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Authors

Scott-Sheldon, Lori

Hedges, Larry

Cyr, Chris

et al.

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Childhood Obesity Evidence Base Project: A Systematic Review and Meta-Analysis of a New Taxonomy of Intervention Components to Improve Weight Status in Children 2–5 Years of Age, 2005–2019

Lori A.J. Scott-Sheldon, PhD,^{1,2} Larry V. Hedges, PhD,³ Chris Cyr, BS,⁴ Deborah Young-Hyman, PhD,⁵ Laura Kettel Khan, PhD,⁶ Mackenzie Magnus, MPH, MBA,⁴ Heather King, PhD,⁴ Sonia Arteaga, PhD,⁷ John Cawley, PhD,^{8,9} Christina D. Economos, PhD,¹⁰ Debra Haire-Joshu, PhD, RN,¹¹ Christine M. Hunter, PhD,⁵ Bruce Y. Lee, MD, MBA,¹² Shiriki K. Kumanyika, PhD, MPH,¹³ Lorene D. Ritchie, PhD, RD,¹⁴ Thomas N. Robinson, MD, MPH,¹⁵ and Marlene B. Schwartz, PhD¹⁶

Abstract

Objective: To evaluate the efficacy of childhood obesity interventions and conduct a taxonomy of intervention components that are most effective in changing obesity-related health outcomes in children 2–5 years of age.

Methods: Comprehensive searches located 51 studies from 18,335 unique records. Eligible studies: (1) assessed children aged 2–5, living in the United States; (2) evaluated an intervention to improve weight status; (3) identified a same-aged comparison group; (4) measured BMI; and (5) were available between January 2005 and August 2019. Coders extracted study, sample, and intervention characteristics. Effect sizes [ESs; and 95% confidence intervals (CIs)] were calculated by using random-effects models. Meta-regression was used to determine which intervention components explain variability in ESs.

Results: Included were 51 studies evaluating 58 interventions ($N=29,085$; mean age=4 years; 50% girls). Relative to controls, children receiving an intervention had a lower BMI at the end of the intervention ($g=0.10$, 95% CI=0.02–0.18; $k=55$) and at the last follow-up ($g=0.17$, 95% CI=0.04–0.30; $k=14$; range=18–143 weeks). Three intervention components moderated efficacy: engage caregivers in praise/encouragement for positive health-related behavior; provide education about the importance of screen time reduction to caregivers; and engage pediatricians/health care providers.

¹Centers for Behavioral and Preventive Medicine, The Miriam Hospital, Providence, RI, USA.

²Department of Psychiatry and Human Behavior, Alpert School of Medicine, Brown University, Providence, RI, USA.

³Department of Statistics, Northwestern University, Evanston, IL, USA.

⁴Impact Genome Project, Mission Measurement, Chicago, IL, USA.

⁵Office of Behavioral and Social Sciences, Office of the Director, National Institutes of Health, Bethesda, MD, USA.

⁶Division of Nutrition, Physical Activity, and Obesity, Centers for Disease Control and Prevention, Atlanta, GA, USA.

⁷Office of the Director, National Institutes of Health, National Institutes of Health, Bethesda, MD, USA.

Departments of ⁸Policy Analysis and Management and ⁹Economics, Cornell University, Ithaca, NY, USA.

¹⁰Division of Nutrition Interventions, Communication, and Behavior Change, Friedman School of Nutrition Science and Policy, Tufts University, Boston, MA, USA.

¹¹Center for Obesity Prevention and Policy Research, Brown School, Washington University, Saint Louis, MO, USA.

¹²CUNY Graduate School of Public Health and Policy, New York, NY, USA.

¹³Department of Community Health and Prevention, Dornsife School of Public Health, Drexel University, Philadelphia, PA, USA.

¹⁴Nutrition Policy Institute, University of California, Division of Agriculture and Natural Resources, Berkeley, CA, USA.

¹⁵Departments of Pediatrics and Medicine, Stanford Solutions Science Lab, Stanford University, Stanford, CA, USA.

¹⁶Department of Human Development and Family Studies, University of Connecticut, Hartford, CT, USA.

Conclusions: Early childhood obesity interventions are effective in reducing BMI in preschool children. Our findings suggest that facilitating caregiver education about the importance of screen time reduction may be an important strategy in reducing early childhood obesity.

Keywords: BMI; intervention; meta-analysis; prevention; taxonomy

Introduction

Childhood obesity is a major public health challenge, with one in three US children between the ages of 2 and 5 meeting criteria for overweight or obesity.¹ The urgency to reverse the course of childhood obesity has led to significant growth in the scientific literature evaluating childhood obesity interventions. Extant reviews of this research have provided limited guidance regarding strategies to reduce the rates of childhood obesity among preschool-age children living in the United States, because most reviews include children from a wide age range (*e.g.*, 2–18 years of age) and multiple countries; report varying outcomes measures (*e.g.*, BMI, nutrition, and/or physical activity); or are limited to a specific intervention setting (*e.g.*, schools).^{2–12} Traditional meta-analytic reviews often narrowly focus on the efficacy of childhood obesity interventions as a whole and do not address the conditions under which the intervention is most impactful.

The objective of this systematic review and meta-analysis is twofold: (1) to evaluate the scientific evidence regarding the efficacy of obesity interventions measuring BMI for children 2–5 years of age living in the United States and (2) to develop and apply a taxonomy of intervention components to identify specific components that increase the efficacy of these interventions in their context. Efficacy was measured as change in BMI, because it is the most commonly used indicator to assess overweight and obesity in children.¹³ We hypothesized that children receiving interventions to prevent obesity or improve weight status would experience less gain in BMI, or perhaps reductions in BMI, relative to children comparable in age, who did not receive the intervention.

