predominantly non-Hispanic White samples (45%−97%). Length of follow-up ranged from 6 months to 7 years.

Intervention characteristics.—The duration of interventions in the childhood stage ranged from four weeks to three years. Fifty-eight percent of these interventions were delivered at the family level, 29% at the school-level, and the rest used a combination of family, school, and community-based approaches.

Of the 14 interventions classified as universal prevention, seven were grounded in SCT alone or in combination with other theories (e.g., self-efficacy theory, socio-ecological model, Theory of Planned Behavior). These interventions were largely conducted in school settings (n = 10) and delivered primarily by teachers or school staff. Key intervention components included teacher trainings, school curriculum changes (e.g., revised lesson plans to include content on healthy lifestyle behaviors, changes to the structure of PE classes), and limited

parental participation (e.g., newsletters with information and parenting tips, health booklets, brochures, parent information sessions). Other universal interventions targeting this developmental stage were conducted on school grounds during after school care.

Unlike the universal interventions, the majority of the 24 studies classified as selective or indicated prevention of obesity during childhood were conducted exclusively at the family level (n = 19) or at the family level in combination with either school- or community-based approaches (n = 4). Selective interventions used a wide range of theoretical frameworks (e.g., SCT, Transtheoretical Model, Health Belief Model) and intervention approaches (e.g., motivational interviewing, positive parenting group sessions, behavior modification training during school lessons) while indicated studies were largely grounded in Behavioral Choice Theory (n = 8) and applied family-based behavioral treatment (FBT). Standard FBT involves a combination of weekly weigh-ins, individual therapy, and separate parent and child group meetings covering principles of weight control, the Traffic Light Diet, behavioral skills (e.g., self-monitoring, goal-setting) and positive parenting skills (e.g., praise).[96] Notably, the majority of the FBT studies (6 of 8) met the US Preventive Services Task Force (USPSTF) recommendation[135] of having at least 26 intervention contact hours for obese 6–18 year olds.

Intervention effects.—Sixty-three percent of studies assessed multiple outcomes of interest for this review whereas the remaining 37% assessed only one. Eighty-two percent assessed weight-related outcomes, 58% assessed physical activity, 37% assessed sedentary behavior, and 58% assessed dietary outcomes. Of those that assessed each outcome, 42% reported significant between-group differences (in favor of the experimental condition) for weight-related outcomes, 45% for physical activity, 36% for sedentary behavior, and 55% for diet. Forty-eight percent had null effects on weight-related outcomes, 50% on physical activity, 57% on sedentary behavior, and 37% on diet.

Of the 14 childhood interventions classified as targeting universal prevention, nine assessed weight-related outcomes, eight assessed physical activity, four assessed sedentary behavior, and five assessed dietary outcomes. Half reported positive significant between group differences in at least one of the outcomes of interest at one or more of the post-intervention and follow-up assessment time points. Four studies reported significant between-group differences (in favor of the experimental condition) for weight-related and physical activity outcomes, three for sedentary behavior, and three for diet.

Of the 24 selective and indicated childhood interventions, 21 assessed weight-related outcomes, 14 assessed physical activity, 10 assessed sedentary behavior, and 16 assessed dietary outcomes. Sixty-three percent reported positive significant between group differences in at least one of the outcomes of interest at one or more of the post-intervention and follow-up assessment time points. Nine studies reported significant between-group differences (in favor of the experimental condition) for weight-related outcomes, six for physical activity, two for sedentary behavior, and nine for diet. Studies evaluating FBT generally showed no significant between-group differences across outcomes. Importantly, however, most of these studies compared variations of FBT (e.g., parent + child problem

solving vs. child only problem solving) that showed equivalent effects across intervention and comparison conditions.

Intervention mediators and moderators.—Thirteen percent of studies in this developmental stage tested mediation effects, 13% did not formally test for mediation but reported the effects of the intervention on theoretically relevant constructs (referred to as "Med as Outcome" in Table 3), and 39% of studies tested moderation effects. Significant mediators included parenting (e.g., limit-setting, monitoring, reinforcement, support, modeling),[73,93] child psychosocial (i.e., knowledge, self-regulation),[71,72] or child behavioral variables (i.e., non-organized physical activity, dessert intake).[90] The Youth Fit 4 Life intervention, for example, found that together, changes in self-regulation for physical activity, mood, and self-efficacy significantly mediated the effects of the intervention on BMI at both three and nine months.[72] Importantly, change in self-regulation for physical activity was a significant independent mediator in this study.

Child gender was the most widely examined moderator in this developmental stage, with four of seven studies reporting differential intervention effects for boys vs. girls, generally finding stronger effects for boys.[77,99,123,130] Other significant moderators included parent (e.g., education, support)[116,118] and child variables at baseline (e.g., pubertal onset, grade, social problems, race),[84,85,103,113] and built environment characteristics.[101] In FBT interventions, greater proximity to parks and less access to convenience stores and supermarkets were associated with greater reductions in child zBMI.[101]

Early-to-Mid Adolescence (12–15 years)

General study characteristics.—We reviewed 18 distinct interventions reported across 34 published articles for the early-to mid-adolescence developmental stage.[136–169] We classified 44% of these as universal prevention, 22% as selective, and 33% as indicated. Sample sizes ranged from 55–3,110 participants, with the majority falling within the normal weight range at baseline. Of the 14 studies that reported participant race and ethnicity, six had predominantly non-Hispanic White samples. Length of follow-up ranged from 6 months to 2 years.

Intervention characteristics.—The duration of early- to mid-adolescent interventions ranged from four weeks to one year. Forty-four percent of these interventions were delivered at the individual level in combination with family, school, or community-based approaches, 39% were delivered exclusively at the school-level, and the rest at the family or family and school levels.

Of the eight interventions classified as universal prevention, half were grounded in SCT or social learning theory. The majority of these interventions were conducted in school settings (n = 6) and primarily involved changes to the school curriculum (e.g., PE courses on energy balance topics), physical environment (e.g., offering healthier products and smaller portions in the school cafeteria, remodeled outdoor spaces) and health-related policies (e.g., restricting access to vending machines, mandatory recess).

The 10 studies classified as selective and indicated prevention for early-to mid-adolescents were largely focused on the individual youth participant in combination with family and community-based strategies. Four of these 10 studies met the minimum USPSTF 26 intervention contact hours. The selective prevention studies were primarily grounded in SCT whereas most (n = 4) indicated studies did not report a specific theoretical framework. Half the studies used motivational interviewing strategies to engage youth or their parents in the behavior change process, and the majority were delivered by trained interventionists.

Intervention effects.—Sixty-one percent of the 18 studies assessed multiple outcomes of interest for this review while the remaining 39% assessed only one. Eighty-eight percent assessed weight-related outcomes, 61% assessed physical activity, 39% assessed sedentary behavior, and 50% assessed dietary outcomes. Of those that assessed each outcome, 56% reported significant between-group differences (in favor of the experimental condition) for weight-related outcomes, 55% for physical activity, 86% for sedentary behavior, and 89% for diet. Forty-four percent had null effects on weight-related outcomes, 45% on physical activity, 14% on sedentary behavior, and 11% on diet.

Of the eight universal early-to-mid adolescence interventions, six assessed weight-related outcomes, six assessed physical activity, three assessed sedentary behavior, and four assessed dietary outcomes. Six of the eight of the early-to mid-adolescence interventions classified as universal prevention reported positive significant between group differences in at least two of the outcomes of interest at one or more of the post-intervention and follow-up assessment time points.

Of the 10 selective and indicated early-to –mid adolescence interventions, all 10 assessed weight-related outcomes, five assessed physical activity, four assessed sedentary behavior, and five assessed dietary outcomes. Six reported positive significant between group differences in at least one of the outcomes of interest at one or more of the post-intervention and follow-up assessment time points. Five studies reported significant between-group differences (in favor of the experimental condition) for weight-related outcomes, one for physical activity, three for sedentary behavior, and four for diet. Although half the selective or indicated interventions in this developmental stage assessed physical activity, Challenge! was the sole study to report positive significant between group effects for this outcome, but only when adolescent weight status was examined as a moderator.[136] The selective and indicated studies in this developmental stage were more likely to improve weight-related and dietary outcomes.

Intervention mediators and moderators.—Twenty-two percent of studies tested mediation effects, 22% did not formally test for mediation but reported the effects of the intervention on theoretically relevant variables that could be tested as mediators, and 38% of studies tested moderation effects. Significant mediators included adolescent psychosocial (autonomous motivation)[156] and behavioral variables (healthy food intake, sugar intake).[149,168] Significant moderators included adolescent gender[162,169], BMI,[136] ethnicity,[149] school level (middle vs. high school),[168] self-concept[166] and family functioning (e.g., problem solving, communication).[166]

Late Adolescence (16–18 years)

General Study Characteristics.—We reviewed three interventions for the late adolescence developmental stage.[170–174] We classified one of these as universal prevention and two of these as selective prevention, with sample sizes ranging from 253–1,800. All three studies had predominantly White samples in the normal weight range. Length of follow-up was one to two years.

Intervention characteristics.—The duration of late adolescence interventions ranged from eight weeks to six months.

The universal intervention was grounded in TTM and conducted in the school setting. This intervention, Health in Motion, relied solely on interactive technology to provide individually-tailored messages to high school students regarding their energy balance behaviors.[174]

The two selective interventions were grounded in SCT alone or in combination with an ecological framework. These interventions were conducted in school settings. BALANCE was delivered by parent educators and targeted the intrapersonal environment of the teen (e.g., knowledge of high-risk patterns), interpersonal interactions among teen parents (e.g., group problem solving activities), and the physical environment (e.g. improving school, home).[170] Healthy Habits, Healthy Girls – Brazil was a multi-component school-based intervention that included enhanced physical education and other school activities (e.g., nutrition workshops).[171–173]

Intervention effects.—Of the late adolescence interventions, only the two classified as selective prevention assessed weight-related outcomes, and all three assessed physical activity, sedentary behavior, and dietary outcomes. Two interventions reported significant between-group differences in either physical activity, sedentary behavior or dietary outcomes at one or more of the post-intervention and follow-up assessment time points.

Intervention mediators and moderators.—None of the studies in this developmental stage tested for mediation or moderation effects of the intervention. One study reported the effects of the intervention on a theoretically relevant construct (i.e., stages of change) and found that those in the intervention condition were more likely to remain in the action and maintenance stages of change for physical activity and television viewing than were those in the comparison condition.[174]

Risk of Bias

Our risk of bias assessment is summarized in Figure 3 (overall) and as a supplement Table 4 (for individual interventions).

Discussion

Following Smith et al.'s[18] conceptual DC model of pediatric obesity, the goals of this systematic review were to identify and describe pediatric obesity prevention interventions from infancy to late adolescence and to provide recommendations for future intervention

research in light of the DC model. We identified a total of 74 distinct interventions, tested in RCTs, that examined immediate and sustained effects on youth weight status, physical activity, sedentary behavior, and/or diet. Only four and 11 of the 74 identified interventions were conducted in the prenatal/infancy and early childhood stages, respectively. The remaining 38 and 21 RCTs were evaluated with children and adolescents, respectively. Interventions in the prenatal/infancy and early childhood stages targeted universal samples, were delivered at the family level, and most often targeted mothers' early feeding practices and positive parenting skills. Relative to their respective comparison conditions, these interventions were more likely to improve child dietary outcomes than they were to improve child weight status, physical activity, or sedentary behavior. In the childhood and adolescence stages, over half of the interventions targeted selective or indicated samples; these interventions tended to involve the family for intensive lifestyle modification. Interventions in childhood and adolescence that targeted universal samples were largely school-based and involved school curriculum changes. Results of these studies were generally mixed, with observed immediate effects on outcomes usually wearing off by follow-up assessments. Of the 74 interventions, only 16% tested for mediation effects and just under a third (31%) tested for moderation effects. Findings from this review provide important insights regarding strengths and gaps of the current literature. For example, while existing interventions seem to include some developmentally relevant constructs (e.g., parent feeding practices), others known to be associated with obesity and related behaviors are largely missing (e.g., family functioning, positive behavior support). We discuss our key findings below, organizing them into general and developmentally-specific recommendations for pediatric obesity prevention.

General Recommendations for Pediatric Obesity Prevention Research

Focus on holistic and ongoing interventions that begin early in life.—As outlined by Smith et al.,[18] four core tenets have emerged from previous empirical DC models regarding interactions between multiple risk and protective factors: (1) change at one point in the cascade leads to downstream effects later on; (2) between early childhood and early adolescence, there is generally stability in child behaviors and ecological influences; (3) while individual risk factors have small effects, the accumulation of small effects over time is large; and (4) early influences are important, not because their effects are necessarily larger than later effects, but because they trigger cascading effects. These tenets point to the critical role of early influences on later outcomes. Despite the DC model's emphasis on early influences and the potential for early intervention to disrupt negative cascades, only 5% and 15% of the included preventive interventions targeted the prenatal/infancy and early childhood developmental stages, respectively. Notably, and despite the low number of studies in these developmental stages, 73% reported significant effects on one or more of our outcomes of interest at either the post-intervention or follow-up assessment time points. Previously published systematic reviews examining interventions for pediatric obesity prevention from birth to 18 years of age have shown that the number of prevention trials in children younger than five years old is somewhat limited, with the majority of preventive interventions generally targeted towards children 6–12 years of age.[175,176] This is likely due to the larger burden of disease during childhood and adolescence as compared to early childhood. In a more recent review of obesity prevention studies with 0–17 year olds that

were exclusively family-based, the 2–5 year old age range was well-represented (by 43% of the 119 included studies), potentially representing a shift in focus to family-based prevention at earlier stages. That said, a major gap in interventions targeting the prenatal period was highlighted (with only 8% of their included studies).[177] Overall, findings from our review are consistent with these studies and call for an increase in prenatal/infancy and early childhood obesity prevention efforts. They also point to the need for ongoing interventions delivered in schools or to families as children grow.