Understanding childhood obesity programs requires developing methods not only to address the question of whether a given intervention works but also to better understand *what works, for whom, and under what conditions* intervention efficacy is improved.¹⁴ Childhood obesity prevention interventions are often evaluated as a whole, as opposed to the specific elements that comprise the interventions, which hinders effective implementation and dissemination of evidence-based approaches to reduce obesity (*cf* Ma et al.¹⁵). Therefore, a taxonomy of intervention components was developed by using the grounded theory^{16,17} to identify the specific content of the interventions and considered within the socioecological model (SEM).^{18,19} (A detailed description of the taxonomy development is described in the Methods paper for this project.¹⁹)

We also examined the extent to which the efficacy of the interventions depended on characteristics of the samples and methods. Hypothesized moderators included: (1) child

demographic characteristics (*e.g.*, proportion obese or overweight at baseline, race/ethnicity, and socioeconomic status); (2) elements of study or intervention design (*e.g.*, recruitment site, implementation setting, intervention recipient, content focus, and duration); and (3) intervention components (*e.g.*, provide education about nutrition and healthy eating patterns to caregivers, engage caregivers in supporting physical activities). We expected that childhood obesity interventions would be more effective when: (1) fewer children of low socioeconomic status or race/ethnic minorities (as healthy lifestyle changes are challenging for caregivers and children experiencing financial hardship²⁰ or living in disadvantaged neighborhoods²¹) or more children meeting criteria for overweight or obesity (given emerging evidence that individual differences in behavioral phenotypes for childhood obesity may impact the efficacy of obesity prevention and treatment interventions²²) were included in the study samples; (2) the sample was recruited from and the intervention was implemented in a school-based setting (as school-based interventions have been shown to be more effective in reducing BMI than interventions implemented in other settings, such as home);¹¹ and (3) targeted both healthy nutrition and physical activity⁴ and involved a caregiver²³ (caregiver refers to a parent, grandparent, other adult family members, or foster-parent who is directly responsible for the care of a child). Because the goal of a taxonomy is to identify intervention components as they emerge in the childhood obesity intervention programs, no hypotheses were generated about the efficacy of the specific individual or combination of components.

Methods

This systematic review and meta-analysis was performed by using established meta-analytic methods^{24,25} and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement.²⁶ The PRISMA checklist (Supplementary Table S1) is available at <https://www.nccor.org/childhood-obesity-evidence-base-test-of-a-novel-taxonomic-meta-analytic-method>.

Eligibility Criteria

The study inclusion criteria were developed based on the Population, Interventions, Comparisons, Outcomes, and Study Design (PICOS) framework.²⁷ Eligible studies: (1) assessed children aged 2–5 years at the beginning of the invention, living in the United States; (2) evaluated an intervention to prevent obesity in children; (3) identified a

same-aged control or comparison group; (4) assessed BMI [weight (kg)/height (m²)], BMI percentile, or BMI z-score; and (5) were available (published or unpublished) between January 1, 2005 and August 31, 2019.

Information Sources

A comprehensive strategy was used to identify, locate, and retrieve available scientific research reports. (This search was independent of the search conducted in the development of the intervention component taxonomy.¹⁹) Our primary strategy involved searches of electronic bibliographic databases (e.g., PubMed, Embase). To supplement this primary strategy, we also reviewed relevant published reviews and meta-analyses, reference lists of manuscripts retrieved from our database searches, electronic databases of funded research (*NIH RePORTER*), and registered clinical trials (www.ClinicalTrials.gov); we consulted with members of the National Collaborative on Childhood Obesity Research (NCCOR) Childhood Obesity Evidence Base (COEB) Project Workgroup (WG) and External Expert Panel (EEP).

Search Strategy

The search string was developed based on the intended recipients and outcome of interest, and it included Boolean operators, wildcard symbols, and quotations that used a combination of the following broad terms: *childhood*, *obesity*, and *intervention*. Because some electronic databases have a controlled vocabulary thesaurus to index records [e.g., Medical Subject Heading (MeSH) terms used in PubMed], specific search parameters were developed for each database. The full search string used for each electronic database search can be found in Supplementary Data S1. A broad search of the childhood obesity literature was conducted rather than restricting the search to children 2–5 years of age to ensure retrieval of all studies that included the targeted age range (i.e., mean age 2 to ≤5 years). No language, geographical region, or publication date restrictions were applied. All electronic bibliographic searches were conducted in June 2019. Records retrieved from each database were imported into a reference management software library (EndNote X8²⁸), and duplicate records were automatically removed.

Study Selection

All records retrieved from the electronic database searches were screened for inclusion based on the title and abstract by two reviewers. This initial screening was conducted to identify any additional duplicate records, irrelevant records, review papers, editorials, and commentaries. Full-text documents of potentially relevant records and references from manuscripts were reviewed based on the inclusion criteria. Registries of funded research and clinical trials were cross-checked with the relevant full-text manuscripts to ensure the retrieval of all available reports. If the study methods or data were reported in multiple documents, they were linked in the database and represented as a single study to avoid multiple/duplicate publication bias.

The manuscript reporting the most complete data was selected as the primary study; additional documents were considered supplemental (e.g., clinical trial record, protocol) but were consulted in the data collection process.

Data Collection Process

Two trained coders independently extracted relevant study information (e.g., publication year) from the primary study and supplemental manuscripts, as well as intended recipient characteristics (e.g., age, gender, race/ethnicity), design and measurement (e.g., random assignment), and intervention details (e.g., dose, number of sessions, length, and duration). In addition to the intended recipient and intervention context characteristic taxonomies developed for the COEB project, a taxonomy of intervention components with 93 distinct components, grouped into 9 categories, were used to identify the specific activity components of the intervention.¹⁹ For each intervention, the distinct components were coded as present (1) or absent (0). Intervention components were coded as absent if no clear evidence of the component could be identified from the intervention details provided in the primary study manuscript or the supplemental documents.

Disagreements between coders were reviewed, discussed, and reconciled by the coders; any unresolved disagreements were reviewed and finalized by the lead methodologist (L.A.J.S.S.). Inter-rater reliability was assessed across the study, sample, design, and intervention characteristics coded. For the categorical variables, coders agreed on 90% of the judgments (mean Cohen's $\kappa = 0.68$; range = 0.20–1.00). For the continuous variables, the average intra-class correlation coefficient (ρ) was 0.88 (median = 1.00).