Assess long-term intervention effects.—Following our recommendation to focus on early prevention is the need to assess the long-term impact of preventive interventions, particularly those that show promise in the shorter term. Only seven of the 74 (9%) included interventions had a follow-up period greater than or equal to five years, only one of which was greater than 10 years. Twenty percent had less than one-year follow-up, 43% had greater than one year but less than two years, and 27% had between 2–5 years follow-up. Further highlighting the overwhelming lack of long-term intervention follow-up in the field is the additional 457 studies that would have been eligible for inclusion in our review (Figure 2) had it not been for our imposed 6-month post-intervention follow-up minimum criteria. Although DC models suggest preventive interventions may be critical for disrupting negative cascades, these potential protective effects go undetected unless participants are followed over long periods, particularly for earlier interventions. Lack of follow-up may be due to lack of intervention success over the short and long term, participant attrition, and limited funding.[178] We recommend that future research examine optimal lengths of follow-up based on the developmental stage of intervention initiation and expected time for change to occur and be sustained.

We also recognize that there are practical challenges associated with long-term follow up that are outside the control of individual researchers and may require changes in broader funding practices and policies. For example, the funding cap for R01 grants from the National Institutes of Health has been $500,000 of annual direct costs for at least the last 20 years. Given corresponding increases in inflation over this time, researchers today would need over $730,000 of annual direct costs to do the same work they did in the year 2000.[179] Understandably, interventionists today face challenging budgetary decisions forcing them to sacrifice additional assessment time points. We encourage funding agencies to reexamine their policies and the effects they might have on understanding the impact of prevention studies.

Identify specific behavior change techniques used within interventions.—The majority of studies (~80%) in our review referenced an overarching theoretical framework that informed intervention content and strategies. These theories were largely behavioral in nature (e.g., Social Cognitive Theory, Social Learning Theory, Behavioral Choice Theory). While we were able to extract information on general behavioral strategies used across interventions (e.g., problem solving around diet issues), we found that intervention descriptions were often not detailed enough to systematically identify specific strategies (e.g., problem solving barriers to a healthy diet vs. problem solving solutions for promoting a healthy diet) or the time spent discussing these strategies. This limited our ability to

understand what exactly was done during intervention sessions and make systematic comparisons across studies, which is critical for determining why some interventions work while others do not. More recent interventions in the field have begun to apply the Behavior Change Technique Taxonomy, or a set of 93 standardized definitions of behavioral strategies,[180] to their pediatric obesity prevention interventions as a way to describe the unique behavior change techniques applied across sessions.[181,182] We strongly recommend that all interventionists do the same moving forward.

Assess underlying mechanisms of action and intervention moderators.—One of the primary implications of DC models for prevention science is that well-timed interventions that target underlying mechanisms of action stand to have the greatest impact. While over 80% of the interventions included in our review referenced an overarching theoretical framework, less than a fifth conducted corresponding mediation analyses used to evaluate underlying mechanisms of action (i.e., 20% of the early childhood interventions, 13% of the childhood interventions, and 19% of the adolescence interventions). The DC model of pediatric obesity suggests that any of the constructs shown in bold in Figure 1, including developmentally-specific risk and protective factors, amplifying factors, and family management practices, could potentially be examined as intervention mediators with obesity/weight status as the outcome. Notably, the few times mediators were examined across interventions, we found that they were generally consistent with the DC model (e.g., parental limit setting, child temperament, child physical activity).

O'Rourke and MacKinnon[183] encourage prevention researchers to test for mediation, even in the absence of significant intervention effects. These authors present situations where there is increased power to detect a mediated effect over a direct intervention effect (e.g., when the mediated effect and the total effect are equal in a sample, when the mediated and direct effects have opposite signs). Moreover, they describe conceptual reasons for testing mediation in the absence of intervention effects, highlighting in particular the differences between action theory, or the theory relating interventions to mediators, and conceptual theory, or the theory relating mediators to outcomes. Mediation analyses provide a way to examine whether interventions changed the underlying constructs they were designed to change (action theory) and/or whether these mediators were in turn related to target outcomes (conceptual theory). Notably, 14% of studies in our review examined action theory only by reporting effects of the intervention on mediating variables. Without a comprehensive understanding of both action and conceptual theory, however, it is difficult to assess how interventions work (or potential reasons they fail to work). Overall, our ability to design more efficacious and effective interventions is contingent on furthering our understanding of change processes. We thus urge interventionists to conduct and report mediation analyses even when direct intervention effects on the primary and secondary outcomes are null. Given mediated effects may not be constant across different groups of individuals receiving an intervention, we also encourage interventionists to consider moderated mediation.[184]

With regard to moderation, approximately a third of studies in our review reported these analyses. Although child gender was the most widely examined moderator, it was only examined as a moderator in 14% of the included studies. Smith et al. highlighted child

gender as a moderator in the DC model of pediatric obesity based on a review of over 300 longitudinal, weight-related studies, many of which found gender differences in the relationships between variables or the developmental processes under investigation. The same processes occur in longitudinal intervention studies. As such, we recommend that gender be examined more routinely as a moderator of intervention effects and both significant and null effects be reported. If gender is found to moderate intervention effects, we recommend that interventionists explore reasons why their intervention may have differential effects on boys vs. girls.

Target parenting and family management across development.—The DC model of pediatric obesity places parenting and family management practices below developmentally-specific risk and protective factors to emphasize their relevance across development. The level of family involvement across interventions decreased from the prenatal/infancy stages through late adolescence. Whereas families were involved in nearly every intervention in the prenatal/infancy and early childhood stages, this was not the case in childhood and adolescence. This pattern is consistent with children's increasing autonomy and the relevance of other systems (e.g., schools, peers) as they grow.[185] Notably, during childhood and adolescence, interventions classified as selective and indicated vs. universal prevention were primarily delivered at the family level, signaling the recognized need to involve families when youth are at increased risk of obesity. Even when interventions are school or community-based, and parenting and family management is not explicitly targeted, these constructs should still be assessed and evaluated as moderators of intervention effects given the connection between familial constructs and weight and the potential that not addressing familial factors will negate the influences of other contexts. There is also the possibility of improving child behavior through improving parenting and vice versa due to bidirectional relationships between parenting and child eating and weight.[186]

With regard to specific parenting and family management practices, Smith et al. identified parenting styles, feeding styles, family functioning, relationship quality, and support as robust family-related predictors of pediatric obesity. Findings from our review suggest that a strength of current interventions, particularly those in earlier developmental stages, is that they often target feeding practices, such as responsive feeding, and parenting and family management skills related specifically to healthy eating, physical activity, and child growth. More general parenting and family constructs such as family functioning, or the quality and degree of family cohesion, parental involvement, positive parenting, and family communication,[187] however, were not as well represented in our included studies. Power and colleagues[188] distinguish general parenting styles and practices (i.e., those that cut across childrearing situations and domains) from domain-specific parenting styles and practices (i.e., those that refer to parents' behavior in specific contexts, e.g., feeding, physical activity) and note that the optimal combination of these within pediatric obesity interventions is not well understood.[188] Importantly, the DC model of pediatric obesity identifies child intrapersonal constructs (e.g., temperament, self-regulation, inhibitory control, self-esteem) as processes that may amplify obesity risk from one stage to the next. A recently proposed biopsychosocial model of the development of pediatric overweight and obesity overlaps with the DC model in that it highlights the contributions of child-level

characteristics such as temperament and self-regulation of energy intake as influencing parent behaviors and practices.[189] Because these intrapersonal constructs have been previously shown to mediate associations between general positive parenting and other adverse child outcomes (e.g., externalizing behavior[190]), it is important to target both general and domain-specific parenting within pediatric obesity prevention interventions across development.

Increase scientific equity in obesity prevention research.—Findings from Smith et al. highlight race/ethnicity as an independent risk factor for obesity, with Hispanic, non-Hispanic Black, and American Indian youth at greatest risk for developing obesity. Sixty-two percent of the 29 USA-based studies that reported this information were conducted with largely non-Hispanic white samples, suggesting high risk populations may have limited access to these interventions. Prevention researchers have advocated for the need to increase "scientific equity," or "equality and fairness in the amount of scientific knowledge produced to understand the potential solutions to such health disparities" (p. 642).[191] We encourage interventionists to increase the number of participants from diverse racial and ethnic populations in their obesity prevention trials and consider using specific research paradigms for better understanding how interventions and the way they are implemented are related to scientific and health equity.[192] Given the majority of interventions conducted outside the USA in this review (62%) failed to report participant race/ethnicity, we also recommend that this information be collected and reported more consistently across studies.

Developmentally-Specific Recommendations for Obesity Prevention

Prenatal/infancy.—The DC model of pediatric obesity identifies maternal health as a key risk factor during the prenatal/infancy stage. Indeed, pre-pregnancy maternal weight and gestational weight gain have been identified as key modifiable risk factors for rapid weight gain trajectories in children.[193] A strength of the four interventions we reviewed for this developmental stage is that mothers were the primary intervention recipients. Because our review was limited to interventions that reported effects on youth, we excluded prenatal studies that reported effects on mothers' weight status and health behaviors only. It is possible that these interventions influence an infant's weight status. As such, future interventions delivered prenatally should assess outcomes in both mothers and children postpartum. Otherwise, the impact of prenatal interventions on child health remains largely unknown.

The DC model additionally identifies adverse events/stress and temperament as processes that may amplify a child's obesity risk as they move from the prenatal/infancy stage to early childhood. The provision of positive parenting skills at this developmental stage is especially important, as they have been shown to buffer against the negative effects of "difficult" temperament.[194] Moreover, general positive parenting interventions have been shown to reduce adverse events (e.g., child maltreatment) and parental stress.[195] Only two of the four interventions included in our review during this developmental stage (NOURISH RCT, Baby Teeth Talk) noted that they covered positive parenting skills, thus we recommend that these skills be better integrated into interventions at this stage.

Early childhood.—During early childhood, the DC model of pediatric obesity highlights nutrition and dietary intake as well as rapid weight gain and adiposity rebound as key risk factors for obesity. While physical activity and sedentary behavior were also risk factors in the model, Smith et al.[18] note that the literature on physical activity and sedentary behavior in toddlers is limited compared to that conducted with children and adolescents, which would be expected based on development and measurement/assessment considerations. Consistent with these identified risk factors, interventions in this developmental stage reported the most success with improving child dietary outcomes. Although eight of the 11 early childhood interventions targeted physical activity, none of them reported significant between group differences. Researchers should devote more attention to understanding how to optimally measure and change physical activity in toddlers. Other notable strengths these interventions include their delivery at the family level, targeting domain-specific parenting constructs (e.g., restructuring the home environment), and simultaneously targeting multiple outcomes. As previously noted, an area for improvement at this developmental stage is targeting general parenting constructs that have been shown to positively impact child inhibitory control (e.g., positive behavior support).[196]

Childhood.—Unlike interventions at the earlier stages of development, the majority (63%) of childhood interventions were classified as selective or indicated prevention, suggesting that universal interventions, although necessary, are recognized as insufficient at this stage to disrupt further negative cascades. In this developmental stage, the prevention type largely dictated the intervention approach; whereas universal interventions were largely school-based, selective and indicated interventions were largely family-based. Our results indicate that a larger proportion of the selective and indicated vs. universal interventions reported positive significant between group differences in at least one outcome. These findings are consistent with another systematic review of child obesity prevention and treatment interventions that addressed parenting and found that all 10 of 16 studies with significant effects were delivered to children already in the overweight or obese weight range rather than to children from the full weight spectrum.[197]

During childhood, the DC model of pediatric obesity highlights nutrition and dietary intake, physical activity and sedentary behavior, and sleep as key risk factors for obesity. Based on our review, researchers are doing moderately well targeting these outcomes. Specifically, over half the interventions in this developmental stage successfully targeted and impacted multiple outcomes, namely weight, physical activity, and diet. Approximately a third of studies targeted changes in sedentary behavior and none of the interventions focused on improving sleep duration or quality. The DC model also identifies adverse events/stress, self-regulation and self-esteem as processes that amplify a child's risk for obesity from childhood to early adolescence. However, only one intervention in this developmental stage assessed self-regulation, specifically, self-regulation for physical activity, and none assessed self-esteem. Based on the DC model, we recommend that studies in childhood should more frequently target and/or assess sedentary behavior, sleep, self-regulation (both general and domain-specific), and self-esteem.

Early-to-Late adolescence.—During adolescence, the DC model of pediatric obesity identifies nutrition and dietary intake and physical activity and sedentary behavior as key risk factors for obesity. As with childhood interventions, the prevention type during this stage largely dictated the intervention approach, with universal interventions being primarily school-based. Selective and indicated interventions, however, tended to focus on the individual youth participant in combination with family and community-based strategies. This represents a developmentally appropriate shift in responsibility to the adolescent while still maintaining the important role of the family and other supports. A notable strength of studies in this developmental stage was that the majority targeted multiple health behaviors, including diet, physical activity, and sedentary behavior. In fact, compared to all other developmental stages, interventions in early-to-mid adolescence were most likely to target and successfully reduce sedentary behavior. Still, less than half (39%) of interventions actually assessed sedentary behavior. Given documented increases in sedentary behavior during adolescence[198] we recommend that future interventions continue to target this particular health behavior.

Limitations

First, although we reported on the presence of significant between group effects, our system of classifying study effects did not account for study sample sizes or provide an indication of effect sizes—only the significance or lack thereof. Our intent from the outset, however, was not to conduct a meta-analysis but rather to simply provide a descriptive account of the current obesity prevention literature from infancy through late adolescence. Second, we limited our search to three commonly used databases (PubMed, PsycINFO, Scopus), which may have limited the breadth of articles included in our review. Finally, because of our imposed terms, search filters, and our minimum 6-month post-intervention follow-up criteria, we may have unintentionally excluded relevant interventions (e.g., longer interventions that only assessed outcomes at baseline and post-intervention, quasi-experimental or other intervention designs) that could have provided additional insights in relation to the DC model. Yet one of the biggest insights we gained by imposing the minimum 6-month post-intervention criterion was the need to increase intervention length of follow up. Despite these limitations, our search covered a span of over 20 years, is easily replicable (see Table 1), and is unique in that findings were organized using a DC model.

Although not directly a limitation of this study, it is important to acknowledge existing gaps in the current DC model of pediatric obesity. These gaps are largely a reflection of the limitations of the longitudinal literature used to develop it, which fails to elucidate change processes due to being primarily epidemiologic in nature or not focused exclusively on understanding weight gain. Investigations of cascades in the obesity literature are still in their infancy and should aim to emulate the child problem behavior literature by moving past risk and protective factors to a greater understanding of mechanisms that contribute to obesity. To truly identify how cascades “work,” a bridge is needed between the developmental and intervention science literatures. We see the current review as providing a next step in the scientific process. As empirical examinations of cascades begin to emerge in the obesity literature, intervention scientists might also draw from other recent reviews

examining pathways leading to pediatric obesity for suggested strategies to promote positive or disrupt negative cascades.[199–201]

Conclusions

Using the first conceptual DC model of pediatric obesity as an organizing framework, this review examined the current obesity prevention literature, highlighting areas of strength and necessary improvement both generally and across specific developmental stages from prenatal/infancy and late adolescence. Although studies generally seem to be targeting important developmentally-specific risk and protective factors (e.g., maternal health, dietary intake) and domain-specific parenting and family management practices (e.g., feeding practices), the amplifying factors (e.g., temperament, adverse events/stress, self-regulation) and more general parenting and family management practices (e.g., family functioning) identified in the DC model of pediatric obesity were not well represented in our included studies, nor were examinations of any of these variables as intervention mechanisms of action. Future preventive intervention efforts should draw on existing knowledge about influence processes and pathways leading to pediatric weight gain when designing preventive interventions and should systematically assess the processes that facilitate change over time. Overall, longitudinal intervention trials that commence at earlier stages of development and assess developmentally-relevant mechanisms of action are likely to have a large and long-standing public health impact.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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List of Abbreviations

DC	Developmental cascade
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)
RCT	Randomized controlled trials
PROBIT I-III	Promotion of Breastfeeding Intervention Trial
SCT	Social Cognitive Theory Social
BMI	Body mass index
EMPOWER	Enabling Mothers to Prevent Pediatric Obesity through Web-Based Education and Reciprocal Determinism

FBT	Family-based behavioral treatment
USPSTF	US Preventive Services Task Force
BALANCE	Balance Adolescent Lifestyle Activities and Nutrition Choices for Energy

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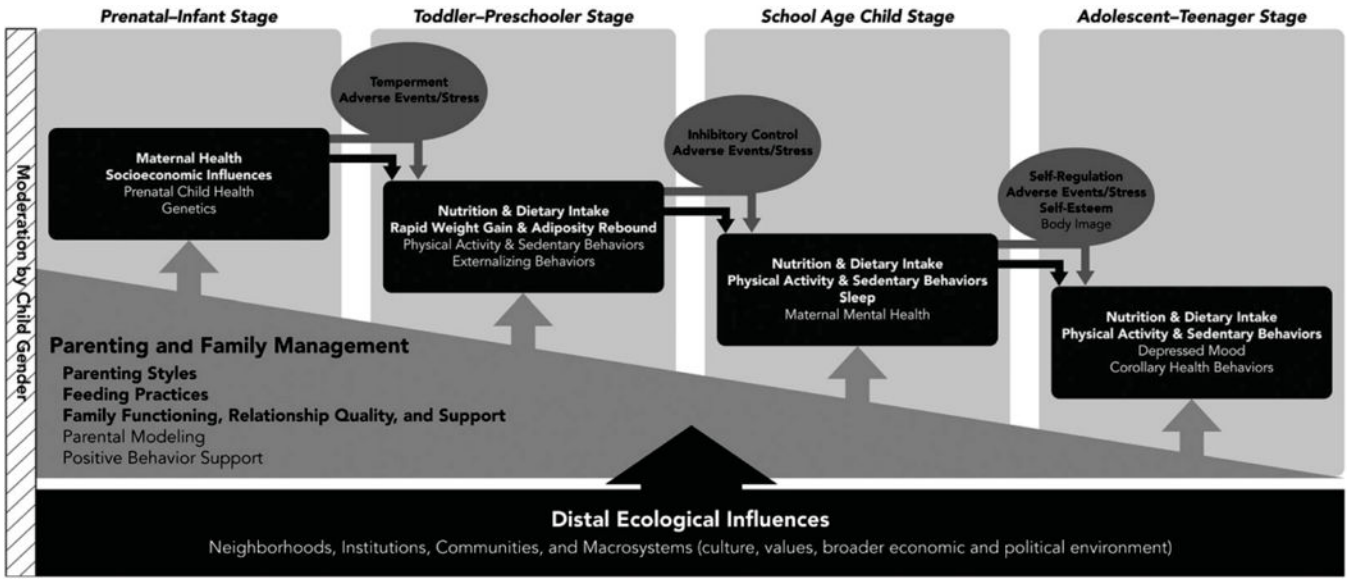

Figure 1:
Developmental Cascade of Pediatric Obesity

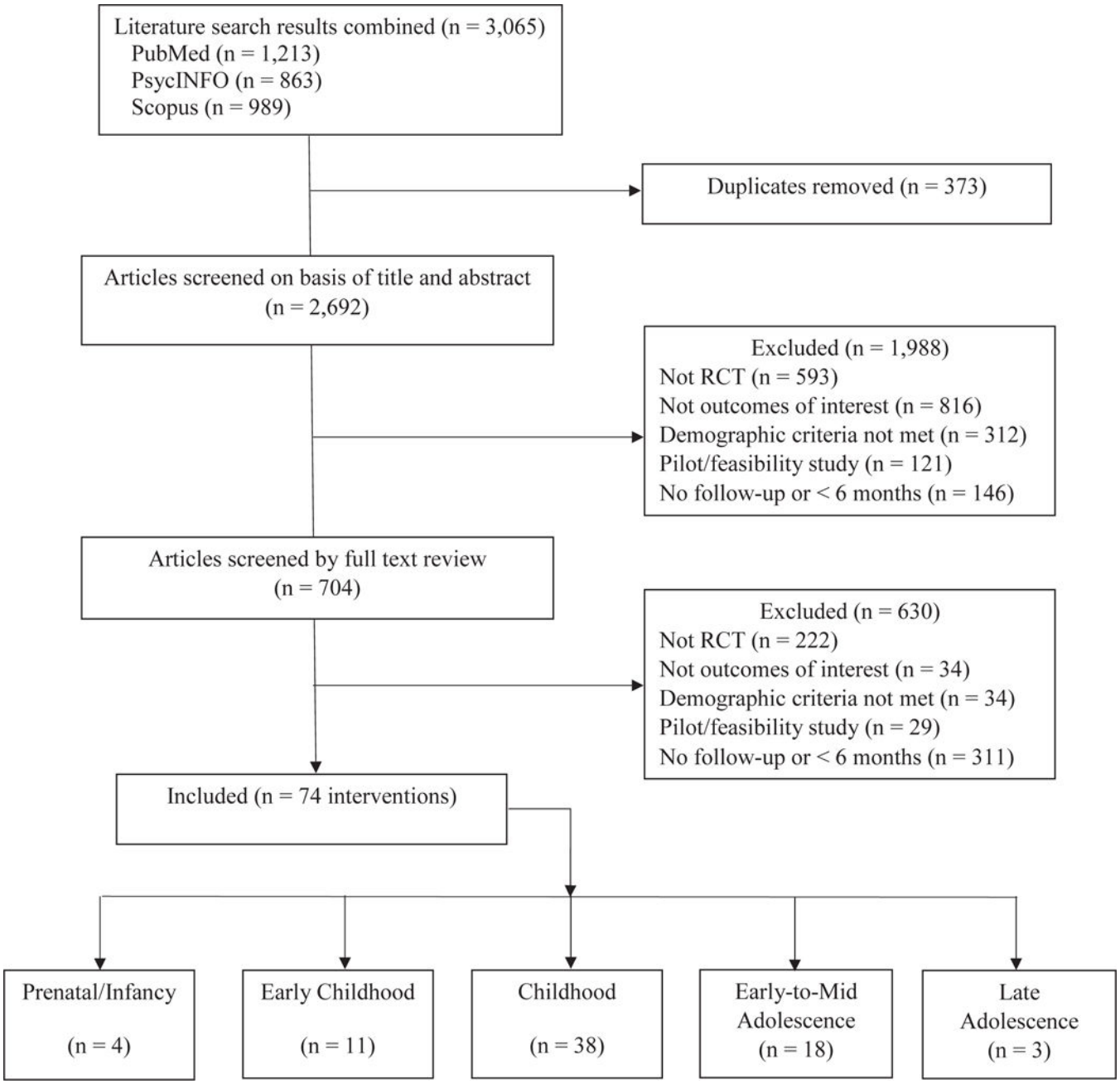

Figure 2:
Study Selection Flow Diagram

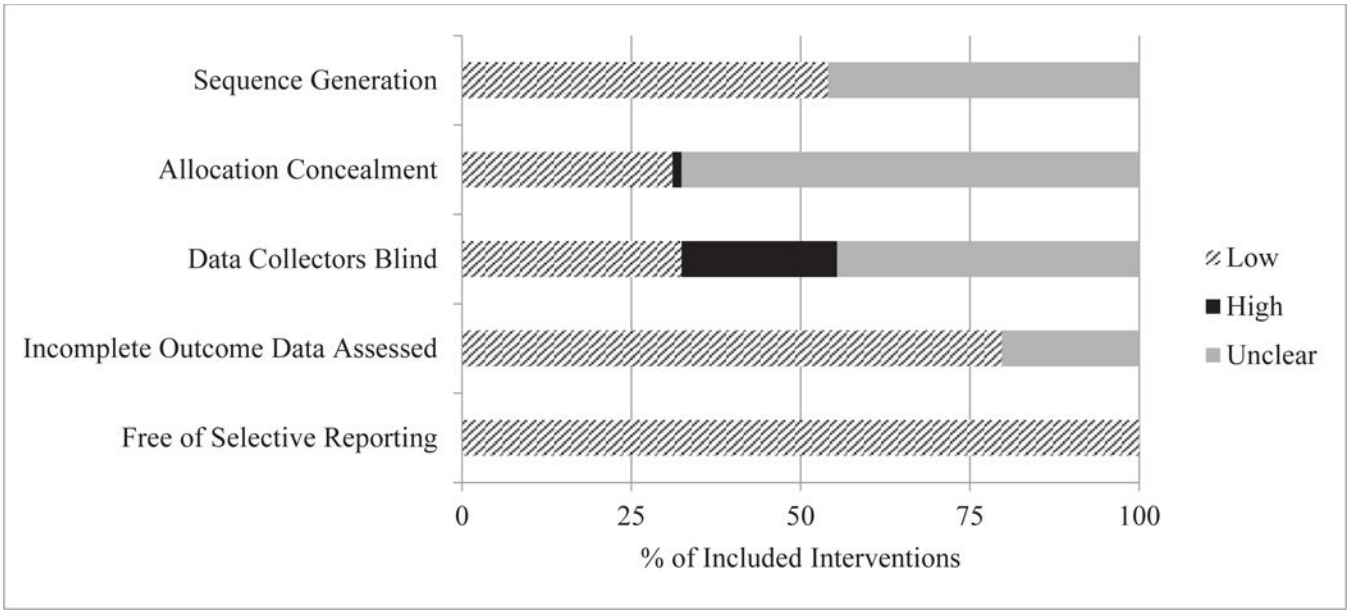

Figure 3:
Risk of Bias

Table 1:

PubMed Search Strategy (using the Advanced Search Builder)

Step	Drop-down menu selection	Search terms
1	Title/Abstract OR	Obese or obesity
	Title/Abstract OR	Overweight
	Title/Abstract OR	"Body mass index" OR BMI
	Title/Abstract OR	"Weight status" OR weight
	Title/Abstract OR	"Body fat"
	Title/Abstract OR	Adiposity
2	Title/Abstract OR	Physical activity
	Title/Abstract OR	Exercise
	Title/Abstract OR	Sport OR sports
	Title/Abstract OR	Fitness
	Title/Abstract OR	Recess
3	Title/Abstract OR	Nutrition
	Title/Abstract OR	Diet OR "healthy diet" OR "dietary intake"
	Title/Abstract OR	Fruit
	Title/Abstract OR	Vegetable
	Title/Abstract OR	Sugar-sweetened beverage* OR sugar sweetened beverage* OR soda OR sugary drink*
	Title/Abstract OR	"Energy intake"
	Title/Abstract OR	Calorie OR calories
	Title/Abstract OR	"Family meal" OR "family meals"
4	Title/Abstract OR	Sedentary OR "sedentary behavior" OR "sedentary lifestyle"
	Title/Abstract OR	Screen time
	Title/Abstract OR	Television OR TV
	Title/Abstract OR	"Video games"
	Title/Abstract OR	"Computer games"
	Title/Abstract OR	"Computer usage"
5	Recent Query	(#1 OR #2 OR #3 OR #4)
		AND
	Title/Abstract	("Obesity prevention" OR "prevent obesity" OR "prevent overweight" OR "reducing obesity" OR "reducing obesity prevalence" OR "preventing weight gain" OR "prevent excessive weight gain" OR "weight control" OR "weight management" OR "healthy weight" OR "health promotion" OR "promoting physical activity" OR "decreases in BMI" OR "reduce gains in BMI" OR "school-based" OR "family-based" OR "community-based")
6 – Filters		Article Types: Randomized Controlled Trial Publication Dates: From 1/1/1995–12/31/2017 Languages: English Ages: birth-18 years
7	Recent Query	#6
		NOT
	All Fields	"Eating disorder" OR "anorexia" OR "bulimia"

Obes Rev. Author manuscript; available in PMC 2021 February 01.