Risk of Bias in Individual Studies

The Cochrane Risk of Bias Assessment Tool (Version 5.1.0) was used to assess the risk of bias in each study.²⁹ The tool assesses seven sources of bias: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other. The sources of bias are assigned a judgment of high, low, or unclear risk of bias when study details are insufficient to make a judgment of the level of risk.

Study Outcomes

The primary study outcome considered for this meta-analysis was change in BMI expressed as weight (kg)/height (m²), percentile, or z-score because it is the most commonly used indicator to assess overweight and obesity in children.¹³ Other discrete measures of BMI (e.g., overweight, obesity) were also included. Secondary outcomes such as measures of physical activity, diet, and sleep were identified during the taxonomy development and included in the outcomes taxonomy, but they were not included in the current meta-analysis due to inconsistent reporting methods and the limited number of studies including these measures.

Summary Measures

Effect sizes (ESs) were calculated as the pretest–posttest change in BMI divided by the pretest standard deviation (SD) in BMI within each condition and then subtracting the control group from the intervention group.^{30,31} Thus, all ESs controlled for baseline. If a study reported proportions, an odds ratio was calculated and transformed to a standardized mean difference ES by using the Cox transformation.³² The sampling variance for each ES was calculated by using standard procedures, correcting for sample size bias (Hedges' g).^{31,33} Multiple ESs were calculated from individual studies when the study reported more than one outcome, timepoint, or intervention condition, or when outcomes were separated by sample characteristics (e.g., girls and boys). To avoid violating the assumption of independence,^{25,34} we: (1) assessed each outcome separately; (2) clustered the ESs by timepoint (end of intervention and last follow-up assessment); and (3) conducted sensitivity analyses to determine whether multiple comparisons from a single study affected the overall outcomes.³⁴ An overall measure of BMI change was created by: (1) using the BMI metric reported among the studies reporting only one metric; and (2) averaging ESs from studies reporting more than one BMI metric (e.g., percentile, z-score). Positive ESs indicated smaller BMI increases over time among children who received the intervention relative to the comparison group.

Synthesis of Results

The distribution of the ESs for each dependent variable was inspected for possible outliers; extreme ESs (i.e., ESs more than 1.5 times the interquartile range beyond the 25th and 75th percentiles) were removed, and the magnitude and direction of the pooled ESs with or without the outliers were compared. Hedges' g (and corresponding 95% CIs) were calculated by using random-effects procedures. The between-study variance was estimated by using full information maximum likelihood.³⁵ The 95% CIs surrounding the weighted mean ES indicates whether the ES is statistically significant as well as the degree of precision. Heterogeneity in ESs was identified and quantified by computing Q and the I^2 index. The Q statistic has a chi-square distribution with degrees of freedom equal to $k - 1$; a significant Q indicates a lack of homogeneity and an inference of heterogeneity. To assess the extent to which outcomes were consistent across studies, the I^2 index and its corresponding 95% CIs were calculated.^{36,37} I^2 values of 25%, 50%, and 75% can be considered low, medium, and high heterogeneity, respectively.³⁸ Data analyses were conducted in Stata³⁹ by using published macros.^{25,40}

Risk of Bias across Studies

Asymmetries in the distributions of ESs, indicating a possible publication bias,⁴¹ were examined by (1) inspecting funnel plots⁴² and (2) using regression⁴³ and rank⁴⁴ tests assessing the degree of funnel plot asymmetry in the distribution of ESs. The trim-and-fill method⁴⁵ was

used to estimate and correct for the possibility of missing studies (using a nonparametric approach based on funnel plot asymmetry) if publication bias was detected.^{43,44}

Moderator Analyses

Meta-regression was conducted to assess the association between study-level moderators and ESs. For these random-effect regression models, the inverse variance for each ES included error associated with within-study level sampling error and additional between-study population variance.⁴⁶ Sample (proportion racial/ethnic minorities, socioeconomic status, proportion obese or overweight), study (recruitment site, implementation setting, intervention recipient, content focus, duration), and intervention (components as identified by our newly developed taxonomy¹⁹) features were examined. Significant moderators were simultaneously entered in a multiple regression model, and they were adjusted for multiple testing by using random permutations.⁴⁶

Results

Study Selection

Comprehensive searches of electronic bibliographic databases located 51 unique studies from 18,177 records with relevant key terms (after removing duplicates). An additional 158 records were identified through other sources (i.e., reviews, reference lists, funded research, clinical trial records, consultation with experts). Of the 18,335 unique records reviewed, 16,311 records were excluded based on title and abstract review because those records did not meet inclusion criteria or were reviews, editorials, or commentaries. An additional 1826 records were excluded after full-text review, because the studies did not meet inclusion criteria (Fig. 1). Importantly, a primary reason for study exclusion was failure to measure (or report) the primary outcome for this meta-analysis, BMI. The final sample included 51 unique studies and 147 supplemental documents that provided additional study details or data for the included studies. Nine supplemental documents provided additional information for more than one primary study (e.g., *Hip Hop to Health* manual⁴⁷). Table 1 provides a description of the 51 included studies reporting on 58 interventions (7 studies evaluated 2 interventions^{48–54}). Additional intervention details can be found in Supplementary Table S2.

Study and Sample Characteristics

Studies were published (or available) between 2005 and 2019 (mean publication date = 2015, SD = 4), and they were typically conducted in the U.S. Midwest (29%), Southeast (24%), or Northeast (18%). Most of the included studies (88%) used a randomized controlled trial design with random assignment of groups (49%) or individuals (39%); six studies used a quasi-experimental design.^{52,54–58} Study samples were recruited from child care centers or preschools (55%), clinical practices (22%), community

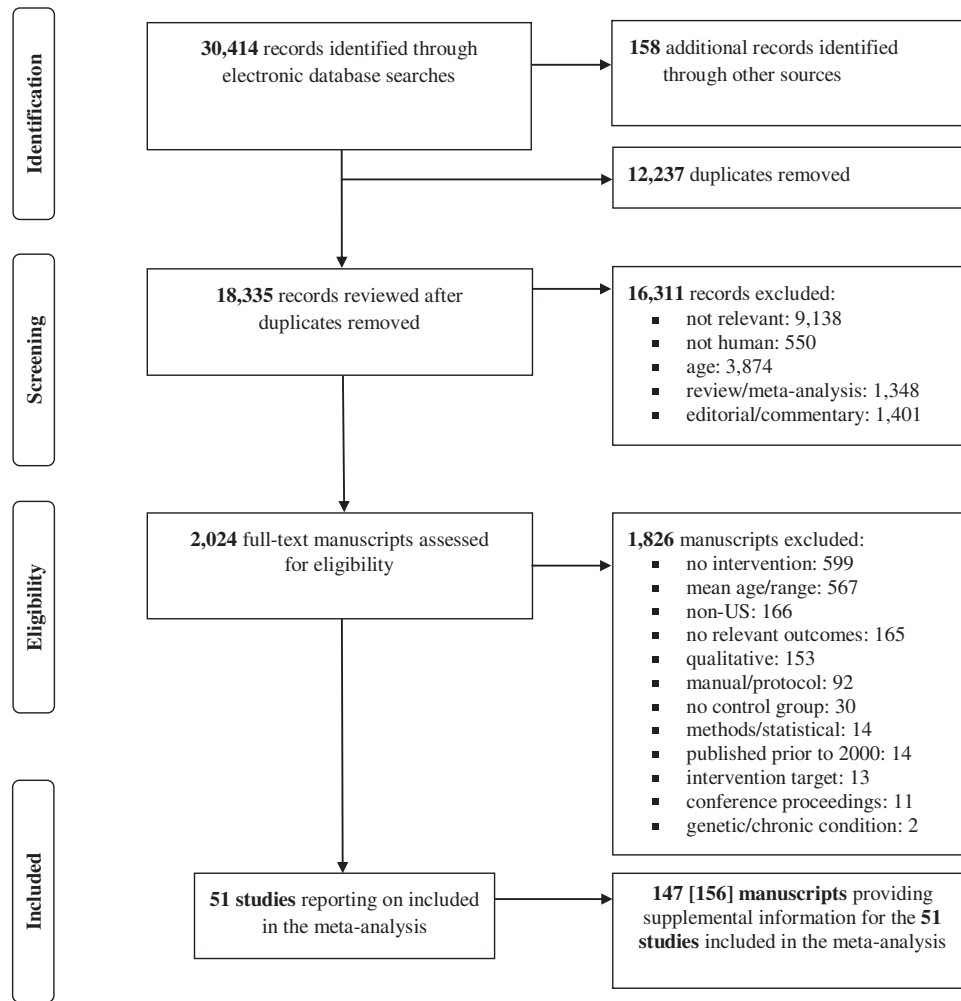


Figure 1. Childhood Obesity Evidence Base Systematic Review and Meta-Analysis Study Search and Selection Process.

sites/programs (14%), or multiple school, clinic, or community sites (10%). Participants included 29,085 children (mean age = 48 months, SD = 7), with an average retention rate of 80% (SD = 0.18) across the studies. The study samples included, on average, 50% (SD = 0.27; range = 20%–100%) of children meeting criteria for overweight or obesity. Details of the study and sample characteristics are provided in Table 2.

Characteristics of Childhood Obesity Interventions

Interventions were typically theory driven (79%) and targeted both nutrition and physical activity (48%), nutrition only (14%), physical activity only (5%), or multiple/other obesogenic behaviors (33%; *e.g.*, screen time, sleep, behavioral self-management). The content of the intervention was most often delivered to the child and caregiver (72%), caregiver alone (17%), or the child (10%). Dose varied by intervention target; that is, interventions were delivered to the child across a median of 21 sessions of <1 hour each (median = 53 minutes), to the parent across a median of nine 1-hour sessions (median = 60 minutes), and to the facilitator (*e.g.*, teacher,

physician) during a single 6-hour session (median = 360 minutes). The average duration of the intensive intervention phase was 9 months (SD = 7; range = 2–36 months). Active control or comparison conditions (43%) were used most often followed by no intervention (31%), waitlist (16%), or education only (10%).

Childhood Obesity Intervention Components Identified Using the Taxonomy

A total of 90 (out of 93) intervention components were identified across the interventions included in the current meta-analysis. Three intervention components included in the taxonomy were not identified: (1) provided materials to support self-control in children; (2) implemented Earned Income Tax Credit (*i.e.*, adoption or expansion of Earned Income Tax Credits); and (3) implemented policies regarding food/beverage costs. (These intervention components, generated in the taxonomy development phase, were not identified in our meta-analysis because we limited the inclusion criteria to studies measuring BMI where a standardized mean difference between the intervention and control group could be calculated.)

Table 1. Childhood Obesity Evidence Base Project Study, Sample, and Design Characteristics of the 51 Studies Included in the Systematic Review and Meta-Analysis