Table 2:

Study Characteristics

1st Author, Publication Year	Prevention Type	Participant Characteristics at Baseline[a]					Country
		N	Age[b]	% Female	Race/Ethnicity	Weight Status	
Prenatal/Infancy (< 2 yrs)							
Daniels, 2009, 2012–2015; Magarey, 2016[33–38]	Universal	698	4.3 ± 1.0 mos	51%	NR	zBMI: −0.3 ± 1.0	Australia
Kramer, 2001, 2007; Martin, 2013[39–41]	Universal	17,046	39.4 wks gestation†	48%†	NR	Birth weight: 3,448 g†	Belarus
Smithers, 2017[42]	Universal	454	prenatal – 6 wks postpartum	NR	86% Aboriginal†	Birth weight: 3,313 ± 635 g†	Australia
Vesco, 2012, 2014, 2016[43–45]	Selective	114	14.9 ± 2.6 wks gestation	56%	86% White, 10% Other, 4% Black	Birth weight: 3.5 ± 0.5 kg†	USA
Early Childhood (2–5 years)							
Birken, 2012[46]	Universal	160	3.1 ± 0.2†	56%†	NR	zBMI: 0.7 ± 1.2†	Canada
Bocca, 2012[47]	Indicated	75	4.6 ± 0.8†	72%	NR	zBMI: 2.7 ± 1.0†	Netherlands
Delisle Nyström, 2015, 2017, 2018[48–50]	Universal	315	4.5 ± 0.1	49%	95% children born in Sweden	BMI: 15.9 ± 1.5†	Sweden
Fletcher, 2013; Wolfenden, 2014; Wyse, 2010, 2012, 2015[51–55]	Universal	394	4.3 ± 0.6	49%	NR	NR	Australia
Haines, 2016[56]	Selective	112	3.6 ± 1.0	50%	59% Hispanic, 22% Black/ African American	zBMI: 0.9 ± 1.4†	USA
Knowlden, 2012, 2015, 2016, 2018[57–60]	Universal	57	5.2 ± 0.8	43%	64% Caucasian, 14% Hispanic†, 9% African American†	NR	USA
Natale, 2014[61]	Selective	307	2–5	49%	36% Black, 34% White, 18% Other, 14% Unknown	70% normal weight†, 17% overweight†, 13% obese†	USA
O'Dwyer, 2013[62]	Selective	240	4.5 ± 0.6	48%	84% White British†	BMI: 16.7 ± 1.7†	England
Reilly, 2006[63]	Universal	545	4.2 ± 0.2	50%	NR	zBMI: 0.4 ± 1.0	Scotland
Skouteris, 2016[64]	Universal	201	2.7 ± 0.6	50%	NR	zBMI: 0.66 ± 0.8	Australia
Smith, 2015[65]	Universal	731	2 yrs, 0 mos – 2 yrs, 11 mos	49%	50% Caucasian, 28% African American, 13% Hispanic	Body size rating: 1.43 ± 0.9 (1 = not overweight, 5 = somewhat overweight)	USA

1st Author, Publication Year	Prevention Type	Participant Characteristics at Baseline[a]					Country
		N	Age[b]	% Female	Race/Ethnicity	Weight Status	
Childhood (6–11 years)							
Adab, 2015, 2018[66,67]	Selective	1,467	6.3 ± 0.3	49%	45% White British, 31% South Asian, 8% Black African-Caribbean, 16% Other	zBMI: 0.19 ± 1.2	England
Anderson, 2016; Kipping, 2014; Lawlor, 2011, 2016[68–71]	Universal	2,221	9.5 ± 0.3	49%	NR	zBMI: –0.1 ± 0.9†	England
Annesi, 2017[72]	Universal	141	10.0 ± 0.9	45%	65% Black, 31% White	BMI: 18.5 ± 3.2	USA
Arredondo, 2018; Ayala, 2015; Horton, 2013[73–75]	Selective	361	10.0 ± 1.9	50%	100% Hispanic, 81% US Born	NR	USA
Bere, 2006a, 2006b, 2007, 2014, 2015; Overby, 2012[76–81]	Universal	1,950	11.8 ± NR	50%	NR	NR	Norway
Berry, 2012, 2014, 2018[82–84]	Indicated	358	9.1 ± 1.0	56%	64% African American, 27% White, 8% Hispanic	BMI%: 95.2 ± 0.4†	USA
Best, 2016; Wilfley, 2007[85,86]	Indicated	204	9.9 ± 1.3	69%	69% White/non-Hispanic	zBMI: 2.2 ± 0.3	USA
Boutelle, 2011[87]	Indicated	80	10.8 ± 1.3†	60%	NR	zBMI: 2.3 ± 0.4†	USA
Boutelle, 2015, 2017[88,89]	Indicated	150	10.4 ± 1.3	66%	43% Non-Hispanic White, 29% Hispanic, 29% Non-Hispanic Other†	zBMI: 2.0 ± 0.4†	USA
Broccoli, 2016; Davoli, 2013[90,91]	Selective	372	6.7 ± 1.0†	62%	NR	zBMI: 1.4 ± 0.2†	Italy
Christison, 2016[92]	Indicated	84	10.1 ± 1.3	54%	66% White, 25% Black, 8% Hispanic/Asian†	zBMI: 2.2 (2.1–2.3) d†	USA
Crespo, 2012[93]	Selective	808	5.9 ± .09	50%	100% Hispanic, 86% US Born	17% overweight, 30% obese	USA
Curtis, 2012[94]	Selective	169 families	8.7 ± 4.4	NR	NR	NR	England
Dietrich, 2008[95]	Universal	491	11.1 ± 0.6	54%	NR	zBMI: 0.5 ± 1.1	Austria
Epstein, 2000a, 2012[96,101]	Indicated	90	10.5 ± 1.2	68%	NR	100% overweight or obese	USA
Epstein 2000b, 2012[97,101]	Indicated	67	10.3 ± 1.1	52%	97% Caucasian, 2% African American, 2% Hispanic	BMI: 27.4 ± 3.2	USA
Epstein, 2001a[98]	Selective	30	8.8 ± 1.8	46%	NR	100% normal weight	USA
Epstein, 2001b[99]	Indicated	67	10.4 ± 1.2	48%	94% White, 4% African American, 2% Hispanic	BMI: 27.4 ± 3.6	USA
Epstein, 2004, 2012[100,101]	Indicated	72	9.8 ± 1.3	63%	90% White, 7% Black, 2% Hispanic	zBMI: 3.2 ± 1.0	USA

1st Author, Publication Year	Prevention Type	Participant Characteristics at Baseline[a]					Country
		N	Age[b]	% Female	Race/Ethnicity	Weight Status	
Forneris, 2010[102]	Universal	2,120	6th graders	50%†	52% Caucasian†, ~46% African American†	NR	USA
Fulkerson, 2015[103]	Universal	160	10.3 ± 1.4	48%	71% non-Hispanic White, 16% non-Hispanic Black	zBMI: 1.0 ± 0.8	USA
Griffin, 2015[104]	Universal	268	11.1 ± NR	58%	NR	20% overweight, 21% obese†	Scotland
Jago, 2013, 2015; Sebire, 2016[105–107]	Universal	571	11–12	100%	NR	zBMI: 0.4 ± 1.2†	England
Kalarchian, 2009[108]	Indicated	192	10.2 ± 1.2	57%	73% White, 26% Black, 1% Hispanic	BMI: 32.1 ± 5.0	USA
Kalavainen, 2007, 2011[109,110]	Indicated	70	8.1 ± 0.8	60%	NR	zBMI: 2.6 ± 0.6	Finland
Khanal, 2016; Welsby, 2014[111,112]	Indicated	458	9.5 ± 1.8	52%	8% Aboriginal	zBMI: 1.9 ± 0.5	Australia
Kriemler, 2010; Meyer, 2014[113,114]	Universal	502	6.9 ± 0.3† (1st grade); 11.0 ± 0.5† (5th grade)	51%	NR	BMI: 17.1 ± 2.5†	Switzerland
Laukkanen, 2015, 2017[115,116]	Universal	91	6.2 ± 1.1	54%	NR	11% overweight	Finland
Llargues, 2011; Mora, 2015[117,118]	Universal	598	6.3 ± 0.02	48%	14% Immigrants	BMI: 16.9 ± 2.3†	Spain
Magarey, 2011[119]	Selective	169	8.2 ± 1.2	56%	NR	zBMI: 2.72 ± 0.62	Australia
McManus, 2008[120]	Universal	210	10.4 ± 0.9	50%	NR	BMI: 18.2 ± 3.3†	China
Morgan, 2019[121]	Universal	153	7.7 ± 2.8	100%	89% fathers born in Australia	75% normal weight, 16% overweight, 5% obese	Australia
Nyberg, 2011, 2015[122,123]	Selective	243	6.2 ± 0.3	49%	70% parents born in Sweden, 7% born in Europe, 23% born outside of Europe	zBMI: 0.4 ± 1.2	Sweden
Reinehr, 2010, 2018; Schaefer, 2011[124–126]	Selective	76	11.5 ± 1.6	58%	NR	BMI: 23.4 ± 1.5	Germany
Robertson, 2013, 2017[127,128]	Indicated	128	9.4 ± 1.6	51%	62% White, 17% Asian, 13% Mixed, 8% Black	zBMI: 2.7 ± 0.7	England
Salmon, 2005, 2008[129,130]	Selective	306	10 yrs 8 ± 4–5 mos	51%	NR	47% overweight/obese (boys); 38% overweight/ obese (girls)	Australia
Tarro, 2014a, 2014b; Llauradó, 2018[131–133]	Universal	2,350	8.4 ± 0.6	50%	78% Western European	BMI: 17.7 ± 3.2†	Spain
Yackobovitch-Gavan, 2018[134]	Indicated	247	8.4 ± 1.5	67%	NR	zBMI: 1.8 ± 0.3	Israel

1st Author, Publication Year	Prevention Type	Participant Characteristics at Baseline[a]					Country
		N	Age[b]	% Female	Race/Ethnicity	Weight Status	
Early-to Mid-Adolescence (12–15 years)							
Black, 2010[136]	Selective	235	13.3 ± 1.0	49%	97% African American	zBMI: 0.8 ± 1.2†	USA
Christiansen, 2017; Toftager, 2011, 2014[137–139]	Universal	1,348	12.5 ± 0.6	48%	>90% Danish	BMI: 18.7 ± 2.6†	Denmark
Christie, 2011, 2017[140,141]	Indicated	174	15.0 ± NR	63%	53% White or Mixed, 25% Asian, 22% Black	zBMI: 2.8 ± NR†	England
Collins, 2014; Dewar, 2013, 2014; Lubans, 2010, 2012[142–146]	Selective	357	13.2 ± 0.5	100%	85% Australian, 10% European	zBMI: 0.8 ± 1.1	Australia
Debar, 2012[147]	Indicated	208	14.1 ± 1.4	100%	71% White	BMI: 32.0 ± 4.8†	USA
Demol, 2009[148]	Indicated	55	14.4 ± 1.7	62%	NR	zBMI: 3.3 ± 0.2c	Israel
Ebbeling, 2012[149]	Indicated	224	15.3 ± 0.7†	45%	55% White, 24% Black, 20% Hispanic	BMI: 30.4 ± 5.2†	USA
Jago, 2006[150]	Universal	473	13.0 ± 0.1c	0%	73% Caucasian; 14% Hispanic	BMI: 21.3 ± 0.5c† (spring); 21.0 ± 0.4c† (fall)	USA
Jelalian, 2010; Lloyd-Richardson, 2012[151,152]	Selective	118	14.3 ± 1.0	68%	76% White; 14% African American	zBMI: 1.6 ± 0.4	USA
Lubans, 2016; Smith, 2014a, 2014b, 2017[153–156]	Selective	361	12.7 ± 0.5	0%	77% Australian, 15% European	BMI: 20.5 ± 4.5	Australia
Melnyk, 2013[157]	Universal	779	14.7 ± 0.7	52%	68% Hispanic; 14% White; 10% Black	BMI: 24.4 ± 5.9	USA
Mihas, 2010[158]	Universal	218	13.1 ± 0.8†	49%	NR	BMI: 24.0 ± 3.1†	Greece
Resnicow, 2005[159]	Indicated	123	13.6 ± 1.4	100%	100% African American	BMI: 32.7 ± 6.7	USA
Singh, 2006, 2007, 2009; Veitch, 2011[160–163]	Universal	1,108	12.8 ± 0.5† (boys); 12.6 ± 0.5† (girls)	50%	88% Dutch or Western ethnicity	BMI: 19.0 ± 3.0† (girls); 18.2 ± 2.6† (boys)	Amsterdam
Savoye, 2007, 2011; Taylor, 2017[164–166]	Indicated	209	12.0 ± 2.5†	60%	38% non-Hispanic Black, 37% non-Hispanic White, 25% Hispanic	zBMI: 2.5 ± 0.3†	USA
Thompson, 2009[167]	Universal	473	13.0 ± 0.1c	0%	73% Caucasian; 14% Hispanic	BMI: 21.3 ± 0.5c† (spring); 21.3 ± 0.4c† (fall)	USA
Viggiano, 2015[168]	Universal	3,110	13.3 ± 0.1c†	47%	NR	zBMI: 0.6 ± 0.1c†	Italy

1st Author, Publication Year	Prevention Type	Participant Characteristics at Baseline[a]					Country
		N	Age[b]	% Female	Race/Ethnicity	Weight Status	
Wilksch, 2015[169]	Universal	1,316	13.21 ± 0.7	64%	NR	BMI: 20.0 ± 0.1[c] (boys); 20.1 ± 0.1[c] (girls)	Australia
Late Adolescence (16–18 years)							
Haire-Joshu, 2015[170]	Selective	1,325	17.7 ± 1.3[†]	100%	50% non-Hispanic White, 28% non-Hispanic Black, 19.4% Hispanic[†]	59% normal weight, 23% overweight, 18% obese	USA
Leme, 2015, 2016, 2018[171–173]	Selective	253	16.3 ± 0.8[†]	100%	88% born in Brazil, 56% Caucasian/White, 26% Brown	70% normal weight, 19% overweight, 8% obese[†]	Brazil
Mauriello, 2010[174]	Universal	1,800	16.0 ± NR	51%	72% non-Hispanic White, 11% non-Hispanic Black	75% normal weight; 8% overweight; 16% obese	USA

Note.