Study citation	Study name; start of data collection	Design	Child sample	Setting and recruitment	Child-level outcomes
Alkon ⁷⁷ Linked ^{76,79}	Child Care Wellness Study on Nutrition and Physical Activity (NCT01921842); 2009	Cluster RCT	N = 552 (61%); 46% F; mean age = 47 months; 46% White ^a ; 38% overweight/obese; low SES	Child care centers in CA, CT, and NC; 18 child care centers (9 interventions, 9 controls).	BMI z-score; % overweight; % obese
Annes ⁸⁰ Linked ⁸¹⁻⁸³	Start for Life; 2011	Cluster RCT	N = 1154 (100%); 51% F; mean age = 53 months; 86% Black; 30% overweight/obese; low SES	Preschools in Atlanta, GA; 98 YMCA-affiliated preschool (60 interventions, 38 controls) classrooms.	BMI (kg/m ²)
Barkin ⁸⁴ Linked ^{85,86}	Salud Con La Familia/Health with the Family (NCT00808431); 2008	RCT	N = 106 (75%); 51% F; mean age = 50 months; 100% Latinx; 42% overweight/obese	Community recreation centers in Nashville, TN; parent-child dyads recruited directly from clinic and community sites and indirectly via advertisements.	BMI (kg/m ²); % obese
Barkin ⁸⁷ Linked ⁸⁸⁻⁹⁷	Growing Right onto Wellness (NCT01316653); 2012	RCT	N = 610 (92%); 52% F; mean age = 52 months; 91% Latinx; 35% overweight/obese; low SES	Community recreation centers in Nashville, TN; parent-child dyads recruited directly from clinic and community sites and indirectly via advertisements.	BMI (kg/m ²); % obese
Bellows ⁹⁸ Linked ⁹⁹⁻¹⁰³	Food Friends Get Movin' with Mighty Moves; 2006	Cluster RCT	N = 274 (73%); 45% F; mean age = 52 months; 57% Latinx; 37% overweight/obese; low SES	Preschools in CO; 8 HS centers (18 interventions, 13 control classrooms).	BMI (kg/m ²); BMI z-score
Bonis ¹⁰⁴ Linked ^{76,105}	Nutrition and Physical Activity Self-Assessment for Child Care Program; 2012	Cluster RCT	N = 251 (83%); 50% F; mean age = 46 months	Child care centers in New Orleans, LA; 26 child care centers (13 interventions, 13 controls).	BMI (kg/m ²); weight (kg)
Butte ¹⁰⁶ Linked ¹⁰⁷⁻¹¹¹	Texas Childhood Obesity Research Demonstration-Coordinated Approach to Child Health Early Childhood (NCT02724943); 2012	RCT	N = 160 (64%); 48% F; mean age = 52 months; 88% Latinx; 100% overweight/obese; low SES	Multiple sites (primary care clinics, YMCAs) in Austin and Houston, TX; 12 primary care clinics serving low-income catchment areas.	BMI (kg/m ²); weight (kg)
Cloutier ⁵⁵ Linked ¹¹²⁻¹¹⁴	Steps to Growing Up Healthy (NCT01973153); 2009	Non-RCT	N = 467 (90%); 45% F; mean age = 35 months; 82% Latinx; 42% overweight/obese; low SES	Primary care clinics in Hartford, CT; patients at a primary care clinic of a large urban medical center.	BMI percentile
Davis ¹¹⁵ Linked ¹¹⁶⁻¹²³	Child Health Initiative for Lifelong Eating and Exercise (NCT00428805); 2008	Cluster RCT	N = 436 (66%); 47% F; mean age = 36 months; 59% White; 31% overweight/obese; low SES	Multiple sites (preschools, community, primary care clinics) in NM; 16 HS centers (8 interventions, 8 controls).	BMI z-score; % overweight; % obese
Dennison ¹²⁴ Linked ^{125,126}	Brocodile the Crocodile; 2000	Cluster RCT	N = 222 (35%); 51% F; mean age = 47 months; 96% White	Multiple sites (preschools, child care centers) in rural upstate NY; 16 preschool or day care centers (8 intervention, 8 controls).	BMI (kg/m ²); BMI z-score; weight (kg)
Esquivel ¹²⁷ Linked ¹²⁸⁻¹³¹	Children's Healthy Living Program (NCT01881373); 2013	Cluster RCT	N = 349 (70%); 46% F; mean age = 44 months; 62% Multiracial; 25% overweight/obese; low SES	Preschools in Oahu, HI; 18 HS centers (11 interventions, 12 control classrooms) in communities participating in the Children's Healthy Living Program.	BMI z-score; % overweight; % obese

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Table 1. Childhood Obesity Evidence Base Project Study, Sample, and Design Characteristics of the 51 Studies Included in the Systematic Review and Meta-Analysis continued

Study citation	Study name; start of data collection	Design	Child sample	Setting and recruitment	Child-level outcomes
Fisher ¹³² Linked ¹³³	Food, Fun, and Families (NCT03646201); 2013	RCT	N = 119 (88%); 55% F; mean age = 44 months; 91% Black ^a ; 30% overweight/obese; low SES	University research center in Philadelphia, PA; participants recruited directly from WIC offices and indirectly from advertisements posted at community venues.	BMI (kg/m ²); BMI z-score; BMI percentile
Fitzgibbon ¹³⁴ Linked ^{47,135,136}	Hip-Hop to Health Jr.; 1999	Cluster RCT	N = 409 (73%); 50% F; mean age = 50 months; 90% Black; low SES	Preschools in Chicago, IL; 12 HS centers (6 interventions, 6 controls) administered through the Archdiocese of Chicago.	BMI (kg/m ²); BMI z-score; weight (kg)
Fitzgibbon ¹³⁷ Linked ^{47,135}	Hip-Hop to Health Jr.—Latino Preschools; 2001	Cluster RCT	N = 401 (86%); 49% F; mean age = 51 months; 81% Latinx; 72% overweight/obese; low SES	Preschools in Chicago, IL; 12 HS centers (6 interventions, 6 controls) administered through the Archdiocese of Chicago.	BMI (kg/m ²); BMI z-score; weight (kg)
Fitzgibbon ¹³⁸ Linked ^{139–143}	Hip-Hop to Health Jr. Obesity Prevention Effectiveness Trial (NCT00241878); 2007	Cluster RCT	N = 618 (89%); 53% F; mean age = 51 months; 94% Black; 33% overweight/obese; low SES	Preschools in Chicago, IL; 18 HS centers (9 interventions, 9 controls) administered through the Chicago Public Schools.	BMI (kg/m ²); BMI z-score; weight (kg)
Fitzgibbon ¹⁴⁴	Family-Based Hip-Hop to Health; 2010	Cluster RCT	N = 147 (87%); 50% F; mean age = 54 months; 94% Latinx; 46% overweight/obese; low SES	Preschools in Chicago, IL; 4 HS centers (2 interventions, 2 controls) in the Chicago Public School System.	BMI (kg/m ²); BMI z-score; weight (kg)
Foster ¹⁴⁵ Linked ^{146–149}	Parent Mentors Using Positive Deviance in Childhood Obesity (NCT02373670); 2015	RCT	N = 59 (81%); 42% F; mean age = 52 months; 100% Latinx; 100% overweight/obese; low SES	Multiple sites (homes, preschools) in Cameron County, TX; parent-child dyads recruited from 16 HS centers providing the Neighbors in Need of Services program.	BMI (kg/m ²); BMI z-score; weight (kg)
French ¹⁵⁰ Linked ^{90–92,151,152}	Now Everybody Together for Amazing and Healthful Kids (NCT01606891); 2012	RCT	N = 534 (92%); 51% F; mean age = 41 months; 58% Latinx; 48% overweight/obese; low SES	Multiple sites (community, home, primary care clinics) in Minneapolis-St. Paul, NM; parent-child dyads recruited from 12 primary care clinics.	BMI (kg/m ²); BMI z-score; BMI percentile; % obese; weight (kg)
Goldberg ⁵⁶ Linked ¹⁵³	I am moving. I am Learning; 2008	Non-RCT, Clustered	N = 354 (100%); 52% F; 3–5 years of age; 57% Latinx; 42% overweight/obese; low SES	Preschools in two counties in VA; 2 HS centers (16 interventions, 6 control classrooms).	BMI percentile; % overweight
Haines ¹⁵⁴ Linked ^{155–157}	Healthy Habits, Happy Homes (NCT01565161); 2011	RCT	N = 121 (92%); 48% F; mean age = 49 months; 51% Latinx; 46% overweight/obese; low SES	Homes; 4 community health centers that serve primarily low-income and racial/ethnic minority families in the greater Boston, MA area.	BMI (kg/m ²); BMI z-score

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Table 1. Childhood Obesity Evidence Base Project Study, Sample, and Design Characteristics of the 51 Studies Included in the Systematic Review and Meta-Analysis continued

Study citation	Study name; start of data collection	Design	Child sample	Setting and recruitment	Child-level outcomes
Haines ¹⁵⁸ Linked ^{159,160}	Parents and Tots Together (NCT02222766); 2012	RCT	N = 112 (86%); 50% F; mean age = 43 months; 59% Latinx ^a ; low SES	Community health centers in MA and RI; community health centers and agencies that primarily serve low-income families.	BMI (kg/m ²); BMI z-score
Hawkins ¹⁶¹ Linked ^{162,163}	Developing Relationships that Include Values of Eating and Exercise (NCT02160847); 2014	RCT	N = 16 (100%); 50% F; mean age = 49 months; 50% White	Homes; community organizations in Atlanta, GA and Baton Rouge, LA.	BMI percentile; BMI z-score; weight (kg)
Hollar ¹⁶⁴	Thriving Communities, Thriving Children; 2013	Cluster RCT	N = 681 (100%); 49% F; 2–5 years of age; 92% Black; 20% overweight/obese; low SES	Preschools in MS and LA; 12 HS centers (6 interventions, 6 controls).	% Overweight
Jastreboff ¹⁶⁵ Linked ¹⁶⁶	Parenting Mindfully for Health (NCT01974102); 2014	RCT	N = 42 (90%); 57% F; mean age = 44 months; 67% Multiracial; low SES	University research center in New Haven, CT; local community.	BMI percentile
Ling ⁵⁷	FirstStep2Health; 2016	Non-RCT, clustered	N = 73 (95%); 64% F; mean age = 54 months; 42% Black; 46% overweight/obese; low SES	Multiple sites (preschools, homes, YMCA) in MI; 2 HS centers (6 interventions, 6 control classrooms).	BMI z-score
Lumeng ⁴⁸ Linked ^{167–170}	The Growing Healthy Study (NCT01398358); 2011	Cluster RCT	N = 697 (99%); 51% F; mean age = 49 months; 48% White; 34% overweight/obese; low SES	Preschools in urban and rural MI; 2 HS centers (4 interventions, 2 control classrooms).	% Obese; % overweight/obese
Messiah ¹⁷¹ Linked ^{172–176}	Healthy Caregivers-Healthy Children Phase II (NCT02697565); 2015	Cluster RCT	N = 1101 (52%); 2–5 years of age; low SES	Child care centers in Miami Dade County, FL; 24 child care centers (12 interventions, 12 controls).	% Overweight/obese
Morshed ¹⁷⁷ Linked ^{178–180}	Healthy Eating and Active Living at Home (NCT01567033); 2012	RCT	N = 230 (78%); 45% F; mean age = 41 months; 57% White; 45% overweight/obese; low SES	Homes in St. Louis, MO; 8 Parents as Teachers child development home visiting program regions.	BMI percentile; BMI z-score
Natale ¹⁸¹ Linked ^{172,182–184}	Healthy Inside-Healthy Outside; 2007	Cluster RCT	N = 307 (60%); 49% F; mean age = 46 months; 62% Latinx; 30% overweight/obese; low SES	Child care centers in Miami Dade County, FL; 8 subsidized child care centers (6 interventions, 2 controls).	BMI z-score
Natale ¹⁸⁵ Linked ^{94,172,186–195}	Healthy Caregivers-Healthy Children (NCT01722032); 2010	Cluster RCT	N = 1211 (100%); 50% F; mean age = 47 months; 56% Latinx; 35% overweight/obese; low SES	Child care centers in Miami Dade County, FL; 28 child care centers (12 interventions, 16 controls) primarily serving low-income children.	BMI percentile
Nezami ¹⁹⁶ Linked ^{197,198}	SMART MOMS (NCT02098902); 2014	RCT	N = 51 (82%); 53% F; mean age = 54 months; 74% White ^a ; 24% overweight/obese	Homes in NC; mother-child dyads recruited from child care centers, pediatrician offices, WIC clinics, listservs, flyers, and social media.	BMI z-score
Nicklas ¹⁹⁹ Linked ²⁰⁰	The Children in Action Feasibility Study (NCT01697124); 2007	Cluster RCT	N = 295 (100%); 46% F; mean age = 52 months; 100% Latinx; 38% overweight/obese; low SES	Child care centers in TX; 4 HS centers (10 interventions, 10 control classrooms).	BMI z-score