[a] Percents rounded to the nearest whole number

[b] Age reported as either M ± SD (rounded to one decimal point) or range in years, unless otherwise specified

[c] Standard error

[d] Confidence Interval

[†] Demographic characteristics for those in the intervention condition only; BMI = Body Mass Index; NR = Not reported; zBMI = Body Mass index z-score

Table 3:

Intervention Description and Effects

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
Prenatal/Infancy (< 2 yrs)													
Daniels, 2009, 2012–2015; Magarey, 2016[33–38]	NOURISH RCT • Two 6-session group education modules focused on parenting skills related to healthy eating and growth (rather than obesity prevention) during infancy (Module 1) and toddlerhood (Module 2) • Modules targeted exposure to healthy foods, responsive feeding, and positive parenting • Dietitians and psychologists delivered sessions at child health clinics to mother-child dyads	SCT, Attachment Theory, anticipatory guidance	Family	12	Module 1: 65% attended ≥ 2 sessions Module 2: 45% attended ≥ 2 sessions	T1: 86% T2: 78% T3: 72% T4: 61%	Usual care – self-directed access to usual community child health services	T1: 14 mos† T2: 24 mos† T3: 3.5 yrs† T4: 5 yrs†	+ 0 0 0			0 0 0	No
Kramer, 2001, 2007; Martin, 2013[39–41]	Promotion of Breastfeeding Intervention Trial (PROBIT I-III) • 18-hr lactation management training course delivered to healthcare providers focused on methods to maintain lactation, promote exclusive and prolonged breastfeeding, and resolve common problems	NR	Hospital	52	NR	T4: 97% T5: 80% T6: 83%	Usual hospital infant feeding policies	T1: 3 mos† T2: 6 mos† T3: 9 mos† T4: 12 mos† T5: 6.5 yrs† T6: 11.5 yrs†	0 0			+ + + +	No
Smithers, 2017[42]	Baby Teeth Talk • Oral health intervention delivered by a research staff member during pregnancy and at 6, 12, and 18 months • Interventionists provided anticipatory guidance (i.e., explaining what to expect as children grow) and used MI to discuss child's oral health and diet • MI sessions focused on: improving oral care during	MI, anticipatory guidance	Family	78	NR	T1: 65%	Usual care	T1: 24 mos	0			+	No

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	pregnancy, increasing understanding of sugary foods and beverages, increasing understanding of oral hygiene, and promoting the child's first dental visit												
Vesco, 2012, 2014, 2016[43–45]	Healthy Moms • Two individual dietary counseling sessions delivered by dietitians using MI followed by 16 wkly group sessions • Individual sessions included specific calorie goals and review of the DASH diet • Group sessions included a check-in, discussion of diet, exercise and behavior change topics, and goal-setting • Participants kept daily food and activity records and brought them to group sessions	MI	Individual	18	NR	T1: 100% T2: 98% T3: 90%	Single information-only control session and usual care	T1: birth T2: 2 wks T3: 1 yr	0 0 0				No
Early Childhood (2–5 years)													
Birken, 2012[46]	• 10-min behavioral intervention on screen time reduction delivered by dietetics students to parents • Strategies included removing TV from the child's bedroom, encouraging meals to be eaten without the TV, budgeting of the child's screen time, and a 1-wk TV turn off period	SCT	Family	10 min.	NR	T1: 83%	Standardized counseling on safe media use	T1: 1 yr	0		0	+	No
Bocca, 2012[47]	GECKO–Outpatients Clinic Study • Multidisciplinary intervention program for children and parents consisting of six 30-min sessions of dietary advice provided by a dietician, twelve 60-min physical activity sessions (e.g., ball playing, dancing) supervised by a physiotherapist, and six 2-hr group sessions of behavioral therapy for parents only delivered by a psychologist (e.g., goal-setting, modeling, reinforcement)	NR; general behavioral strategies	Family	16	NR	T1: 83% T2: 76%	Treatment as usual	T1: 16 wks T2: 12 mos	+ +	0 0		+ 0	No

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
Delisle Nyström, 2015, 2017, 2018[48–50]	Mobile-based Intervention intended to Stop Obesity in Preschoolers (MINISTOP) • Mobile web-based application for parents to promote healthy eating and physical activity in preschoolers • Intervention covered 12 topics that changed every other wk (e.g., breakfast, healthy foods and snacks, physical activity, sedentary behavior, sleep); app allowed parents to track child food intake, receive feedback, and interact with a dietitian and psychologist	SCT	Family	26	57% of parents read ≥87 of 140 feedback messages; 50% of parents tracked child behaviors for >50 days	T1: 89% T2: 83%	Pamphlet on healthy eating and physical activity guidelines in pre-school children	T1: 6 mos T2: 12 mos	0 0	0 0	0 0	+ 0	No
Fletcher, 2013; Wolfenden, 2014; Wyse, 2010, 2012, 2015[51–55]	Healthy Habits • Four 30-min phone calls to parents by a trained interviewer using a script that targeted 3 areas of the home food environment: (1) parental role-modeling of fruit and vegetable intake; (2) home availability and accessibility of healthy foods; and (3) supportive food routines (e.g., family dinners) • Script integrated behavior change strategies including goal setting, self-monitoring, barrier identification, and identifying cues	Socio-ecological model	Family	4	87% of parents completed all phone calls	T1: 91% T2: 87% T3: 84% T4: 83%	Parents mailed a printed booklet containing dietary advice for adults and children	T1: 2 mos T2: 6 mos T3: 12 mos T4: 18 mos				+ + + 0	Med ✓
Haines, 2016[56]	Parents and Tots Together • Nine 2-hr wkly group parenting sessions, children's sessions, and homework assignments held at a community health center and led by trained facilitators • Sessions focused on improving weight-related behaviors and included reading a book, engaging in physical activity (e.g., yoga, music/dance), and preparing a healthy snack	Social contextual framework	Family	9	52% attended ≥ 6 sessions; 11% attended 3–5 sessions; 37% attended ≤ 2 sessions	T1: 84% T2: 86%	Wkly mailings	T1: 9 wks T2: 9 mos	0 0	0 0	0 0	0 0	No
Knowlden, 2012, 2015, 2016, 2018[57–60]	Enabling Mothers to Prevent Pediatric Obesity through Web-Based Education and Reciprocal Determinism (EMPOWER)	SCT	Family	8	98–100% of dose exposure	T1: 89% T2: 88% T3: 77% T4: 65%	Active control – Healthy Lifestyles	T1: 4 wks T2: 8 wks		0 0 0 0	0 0 0 0	+ + + +	Med ✓

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	• Two-arm trial consisting of an experimental intervention (EMPOWER) and active control (Healthy Lifestyles) • Both web-based interventions included five modules, with each devoted to one of four child behaviors (i.e., physical activity, fruit/vegetable intake, sugar-free beverage intake, and screen time) and a fifth module covering all behaviors • Modules included a 10–15 min audiovisual presentation, interactive worksheet, and discussion board post • EMPOWER targeted SCT constructs (environment, emotional coping, expectations, self-control, self-efficacy); Healthy Lifestyles was knowledge-based only							T3: 60 wks T4: 112 wks					
Natale, 2014[61]	Healthy Inside-Healthy Outside (HI-HO) • Culturally sensitive, multi-dimensional intervention with teacher-and family-based components as well as environmental changes in childcare centers for improved nutritional intake • Teacher component included two trainings for integrating nutrition into lessons and technical assistance visits from intervention staff • Parent component included monthly educational dinners led by dietitians, newsletters and at-home activities • Childcare centers changed school menus and physical activity policies	Socio-ecological model	School, Family	26	NR	T2: 75% T3: 58%	Attention control – injury prevention	T1: 3 mos T2: 6 mos T3: 12 mos	0 0 0	0 0 0	0 0 +*	0 + 0	No
O'Dwyer, 2013[62]	Active Play Intervention • Active curriculum delivered using a 2–2-2 approach: 2 wks led by active play specialists, 2 wks of co-instruction including preschool staff with active play staff, 2 wks	Socio-ecological model	School	6	NR	T1: 99% T2: 91%	Usual PA provision from the schools and a resource pack for schools	T1: 6 wks T2: 6 mos		0 0	0 0		No

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	of independent instruction by preschool staff • Wkly sessions lasted about 60 min.												
Reilly, 2006[63]	Movement and Activity Glasgow Intervention in Children (MAGIC) • Three 30-min physical activity sessions/wk delivered by trained school staff • Home-based component included materials for parents about increasing physical play and reducing TV time	Health education model	School, Family	24	83% of scheduled sessions offered at schools; 71% of children	T1: 88% T2: 93%	Treatment as usual – standard school curriculum	T1: 6 mos T2: 12 mos	0 0	0 0	0 0		No
Skouteris, 2016[64]	MEND 2–4 (Mind, Exercise, Nutrition…Do it!) • 10 wkly 90 min workshops on nutrition, physical activity, and parenting delivered by community team members (e.g., maternal and child health nurse, childcare worker) • Each session included three parts: (1) 30 min of guided active play; (2) 15 min of healthy snack to increase exposure to and acceptance of fruit and vegetables, and (3) 45 min of supervised creative play activities for youth while parents attended an education and skill development session	Learning, SCT	Family	10	Parent-child dyads attended 7.75 of 10 sessions, with 82% attending ≥ 7 sessions	T1: 93% T2: 96% T3: 96%	Wait-list control	T1: 10 wks T2: 6 mos T3: 12 mos	0 0 0	0 0 0	0 0 0	+ 0 0	No
Smith, 2015[65]	Family Check-Up • 3-session intervention tailored to the needs of the family including an initial contact session, a home-based multi-informant ecological assessment, and a feedback session • Feedback emphasized parenting/ family strengths and identified areas of change • Intervention targeted positive behavior support strategies (e.g., positive reinforcement)	Socio-ecological model	Family	3 sessions	75% participated in feedback session	NR	Treatment as usual – standard WIC services	T1: 3 yrs† T2: 5 yrs† T3: 7.5 yrs† T4: 8.5 yrs† T5: 9.5 yrs†	+* +* +* +*			+ +*	Med ✓ Mod ✓
Childhood (6–11 years)													

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
Adab, 2015, 2018[66,67]	West Midlands Active Lifestyle and Healthy Eating in Schoolchildren (WAVES study) • Intervention included four components: (1) 30 min of additional moderate-to-vigorous physical activity during each school day; (2) cooking workshops during school time, with parents invited to participate; (3) a 6-wk program (Villa Vitality) delivered by staff from a sporting institution on healthy eating and physical activity; (4) information handouts for families on ways to be active in the summer and local opportunities for physical activity	NR; general behavioral strategies	School, Family	52	NR	T1: 85% T2: 78% T3: 33%	Usual school health curriculum	T1: 3 mos T2: 18 mos T3: 27 mos	0 0 0	0 0		0 0	Mod ✓
Anderson, 2016; Kipping, 2014; Lawlor, 2011, 2016[68–71]	The Active for Life Year 5 (AFLY5) • Intervention was adapted from US-based intervention (Planet Health and Eat Well Keep Moving) and included the following components: 1) training for classroom teachers; 2) 16 lesson plans and teaching materials including pictures, CDs and journals; 3) 10 parental-child interaction homework activities; 4) information in the school newsletters about the importance of increasing physical activity, reducing sedentary behavior and improving diet; 5) written information for parents on how to encourage child healthy eating and physical activity	SCT	School	30	NR	T1: 56–96% T2: 49–93% (for collecting different outcome measures)	Schools receiving delayed intervention	T1: 12 mos T2: 24 mos	0 0	0 0	+ 0	+ 0	Med ✓
Annesi, 2017[72]	Youth Fit 4 Life • After school care-based intervention led by trained after school care counselors to improve physical activity and nutrition • Intervention was delivered during school days and each 45 min lesson consisted of a warm up, physical activity games, self-management/self-regulatory skills (e.g., productive self-talk,	SCT, self-efficacy theory	School	24	NR	T2: 86%	After school care as usual	T1: 3 mos T2: 9 mos	+ +	+ +			Med ✓ Mod ✓

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	recruiting social support, deep breathing) and nutrition education												
Arredondo, 2018; Ayala, 2015; Horton, 2013[73–75]	Entre Familia: Reflejos de Salud • Promatora-delivered intervention that targeted fruit and vegetable intake through modifying parent health behaviors, parenting strategies, and other family/ household influences on children's dietary intake • Intervention consisted of 11 home visits and 4 phone calls: home visits were 1.5–2 hrs and involved watching a telenovela, family discussion of key themes, a goal-setting activity, and fun family activity to teach behavioral skills; phone calls were 15–30 min check-ins with mothers on family progress	SCT, Family Systems Theory	Family	16	97% received an average dose of 16.5 hrs	T1: 89% T2: 91%	Delayed intervention control	T1: 4 mos T2: 10 mos				+ +	Med ✓
Bere, 2006a, 2006b, 2007, 2014, 2015; Overby, 2012[76–81]	Fruits and Vegetables Make the Marks • Three components (classroom, parental involvement, school fruit program) delivered over 7 months in two Norwegian counties (effects are reported separately by county at T1 and T2) • Classroom component included a curriculum delivered by home economics teachers on the health benefits of fruits and vegetables and preparation of dishes with fruits and vegetables; students self-monitored intake for three days • Parental involvement included newsletters for parents to increase communication on fruits and vegetables; parents were also invited to attend meetings at school • Free school fruit subscription program provided a fruit or carrot each school day to enrolled students	SCT	School	28	NR	T1: 92% T3: 82% T5: 16%	No intervention control schools	T1: 1 yr T2: 2 yrs T3: 3 yrs T4: 6 yrs T5: 7 yrs	0 0			0/+ 0/+ + + +	Med as Outcome Mod ✓
Berry, 2012, 2014, 2018[82–84]	Family Partners for Health • Two-phase nutrition/exercise and coping skills intervention that	SCT	Family	52	NR	T3: 58%	Wait list control	T1: 3 mos	0 0 0	0 0 0		+ 0 0	Mod ✓

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	included 21 contacts:12 wks of wkly contact followed by 9 months of monthly contact • Each contact involved parents and children attending 60 min of nutrition/exercise education and coping skills training taught by a nurse practitioner or registered dietitian followed by 45 min of exercise taught by a certified trainer							T2: 12 mos T3: 18 mos					
Best, 2016; Wilfley, 2007[85,86]	Family-based behavioral treatment • After the standard 5 months of family-based weight loss treatment, families were randomly assigned to three groups: behavioral skills maintenance (16 wks), social facilitation maintenance (16 wks), or no-further treatment • The 5-month weight loss intervention focused on dietary modification, physical activity increases, and behavior change skills • The behavioral maintenance condition took a cognitive-behavioral approach to weight maintenance that emphasized self-regulation and relapse prevention • The social facilitator maintenance condition took a social-ecological approach to weight maintenance that encouraged parents to facilitate child peer networks that would support healthy lifestyle behaviors; it also targeted peer (e.g., teasing) and self-perceptual (e.g., body image) factors	Behavioral Choice Theory, Cognitive Behavioral approach, socio-ecological model	Family	36	Families attended a median of 68–75% of sessions across conditions	T1: 74% T2: 69% T3: 63% T4: 61%	No-further treatment control	T1: 5 mos T2: 9 mos T3: 17 mos T4: 29 mos	+ + 0 +			+* +* +*	Med as Outcome Mod ✓
Boutelle, 2011[87]	Parent-only Treatment • Based on FBT developed by Epstein and colleagues • Wkly 60-min parent-only group sessions that included information on dietary modification (traffic-light diet), physical activity, and behavioral/positive parenting skills	Behavioral Choice Theory	Family	~22	NR	T1: 65% T2: 65%	Parent + child treatment	T1: 5 mos T2: 11 mos	+NI +NI	+NI +NI		0 0	No

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	(e.g., self-monitoring, positive reinforcement, stimulus control, preplanning, modeling)												
Boutelle, 2015, 2017[88,89]	The Family, Responsibility, Education, Support and Health (FRESH) Study • Parent-based treatment included twenty 60-min parent-only groups + 30 min individual parent meeting with behavioral coach • Group sessions covered information on diet, physical activity, and behavioral/parenting strategies	Behavioral Choice Theory	Family	26	12.2 ± 6.3 sessions for parent-based treatment; 14.6 ± 5.0 for family-based treatment	T1: 83% T2: 83% T3: 85% T4: 87%	Family-based treatment (parent + child)	T1: 3 mos T2: 6 mos T3: 12 mos T4: 18 mos	+ NI + NI + NI	+ NI +NI + NI		+ NI + NI + NI	No
Broccoli, 2016; Davoli, 2013[90,91]	MI to Treat Overweight Children • Five MI sessions delivered by pediatricians at 1, 4, 7, and 12 months after the baseline visit • Parents and children left each session with two clearly defined goals (one related to food, the other related to physical activity)	TTM of addiction and behavioral change, MI	Family	52	94% completed all 5 sessions	T1: 95% T2: 91%	Usual care with additional booklet covering health information	T1: 12 mos T2: 24 mos	+ 0		+ 0	+ 0	Med ✓
Christison, 2016[92]	Exergaming for Health • Community-based weight management program that included facilitated group activity with exergaming (activity-promoting video games) and family didactics on nutrition and behavior modification • The program included 10 wkly 2-hr sessions comprised of "exergaming" done in a group setting and led by volunteer medical students, nutrition sessions facilitated by a dietitian, and counseling sessions on various topics (e.g., positive body image, family communication, parenting, behavior change) led by a licensed social worker	Family Systems Theory, SCT	Family	26	8.8 ± 1.2 sessions for exergaming condition; 7.5 ± 1.9 for control group	T2: 57%	Didactics only (no exergaming) comparison condition	T1: 10 wks T2: 6 mos	0 0	0	0	-	No
Crespo, 2012[93]	Aventuras Para Niños Study • 13 schools randomized to one of 4 conditions: Family-only environmental change (Fam only);	SCT, Health Belief Model, Structural	Family, School, Community	156	Fam only: 53% received all in home visits, 13%	T3: 55%	No treatment control	T1: 1 yr T2: 2 yrs	0* 0* 0*	+*	+*	+	Med ✓

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	Community-only environmental change (Com only); Family-plus-Community environmental change (Fam+Com) and control condition • Family intervention consisted of seven monthly home visits and four calls by promatoras to discuss barriers, goal-setting, and monitoring • Community interventions consisted of playground improvements, increased availability of PE equipment, salad bars, newsletters and posters on healthy eating changes, and changes in teachers' class practices (e.g., non-food rewards); improvement of community parks; healthy child menus at local restaurants	Model of Health Behavior			received booster calls			T3: 3 yrs					
Curtis, 2012[94]	The Family Food and Health Project • Compared three interventions led by dietitians • Intervention A: Education only; families attended a single health fair aimed to increase awareness of low fat starchy foods, identify appropriate portion sizes and emphasize health benefits of consuming these foods • Intervention B: Cooking skills only; families participated in four cook and eat sessions that covered meal planning, food preparation and cooking Intervention C: Education + cooking skills + personalized goal setting based on the stages of change model	Stages of Change Model	Family, Community	~ 6	NR	T1: 75% T2: 63% T3: 40%	Intervention A (education only); Intervention B (cooking skills only)	T1: 3 mos T2: 6 mos T3: 18 mos				+ 0 +	No
Dietrich, 2008[95]	PRESTO • School-based intervention delivered by a multi-professional team (physician, psychologist, nutritionist, exercise physiologist) • Intervention included 12 wkly classes (9 nutrition, 2 health related, 1 final session with a	NR	School	14	NR	T1: 88% T2: 80%	Usual care of standard class curriculum	T1: 14 wks T2: 10 mos	0 0				No

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	healthy school lunch) and used "a playful experience-oriented learning" approach (e.g., learning through sensory exercises)												
Epstein, 2000a, 2012[96,101]	Family-based behavioral treatment (FBT) • Standard FBT includes: ◦ A combination of wkly, biwkly and monthly sessions ◦ Individual therapy (15–30 min) followed by separate parent and child group meetings (30 min) ◦ Weigh-ins for participating family members ◦ Parent and child workbooks containing information on weight control, self-monitoring, the Traffic Light Diet, and behavior change techniques ◦ Behavioral and positive parenting strategies for improving lifestyle behaviors (e.g., praise, reciprocal contracts, goal-setting) • In this study, families were randomized to one of four groups that varied by targeted behavior (sedentary behaviors vs. physical activity) and treatment dose (low vs. high)	Behavioral Choice Theory	Family	26	91–100% of participants attended ≥ 50% of sessions across the four conditions	T3: 82–91% across the four conditions	Decrease sedentary groups (low vs. high dose)	T1: 6 mos T2: 12 mos T3: 24 mos	0 0*	0*	0*		Mod ✓
Epstein 2000b, 2012[97,101]	Family-based behavioral treatment (FBT) • Standard FBT (see Intervention Description for Epstein, 2001a) • In this study, families were randomized to three groups: standard FBT + parent and child problem solving, standard FBT + child only problem solving, or standard FBT with no additional problem solving	Behavioral Choice Theory	Family	26	NR	T1: 97% T2: 89% T3: 85%	Standard FBT with no additional problem solving	T1: 6 mos T2: 12 mos T3: 24 mos	-*				Mod ✓
Epstein, 2001a[98]	Childhood Weight Control and Prevention Programs • Standard FBT (see Intervention Description for Epstein, 2001a) • In this study, families were randomized to two groups: standard FBT focused on	Behavioral Choice Theory	Family	26	82% of sessions attended for fruit and vegetable group; 87% of sessions	T1: 90%	Decrease fat and sugar intervention	T1: 12 mos				0	No

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	increasing fruits and vegetables or standard FBT with a focus on decreasing fat and sugar				attended for fat and sugar group								
Epstein, 2001b[99]	Family-based behavioral treatment (FBT) • Standard FBT (see Intervention Description for Epstein, 2001a) • In this study, families were randomized to two groups: standard FBT focused on the combination of reducing sedentary behavior and increasing physical activity or standard FBT focused on increasing physical activity only	Behavioral Choice Theory	Family	26	NR	NR	Increase physical activity intervention	T1: 6 mos T2: 12 mos	+				Mod ✓
Epstein, 2004, 2012[100,101]	Family-based behavioral treatment (FBT) • Standard FBT (see Intervention Description for Epstein, 2001a) • In this study, families were randomized to two groups: standard FBT that reinforced reduced sedentary behavior or standard FBT that used stimulus control for reducing sedentary behavior See Intervention Description for Epstein, 2000a	Behavioral Choice Theory, Behavioral Economics Theory	Family	26	85% attended > 50% of sessions across the two groups	T2: 83%	Stimulus control for reducing sedentary behavior	T1: 6 mos T2: 12 mos	0 0*	0	0	0	Mod ✓
Forneris, 2010[102]	Goals for Health • Goal-setting and life skills intervention adapted from an existing life skills program (Going for the Goal) • The 12-wk curriculum was delivered by peer leaders (high school students) to middle school students	Life Dev Intervention framework; life skills	School	12	NR	T1: 86% T2: 67% T3: 47%	Wait-list control	T1: 3 mos T2: 1 yr T3: 2 yrs				0 0 0	No
Fulkerson, 2015[103]	(HOME) Plus Study • 10 monthly group sessions and five goal-setting telephone calls delivered by registered dietitians and a public health nurse; phone calls were ~20 min and providers used MI	SCT, socio-ecological model, MI	Family	40	68% for group sessions; 87% for goal-setting calls	T1: 93% T2: 89%	Monthly family-focused newsletter only	T1: 12 mos T2: 21 mos	0 0				Mod ✓

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	• The intervention targeted family change in the planning, frequency and healthfulness of family meals/ snacks and limiting screen time during meals • Families received a guidebook with session topics, behavior change strategies, recipes and community resources												
Griffin, 2015[104]	• Two 45-min interactive educational sessions on sugar intake and the content of food and beverages delivered in the classroom by the lead author • The first session included sugar education, a description of the sugar content of food and beverages, and the importance of minimizing sugar intake for health. The second session (7–10 days later) reinforced health messages about sugar and described energy balance	NR	School	4	NR	NR	No intervention control schools	T1: 4 wks T2: 10 wks T3: 34 wks				0 0 0	No
Jago, 2013, 2015; Sebire, 2016[105–107]	Bristol Girls Dance Project • After school dance intervention that included forty 75 minute sessions (2 sessions/wk) • The dance program targeted increases in girls' autonomy, competence, and belongingness and provided exposure to diverse dance styles • Participants were given a "dance diary" to set goals and reflect between dance sessions	SDT	School	20	9.1 students per school attended 66% of all sessions; average 12.8 ± 7.0 girls per session (max = 32)	T1: 99% T2: 98%	No intervention control schools	T1: 20 wks T2: 52 wks		0 0			Med as Outcome
Kalarchian, 2009[108]	Family-based behavioral weight management • Based on FBT developed by Epstein and colleagues • Twenty 60-min group meetings with separate parent and child groups • Families were given a modified version of the Stoplight Eating plan and taught behavioral strategies (e.g., self-monitoring, positive reinforcement, stimulus	Behavioral Choice Theory	Family	26	51% of families attended ≥ 75% of sessions	T1: 84% T2: 72% T3: 84%	Usual care with wo additional nutrition consultation sessions	T1: 6 mos T2: 12 mos T3: 18 mos	+ 0 0				No