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Table 1. Childhood Obesity Evidence Base Project Study, Sample, and Design Characteristics of the 51 Studies Included in the Systematic Review and Meta-Analysis continued

Study citation	Study name; start of data collection	Design	Child sample	Setting and recruitment	Child-level outcomes
Ostbye ²⁰¹ Linked ²⁰²⁻²⁰⁵	Kids and Adults Now-Defeat Obesity! (NCT00563264); 2007	RCT	N = 400 (77%); 44% F; mean age = 37 months; 75% White ^a ; 24% overweight/obese; low SES	Multiple sites (homes; university research center) in the Triangle and Triad regions of NC; women identified from state birth certificate records in 14 counties.	BMI z-score
Quattrin ²⁰⁶ Linked ^{207,208}	Treating Pre-School Children at Risk for Overweight in the Primary Care Setting (NCT01029834); 2012	Cluster RCT	N = 96 (83%); 67% F; mean age = 54 months; 73% White	Primary care clinics in Buffalo and Williamsville, NY; 4 large pediatric practices.	BMI z-score; weight (kg)
Romero ⁴⁹	Development of a Nutrition Education Curriculum; 2002	Cluster RCT	N = 269 (43%); 2–5 years of age; 100% overweight/obese; low SES	Community sites in UT; 3 WIC clinics in the same WIC district (2 interventions, 1 control).	BMI percentile
Sharma ⁵⁸ Linked ²⁰⁹	TX-CORD-Coordinated Approach to Child Health Early Childhood; 2012	Non-RCT	N = 672; 47% F; mean age = 51 months; 73% Latinx; 35% overweight/obese; low SES	Preschools in Houston and Austin, TX; 25 HS centers (12 interventions, 13 controls).	BMI percentile; BMI z-score
Sherwood ²¹⁰ Linked ²¹¹	Healthy Homes, Healthy Kids—Preschool (NCT01080885); 2010	RCT	N = 60 (82%); 45% F; mean age = 33 months; 80% White	Multiple sites (primary care clinics, homes) in the greater Minneapolis-St. Paul area, NM; parent-child dyads recruited from 20 pediatric clinics.	BMI percentile; BMI z-score
Slusser ⁵⁹ Linked ²¹²	Parent Training; 2006	RCT	N = 160 (51%); 56% F; 2–4 years of age; 100% Latinx; 47% overweight/obese; low SES	Multiple sites (preschools, community, and primary care clinics) in the greater Los Angeles, CA area.	BMI percentile; BMI z-score
Stark ²¹³ Linked ²¹⁴	LAUNCH; 2008	RCT	N = 18 (89%); 33% F; mean age = 57 months; 84% White; 100% overweight/obese	Multiple sites (primary care clinic, home) in Cincinnati, OH; preschool children recruited from a large Midwestern pediatric practice.	BMI percentile; BMI z-score; weight (kg)
Stark ⁵⁰ Linked ²¹⁵	LAUNCH with Home Visit; 2009	RCT	N = 42 (67%); 55% F; mean age = 55 months; 86% White; 100% overweight/obese	Multiple sites (primary care clinic, home) in Cincinnati, OH; preschool children recruited from a large Midwestern pediatric practice.	BMI percentile; BMI z-score; weight (kg)
Stark ⁵¹ Linked ²¹⁶⁻²²⁰	Behavioral Treatment for Obese Preschoolers: LAUNCH (NCT01546727); 2012	RCT	N = 167 (77%); 57% F; mean age = 55 months; 76% White; 100% overweight/obese	Multiple sites (primary care clinics, home) in Greater Cincinnati/Northern Kentucky; preschool children recruited from 27 pediatric practices.	BMI percentile; BMI z-score; weight (kg)
Stokey ²²¹ Linked ²²²	Healthy Apple Program (NCT02799433); 2011	Cluster RCT	N = 902 (88%); 50% F; mean age = 42 months; low SES	Child care centers in San Francisco, CA; 43 child care centers (19 interventions, 24 controls) that participated in the CCHP nutrition screenings in 2011–2012.	BMI z-score; BMI percentile; % overweight/obese

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Table 1. Childhood Obesity Evidence Base Project Study, Sample, and Design Characteristics of the 51 Studies Included in the Systematic Review and Meta-Analysis continued