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	control, preplanning, modeling) for increasing physical activity and decreasing sedentary behavior												
Kalavainen, 2007, 2011[109,110]	• Fifteen 90-min sessions held separately for parents and children, with one joint session focused on preparing healthy snacks • The program focused on promoting a healthy lifestyle rather than on weight management • Parents and children received manuals and workbooks, respectively, adapted from Magnificent Kids and Magnificent Teens materials and a cognitive behavior therapy workbook • Child sessions consisted of non-competitive physical activities	Principles of behavior and solution-oriented therapy	Family	26	87–99% participation rate in sessions	T1: 97% T2: 99% T3: 99% T4: 97%	Health booklets for families and two individual counseling sessions with children by school nurses	T1: 6 mos T2: 1 yr T3: 2 yrs T4: 3 yrs	+ + 0 0				No
Khanal, 2016; Welsby, 2014[111,112]	Go4Fun Programme (Adapted from the UK Mind Exercise Nutrition Do It (MEND) program) • 10 wkly 2 hr sessions attended by parents and children once per wk • During the first hr, parents and children met together; during the second hr, children engaged in physical activity while parents engaged in facilitated discussions • Sessions included behavioral skills (e.g., goal-setting, rewards, problem solving, role modeling)	SCT	Family	10	Once per wk participants attended 71.2% of sessions; twice per wk attended 69.2% of sessions	T1: 66% T2: 41%	Twice per wk family-based program	T1: 10 wks T2: 6 mos	0 0	+			No
Kriemler, 2010; Meyer, 2014[113,114]	KISS Program • Multi-component physical activity program delivered in school that included structuring the three existing PE classes, adding two more PE classes/wk, engaging in daily short activity breaks during regular classes (e.g., motor skill tasks such as jumping or balancing on one leg), and assigning daily physical activity homework of ~10 min	Socio-ecological model	School	36	NR	T1: 96% T2: 60%	No intervention control schools	T1: 9 mos T2: 3 yrs	+ 0	+ 0			Mod ✓

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
Laukkanen, 2015, 2017[115,116]	InPact • Individually tailored physical activity counseling aimed at increasing leisure time physical activity in adults and in their young children • The intervention was delivered with a combination of a lecture, face-to-face discussions, and phone consultations • The intervention provided parents with instruction and information on benefits of physical activity, encouraged parents to be role models, set goals, and provide support for their children, and problem solve barriers	SCT, Theory of Planned Behavior	Family	26	NR	T2: 70% T4: 65%	No counseling control	T1: 3 mos T2: 6 mos T3: 9 mos T4: 12 mos		-* -* -* -*	0* 0* 0* 0*		Mod ✓
Llargues, 2011; Mora, 2015[117,118]	AVall • Teachers were trained on the Investigation, Vision, Action, and Change educational method • Intervention schools were given educational material on healthy food and on games to promote physical activity during break times • Every classroom used 3 hrs/wk to develop activities related to healthy lifestyle behaviors • Parents attended an information session at the beginning of the intervention. Each family also received monthly recipes, a guide of the local areas to exercise, and recommendations of books about balanced eating	Investigate, Vision, Action, and Change educational method	School	104	NR	T1: 85% T3: 71%	No intervention control schools	T1: 2 yrs T2: 4 yrs T3: 6 yrs	+ + +				Mod ✓
Magarey, 2011[119]	Parenting Eating and Activity for Child Health (PEACH) • Healthy lifestyle education with parenting skills training delivered across twelve 90-to 120-min group sessions (4 focused on positive parenting, 8 focused on healthy lifestyle) plus four additional telephone calls • The Positive Parenting Program (Triple P) was delivered in four group sessions and focused on	Social Learning principles, Child Dev Theory	Family	26	43% attended ≥ 12 of 16 sessions; 46% attended 5–11 sessions	T1: 80% T2: 73% T3: 60% T4: 63%	Healthy lifestyle education without specific parenting skills training	T1: 6 mos T2: 12 mos T3: 18 mos T4: 24 mos	0* 0* 0* 0*				Med as Outcome

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	ensuring a safe and positive learning environment and using appropriate discipline • Eight subsequent healthy lifestyle sessions included food recommendations, skills for healthy eating, reduced sedentary behavior and increased activity, monitoring of behaviors and support strategies												
McManus, 2008[120]	• The educational group completed a two-wk education program covering heart rate monitor skills, information about heart health, goal-setting, and role plays; the no educational group completed PE classes without physical activity or heart health education • Following the educational program, children in both the educational group and no educational group completed two wks of wearing heart rate feedback devices and two wks without heart rate feedback devices	Health Belief Model, SCT, Diffusion and Innovation Theory	School	6	NR	T3: 96%	No-educational program control and no intervention control	T1: 4 wks T2: 6 wks T3: 6 mos		0 * 0 * 0 *			No
Morgan, 2019[121]	Dads and Daughters Exercising and Empowered Program (DADEE) • Physical activity intervention for fathers and daughters delivered by research staff at a local university across eight 90-min sessions • Sessions included combined education for fathers and daughters (15 min), father-only and daughter-only education sessions (30 min), and a combined practical physical activity session (45 min); fathers and daughters also received take-home resources (e.g., dad's log book with tasks to promote physical activity, a sport equipment pack, pedometers, access to an app at the end of the program)	SDT, SCT	Family	8	93% of fathers and 89% of daughters attended 7 of 8 sessions	T1: 93% T2: 88%	Wait-list control	T1: 2 mos T2: 9 mos	0 0	+ +	+ +		No
Nyberg, 2011, 2015[122,123]	Healthy School Start Study • Intervention included three components: 1) a health	SCT, MI	Family, School	26	NR	T2: 98%	Wait-list control	T1: 6 mos	0 0	0 0	0 0	+ +	Mod ✓

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1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	information brochure for parents divided into seven topics (e.g., parental feeding practices, heathy food and family meals, physical activity, fruits and vegetables); 2) two 45 min MI sessions with the parents; and 3) ten 30 min teacher-led classroom activities with corresponding child homework (teachers provided with tool box that included food models and educational materials)							T2: 12 mos					
Reinehr, 2010, 2018; Schaefer, 2011[124–126]	"Obeldicks light" • Group-based intervention delivered by therapists that consisted of 1.5 hrs/wk physical activity training, nutrition education, and behavior counseling for parents and children. • The first three months of the intervention ("intensive phase") involved 6 wkly 1.5-hr nutrition/ eating behavior sessions based on cognitive-behavioral principles for children and separate parent meetings. Families also had a 30 min individual nutrition counseling session. • The second three months of the intervention ("establishing phase") involved one additional individual nutrition counseling session and three individual behavior counseling sessions for parents and children.	NR; cognitive behavioral approach	Family	26	NR	T3: 42%	No intervention control	T1: 6 mos T2: 18 mos T3: 7 yrs	+ + * + *	+	0	+	No
Robertson, 2013, 2017[127,128]	Families for Health V2 (FFH) • 10 wkly 2.5 hr sessions (and two follow-up sessions) held at a community center with parents and children attending separate, parallel groups • Intervention was led by facilitators with backgrounds in nursing, teaching, youth work, leisure services and nutrition • Intervention covered parenting skills (based on the Nurturing Programme for Family Links),	NR	Family	10	63% of families completed ≥ 5 of 10 sessions	T1: 80% T2: 72%	Usual care available in the area (e.g., One Body One Life program, Choose It, Weight Watchers for young people, MEND)	T1: 3 mos T2: 12 mos	0 -	0	0	0 0	Med as Outcome

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	social and emotional development, and lifestyle change through discussions, role-plays, goal-setting, skill practice, and homework												
Salmon, 2005, 2008[129,130]	Switch-Play • Schools randomized to one of four conditions: behavioral modification only, fundamental motor skills only, combined behavioral modification and fundamental motor skills, and usual classroom lessons • Behavioral modification consisted of 19 lessons designed to encourage children to reduce screen time and identify physical activity alternatives • Fundamental motor skills consisted of 19 lessons focused on mastery of 6 motor skills (e.g., running, throwing, jumping, kicking) • The combined group received all lessons from behavioral modification and motor skills groups. • Lessons were delivered by PE teachers and lasted 40–50 min each	SCT, Behavioral Choice Theory, socio-ecological model	School	36	88% lessons attended	T3: 88%	Usual classroom lessons	T1: 9 mos T2: 15 mos T3: 21 mos	+ + +	+ + +	- - -			Mod ✓
Tarro, 2014a, 2014b; Llauradó, 2018[131–133]	Educació en Alimentació (EdAl) • School-based intervention that included three components: 1) educational intervention activities focused on eight lifestyle topics delivered by university students acting as “health promoting agents;” 2) teaching practice delivered by the health promoting agents and regular school teachers using specially-designed booklets which focused on the lifestyle topics presented during educational activities; 3) parental involvement through joint parent-child healthy activities	NR	School, Family	112	NR	T1: 83% T2: 62% T3: 36%	No intervention control schools	T1: 3 yrs T2: 5 yrs T3: 7 yrs	+ + +	+ + 0	0 + 0	0 +		No

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
Yackobovitch-Gavan, 2018[134]	• Participants randomized to one of three conditions: parents-only group (parents-only group meetings), parents-child group (separate parent and child group meetings), and a no intervention control • The family-based interventions involved wkly 1-hr sessions with a dietitian and psychologist focused on cognitive-behavioral skill-building specific to different physical activity or dietary goals (e.g., reducing fast food, limiting sweetened beverages, increasing physical activity, limiting screen time)	NR; targeted cognitive-behavioral changes	Family	12	Families attended a median of 6 (parents-only group) and 7 (parents-child) sessions	T1: 68% T2: 51%	No intervention control	T1: 3 mos T2: 24 mos	0 0	0 0	0 0	0 0	No
Early-to Mid-Adolescence (12–15 years)													
Black, 2010[136]	Challenge! • 12-session intervention delivered in the home by college-enrolled African American mentors trained in MI • Sessions included goal-setting, self-monitoring, evaluation/ revision of physical activity and diet, preparing healthy snacks, engaging in physical activity; rap music video promoting healthy physical activity and diet; field trips to community sites with mentor (e.g., convenience stores, parks)	SCT, MI	Individual, Community	43	52% attended ≥ 10 of 12 sessions; 33% attended 4.6 ± 2.7 sessions	T1: 78% T2: 76%	No intervention control	T1: 10 mos T2: 24 mos	0 +	+ 0		+ +	Mod ✓
Christiansen, 2017; Toftager, 2011, 2014[137–139]	School site, Play Spot, Active transport, Club fitness and Environment (SPACE) Study • Multicomponent intervention that included organizational and physical environment changes to the school in three areas: after school fitness program, active school transport, and recess • Organizational changes included policies for promoting physical activity in school (e.g., mandatory outdoor recess), education of	Social ecological models of behavior change	School	~52	NR	T1: 65%	No intervention control schools	T1: 6 mos		+			Mod ✓

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	students as traffic ad play patrols, education of teachers as “recess kick-starters” Physical environment changes included remodeled/ redesigned outdoor areas, “playspots” (playgrounds) appropriate for adolescents, club fitness												
Christie, 2011, 2017[140,141]	The Healthy Eating and Lifestyle Programme (HELP) • Twelve 40–45 min sessions with adolescents and their families using MI and solution-focused approaches • Delivered in local community settings by trained graduate mental health workers • Sessions targeted ‘where and how we eat’ (eating behaviors, regular eating patterns), ‘what we do’ (sedentary behaviors, physical activity), ‘what we eat’ (healthy food choices), and ‘why we eat (emotional eating)	MI	Family	26	31% attended all 12 sessions; 79% attended ≥ 6 of 12 sessions	T1: 78% T2: 83% T3: 66%	Enhanced standard care with a 40–60 min educational session	T1: 13 wks T2: 26 wks T3: 52 wks	0 0				No
Collins, 2014; Dewar, 2013, 2014; Lubans, 2010, 2012[142–146]	Nutrition and Enjoyable Activity for Teen Girls (NEAT Girls) • Multicomponent school-based intervention that included forty 90-min school sport sessions, three 30-min interactive seminars, three 90-min nutrition workshops, thirty 30-min lunchtime physical activity sessions, nutrition/physical activity handbooks, four parent newsletters, pedometers for self-monitoring, and text messaging for social support • Targeted constructs included: outcome expectations, social support, self-efficacy, physical self-perception, and intentions	SCT	School	52	Girls attended 61% of school sports sessions, 65% of nutrition workshops, 25% of lunch sessions, and completed 9% of home challenges	T1: 82% T2: 66%	Wait-list control schools provided with equipment packs	T1: 12 mos T2: 24 mos	0 +	0 0	+ 0	0 0	Med as Outcome
Debar, 2012[147]	Primary care-based, multicomponent lifestyle intervention for overweight adolescent females • 16 group sessions for teens (wkly for 3 months, biwkly during	NR	Individual, Family, Primary Care	22	Adolescents attended 10.3 ± 5.1 of 16 intervention sessions; parents	T1: 94% T2: 83%	Usual care with packet of weight management and healthy	T1: 6 mos T2: 12 mos	+* +*	0* 0*	0* 0*	+* +*	No

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	months 4 and 5; 90 min each) led by trained interventionists that included: strategies for changing dietary intake and eating patterns, strategies for increasing PA and practice of developmentally tailored forms of exercise (yoga, dance), discussion of issues associated with obesity (depression, disordered eating, body image) • 12 group sessions for parents during first 3 months that covered similar content to teen groups and encouraged parents to provide support and autonomy-supportive monitoring • Training for primary care providers on motivational enhancement techniques to support behavioral weight management goals and two provider-teen sessions at baseline and post-treatment				attended 7.9 ± 3.9 of 12 sessions		lifestyle materials						
Demol, 2009[148]	Low-carbohydrate versus high-carbohydrate diet for adolescents in the obese weight range • Compared low-carbohydrate diets with varying fat and protein rations with a high-carbohydrate, low fat diet • Participants attended wkly sessions for 3 months with a dietician and psychologist. • They received menus, detailed instruction according to their diet group, and a general recommendation to engage in physical activity. • At the end of the 3 months, participants were given new menus and instructions for a high carbohydrate, low fat maintenance diet	NR	Individual	12	NR	T1: 71–83% T2: 41–61%	High-carb, low-fat diet	T1: 12 wks T2: 52 wks	0 0				No
Ebbeling, 2012[149]	Home delivery of noncaloric beverages • Intervention included home delivery of noncaloric beverages	NR	Individual, Family	52	NR	T1: 97% T2: 93%	No home delivery of non-caloric beverages;	T1: 12 mos T2: 24 mos	+ 0	0 0	+ +	+ +	Med ✓ Mod ✓

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	(water, “diet” beverages) every 2 wks, monthly motivational phone calls with parents, and three check-in visits • Noncaloric drink delivery came with instructions to drink the delivered beverages and not to buy or drink sugar-sweetened beverages • Telephone calls and check-in visits focused exclusively on beverage consumption; no attention was given to other dietary behaviors or to physical activity						control participants mailed $50 supermarket gift cards at 4 and 8 mos						
Jago, 2006[150]	Boy Scout Fit for Life Badge Program • 9 wkly boy scout troop meetings led by trained staff that included a combination of a troop knowledge activity (e.g., types of fitness), physical activity, and Internet programming to increase self-efficacy/behavioral skills • Boys were encouraged to log onto a website 2x/wk; the website used comic characters and facilitated goal-setting, self-monitoring, and problem solving to enhance self-regulation; boys could earn points towards badges for meeting goals • Boys were taught “asking skills” for eliciting social support from parents	SCT	Individual, Community	9	Average troop attendance 81%; 75% logged in to study website at least 1x/wk	T1: 96% T2: 88%	Boy Scout 5-a-Day Badge Program for increasing fruit and vegetable intake (see Thompson, 2009)	T1: 9 wks T2: 8 mos	0 0	+ 0	+ 0		Med as Outcome
Jelalian, 2010; Lloyd-Richardson, 2012[151,152]	Cognitive Behavioral Therapy with Peer-Enhanced Adventure Therapy • 16 wkly 1-hr group sessions led by trained graduate students • Parents and adolescents attended separate sessions followed by 4 biwkly maintenance sessions • Sessions focused on behavioral skill building (self-monitoring, stimulus control, relapse prevention) and adolescents were prescribed calorie deficits for weight loss; parents also received	Cognitive Behavioral Therapy	Individual, Family	20	Average of 83% of sessions attended by participants	T1: 85% T2: 79% T3: 75%	Cognitive Behavioral Weight Control Treatment with supervised aerobic exercise	T1: 16 wks T2: 12 mos T3: 24 mos	0 0 0				Med as Outcome

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								Time point	BMI	PA	SB	Diet	
	information on supporting adolescent behavior change • Peer-enhanced adventure therapy included a warm-up, a group challenge with physical and mental components for building social and problem-solving skills												
Lubans, 2016; Smith, 2014a, 2014b, 2017[153–156]	Active Teen Leaders Avoiding Screen Time (ATLAS) • Multicomponent school-based intervention that included the provision of school fitness equipment, two 5-hr teacher professional learning workshops, three 20-min researcher-led student seminars, twenty 90-min teacher-delivered physical activity sessions, six 20-min student-led lunch-time physical activity leadership sessions, four parent newsletters, pedometers for self-monitoring, and a web-based smartphone application • Targeted constructs included: autonomy, competence, relatedness, and self-efficacy	SCT, SDT	School	20	NR	T1: 81% T2: 74%	No intervention control schools	T1: 8 mos T2: 18 mos	0 0	0 0	+ +	+ 0	Med ✓
Melnyk, 2013[157]	COPE Healthy Lifestyles TEEN • 15-session manualized educational and cognitive-behavioral skills-building program taught by classroom teachers that included a 15–20 min physical activity component in each class • Sessions covered self-esteem, positive self-talk, goal-setting, problem-solving, emotional and behavioral regulation, effective communication, personality and communication styles, and specific nutrition (e.g., portion sizes, snacking, eating out) and physical activity topics (e.g., stretching, heart rate) • Teens received a COPE manual with homework activities; four newsletters were sent home to parents	Cognitive theory	School	15	NR	T1: 86% T2: 78%	Healthy Teens: Attention control focused on safety and general health (e.g., road safety, dental/ skin care)	T1: 16 wks T2: 6 mos	+ +	+			No

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								Time point	BMI	PA	SB	Diet	
Mihas, 2010[158]	Vyronas Youth Regarding Obesity, Nutrition and Attitudinal Styles (VYRONAS) • 12 modules delivered by teachers and designed to develop behavioral capability, expectations and self-efficacy for healthy eating and food selection • Behavioral and motivational strategies (e.g., modeling, guided practice, problem-solving, goal-setting) were integrated into modules • Parents met with teachers to discuss the importance of healthy dietary habits • Students received workbooks that covered dietary issues, dental hygiene, and consumption attitudes	Social Learning Theory	School, Family	12	NR	T1: 95% T2: 88%	No intervention control schools	T1: 15 days T2: 12 mos	0 +			+ +	No
Resnicow, 2005[159]	Go Girls! • High intensity (20–26 sessions) culturally-tailored behavioral group sessions conducted at participating churches and led by a dietitian and exercise physiologist that each included an experiential activity, 30 min of physical activity, and healthy food preparation • Parents of participating girls were invited to attend every other group session • Girls received 4–6 MI phone calls • Girls also received a two-way paging device for sending and receiving messages about their target foods and physical activities	MI	Individual, Family, Community	26	Girls attended an average of 57% of sessions; average of 4 of 6 phone calls completed	T1: 84% T2: 73%	Moderate intensity (6 sessions) of Go Girls!	T1: 6 mos T2: 1 yr	0 0				No
Singh, 2006, 2007, 2009; Veitch, 2011[160–163]	Dutch Obesity Intervention in Teenagers (DOiT) • Intervention included curriculum and environmental changes in the school and targeted increases in student knowledge, awareness, skills, social support, self-efficacy • Curriculum included 11 lessons for biology and PE courses on energy-balance topics such as	Behavioral constructs from behavior change taxonomy	School	35	NR	T1: 93% T2: 85% T3: 82%	No intervention control schools	T1: 8 mos T2: 12 mos T3: 20 mos	+ 0 +	0 0 0	0 0 +	+ + 0	Med ✓ Mod ✓

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								Time point	BMI	PA	SB	Diet	
	reducing sugar sweetened beverages and reading nutrition labels • For environmental changes, schools were encouraged to offer additional physical activity options and advice on changes to the school cafeteria (e.g., offering smaller portions, offering healthier products, restricting access to vending machines).												
Savoye, 2007, 2011; Taylor, 2017[164–166]	Yale Bright Bodies Weight Management Program • Family-based intensive lifestyle intervention tailored for inner-city ethnic minority youth and their families • Sessions were jointly attended by parents and adolescents, occurred twice wkly for the first 6 months and twice monthly for the second 6 months, and included exercise (50 min 2x/wk) and nutrition/ behavior modification (40 min 1x/wk) • Physical activity portion was led by an exercise physiologist • Nutrition and behavior modification portions were led by a dietitian or social worker and included self-awareness, goal-setting, stimulus control, coping skills training, cognitive behavior strategies, and contingency management	NR; general behavioral strategies	Family	52	NR	T1: 67% T2: 60% T3: 36%	Usual care consisting of traditional clinical weight management counseling every 6 mos	T1: 6 mos T2: 12 mos T3: 24 mos	+ + +				Mod ✓
Thompson, 2009[167]	Boy Scout 5-a-Day Badge Program • 9 wkly boy scout troop meetings led by trained staff that included a combination of a troop knowledge activity (e.g., identifying and eating fruits and vegetables), preparation of healthy recipes/taste testing, and Internet programming to increase self-efficacy/behavioral skills • Boys were encouraged to log onto a website 2x/wk; the website used comic characters and	SCT	Individual, Community	9	Average troop attendance 81%; 78% logged in to study website at least 1x/wk	T1: 96% T2: 88%	Boy Scout Fit for Life Badge Program for increasing physical activity (see Jago, 2006)	T1: 9 wks T2: 8 mos				+/− 0	Med as Outcome

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	facilitated goal-setting, self-monitoring, and problem solving to enhance self-regulation; boys could earn points towards badges for meeting goals • Boys were taught “asking skills” for eliciting social support from parents												
Viggiano, 2015[168]	Kaledo • Board game intervention designed to increase nutrition education and improve dietary behavior • The intervention involved 15–30 minute game sessions in class once/wk • Games challenged players to balance energy intake and expenditure through learning about their basal metabolic rate, daily meals of the Mediterranean diet, and common daily activities	NR; behavior-focused nutrition education	School	20	NR	T1: 69% T2: 34%	No intervention control schools	T1: 6 mos T2: 18 mos	+ +	+ 0		+ 0	Med ✓ Mod ✓
Wilksch, 2015[169]	Media Smart; Life Smart; the Helping, Encouraging, Listening and Protecting Peers (HELPP) initiative • Three intervention conditions, all delivered across two 50-min lessons/wk by trained psychology graduate students; all interventions were designed to be interactive (e.g., role plays, small group discussions) and avoid psychoeducation about eating disorders and obesity • Media Smart: Targeted risk factors for eating disorders, including media internalization, perceived pressure to be thin/muscular, and weight concern • Life Smart: Targeted risk factors for both eating disorders and obesity, including dieting, meal-skipping, physical activity, sleep, perfectionism, emotion regulation, and social support • HELPP: Targeted risk factors for eating disorders, including media	NR	School	4	NR	T3: 77%	No intervention control	T1: 5 wks T2: 6 mos T3: 12 mos	0 0 0	+ + 0	+ + +		Mod ✓

1st Author, Publication Year	Intervention Description	Theory	Level	Duration (wks)	Attendance	Retention	Comparison Condition(s)	Between-group Differences					Med and/or Mod?
								Time point	BMI	PA	SB	Diet	
	internalization, perceieved pressure to be thin/muscular, appearance comparisons, and dieting												
Late Adolescence (16–18 years)													
Haire-Joshu, 2015[170]	Balance Adolescent Lifestyle Activities and Nutrition Choices for Energy (BALANCE) • Developed in partnership with Parent As Teachers program • Included three components delivered by trained parent educators: up to five home visits, up to five school based classroom-group meetings, and internet activities • Intervention targeted the intrapersonal environment (e.g., knowledge of high-risk patterns), interpersonal interactions among teen parents (e.g., problem solving), and the physical environment (e.g. improving school, home) • Content focused on replacing unhealthy behaviors with healthy ones	SCT, Ecological Framework	School	24	2.5 ± 1.9 home visits; 1.3 ± 1.6 classroom visits	T1: 69% T2: 51%	Treatment as usual	T1: 12 mos. T2: 24 mos.	0 0	0 0	0 0	0 0	No
Leme, 2015, 2016, 2018[171–173]	Healthy Habits, Healthy Girls – Brazil (“H3G-Brazil”) • Multicomponent school-based intervention that included the following: enhanced physical education classes, physical activities during recess, wkly nutritional and physical activity messages, nutrition and physical activity handbooks, interactive seminars, nutrition workshops, parents’ newsletters, text messages, and dietary and physical activity diaries for adolescent girls	SCT	School	26	88–99% attended enhanced PE, nutrition workshops, interactive seminars; 86% completed home challenges	T1: 75% T2: 57%	No intervention control schools	T1: 7 mos T2: 12 mos	0 0	0 0	+ -	+ 0	No
Mauriello, 2010[174]	Health in Motion • Three self-directed 30-min intervention sessions (baseline, 1 month, 2 months) in which students completed computer	TTM	School	8	90% received at least 3 sessions	T1: 91% T2: 72% T3: 79% T4: 66%	No treatment	T2: 2 mos. T3: 6 mos.		+ 0 0	0 0 0	+ + +	Med as Outcome

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								Time point	BMI	PA	SB	Diet	
	assessments and received corresponding stage-matched and tailored feedback for physical activity, fruit and vegetable intake, and TV viewing • Sessions included audio, video, and animations							T4: 12 mos.					

Note. T1 is the first assessment time point following baseline, T2 is the second time point following baseline, etc.

†Timepoints based on child age; studies received a rating of either +, -, 0; based on whether significant between-group effects in outcomes of interest were reported at the specified time point ("+" indicates a significant between-group difference in favor of the experimental condition; "-" indicates a significant between-group difference in favor of the comparison condition, "0" indicates no significant between-group difference);

*growth curve model or repeated measures ANOVA (+ reflects changes over time in slope, not necessarily a particular time point); Med (Mediator) and/or Mod (Moderator) = Intervention included a test for mediation and/or moderation; MI = motivational interviewing; NI = tests of non-inferiority, where "+" indicates the intervention is not inferior to the comparison treatment; SCT = Social Cognitive Theory; SDT = Self-Determination Theory; TTM = Transtheoretical Model