Study citation	Study name; start of data collection	Design	Child sample	Setting and recruitment	Child-level outcomes
Sun ²²³	2015	RCT	N = 32 (91%); 47% F; mean age = 52 months; 100% Asian ^a ; low SES	Homes in the San Francisco Bay Area, CA; 4 HS programs.	BMI (kg/m ²)
Taveras ²²⁴ Linked ^{182,225-233}	The High Five for Kids Study (NCT00377767); 2006	Cluster RCT	N = 475 (94%); 48% F; mean age = 59 months; 57% White; 100% overweight/obese	Primary care clinics in MA; 10 primary care pediatric offices (5 interventions, 5 controls).	BMI (kg/m ²); BMI z-score
Tomayko ²³⁴ Linked ²³⁵⁻²⁴⁰	Health Children, Strong Families; 2007	RCT	N = 150 (65%); 47% F; mean age = 48 months; 92% American Indian; 48% overweight/obese; low SES	Homes; HS sites serving four American Indian tribes in rural WI—the Bad River band of Lake Superior of Chippewa, Lac du Flambeau band of Lake Superior Chippewa, the Menominee Nation, and the Oneida Tribe of Indians of Wisconsin.	BMI (kg/m ²); BMI percentile; BMI z-score
Tomayko ²⁴¹ Linked ²⁴²⁻²⁴⁷	Healthy Children, Strong Families: American Indian Communities Preventing Obesity (NCT01776255); 2013	RCT	N = 450 (84%); 50% F; mean age = 45 months; 87% American Indian; 40% overweight/obese; low SES	Homes; 5 tribal-based child care or HS programs in 4 rural tribal reservations.	BMI z-score
Tucker ²⁴⁸ Linked ²⁴⁹	Evaluation of a Primary Care Weight Management Program in Children Aged 2 to 5 Years (NCT03487614); 2014	Cluster RCT	N = 165 (77%); 56% F; mean age = 43 months; 90% White; 95% overweight/obese	Primary care clinics; 4 pediatric offices (2 intervention, 2 controls) from We Are for children in western MI.	BMI (kg/m ²); BMI z-score
Winter ²⁵⁰	Healthy & Ready to Learn; 2008	Cluster RCT	N = 405 (100%); 48% F; mean age = 51 months; 95% Latinx; 29% overweight/obese; low SES	Preschools in San Antonio, TX; 4 HS centers (2 interventions, 2 controls) administered by one agency in a high-poverty, low-income neighborhood.	BMI (kg/m ²); weight (kg)
Woo Baidal ⁵² Linked ²⁵¹⁻²⁵⁸	Massachusetts Childhood Obesity Research Demonstration Initiative (NCT02110615); 2010	Non-RCT	N = 11,876 (12%); 49% F; mean age = 28 months; 48% White; 25% overweight/obese; low SES	Community sites in MA; local WIC programs in 3 communities (2 interventions, 1 control).	BMI z-score
Yeh ⁵³ Linked ²⁵⁹	Healthy Kids Healthy Lives; 2011	Cluster RCT	N = 203 (81%); 44% F; 3–5 years of age; 95% Black; 41% overweight/obese; low SES	Preschools in Detroit, MI; 6 United Children and Family HS programs (4 interventions, 2 controls).	BMI percentile; % overweight; % obese
Yin ⁵⁴ Linked ^{260,261}	Miranos! Look at Us, We are Healthy!; 2011	Non-RCT	N = 384 (88%); 52% F; mean age = 49 months; 90% Latinx; 37% overweight/obese; low SES	Multiple sites (preschools, homes) in San Antonio, TX; 4 HS centers (19 interventions, 6 control classrooms).	BMI z-score; weight (kg)

^aRace/ethnicity of the parent was available and used in six studies where race/ethnicity was not reported for the child.

CCHP, Child Care Health Program; F, female; HS, Head Start; Latinx, Latino or Latina; LAUNCH, Learning about Activity and Understanding Nutrition for Child Health; Low SES, low socioeconomic status [low SES of the sample was determined by using any information provided in the studies including income level at or below the poverty line and eligibility for any of the following programs: Supplemental Nutritional Assistance Program (SNAP), Woman, Infants, and Children (WIC), free/reduced lunch, and HS]; N (%), number of children who participated in the study (retention); RCT, randomized controlled trial.

Table 2. Childhood Obesity Evidence Base Project Study, Sample, and Intervention Characteristics of the 51 Studies (58 Interventions) Included in the Childhood Obesity Prevention Meta-Analysis

Study and design characteristics	
Publication year, median (range)	2015 (2005–2019)
Data collection year, median (range)	2010 (1995–2016)
Source, <i>n</i> (%)	
Journal	48 (94)
Dissertation	2 (4)
Conference Abstract	1 (2)
Funded research, %	98
RCT, %	88
U.S. region, %	
Northeast	18
Southeast	24
Midwest	29
West	10
Southwest	14
Multiple regions	6
Setting, %, (<i>n</i> =27)	
Urban	70
Rural	11
Urban and suburban	4
Urban and rural	15
Recruitment site, %	
Child care/preschool	55
Clinical contact	22
Community/other	14
Multiple	10
Random assignment, %	
Quasi-experimental	12
Random assignment of groups	49
Matching then random assignment	16
True randomization	24
Multisite study design, %	67
No. of post-tests, median (range)	1 (1–5)
Sample characteristics	
Children	
Sample size	29,085
Retention, M % (SD), (<i>n</i> =50)	80 (18)
Girls, M % (SD), (<i>n</i> =49)	50 (5)

continued

Table 2. Childhood Obesity Evidence Base Project Study, Sample, and Intervention Characteristics of the 51 Studies (58 Interventions) Included in the Childhood Obesity Prevention Meta-Analysis *continued*

Non-white, M % (SD), (<i>n</i> =48)	71 (31)
Low SES, <i>n</i> (%)	39 (76)
Program eligibility, %	
Free/reduced lunch	8
SNAP or WIC	35
HS	45
Medicaid	12
Age months, M (SD), (<i>n</i> =45)	48 (7)
Age group, <i>n</i> (%)	
2–4 Years	6 (12)
2–5 Years	18 (35)
2–6 Years	4 (8)
3–4 Years	2 (4)
3–5 Years	20 (39)
4–5 Years	1 (2)
Child BMI status, M % (SD)	
Underweight (<i>n</i> =39)	1 (2)
Normal weight (<i>n</i> =38)	47 (27)
Overweight (<i>n</i> =40)	20 (12)
Obese (<i>n</i> =40)	29 (27)
Parent/caregivers	
Sample size (<i>n</i> =35)	10,410
Female, M % (SD), (<i>n</i> =27)	94 (8)
Age in years, M (SD), (<i>n</i> =25)	32 (2)
Non-white, M % (SD)	74 (30)
Marital status, M % (SD)	
Married/cohabitating (<i>n</i> =20)	64 (23)
Divorced/widowed (<i>n</i> =5)	11 (18)
Single (<i>n</i> =10)	36 (29)
Education, M % (SD)	
Less than high school (<i>n</i> =15)	31 (20)
High school/GED (<i>n</i> =13)	25 (13)
Some college/technical (<i>n</i> =14)	31 (12)
College degree or higher (<i>n</i> =18)	32 (28)
Employment, M % (SD)	
Full-time (<i>n</i> =10)	38 (17)
Part-time (<i>n</i> =8)	18 (8)

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Table 2. Childhood Obesity Evidence Base Project Study, Sample, and Intervention Characteristics of the 51 Studies (58 Interventions) Included in the Childhood Obesity Prevention Meta-Analysis *continued*

Unemployed (<i>n</i> = 10)	42 (18)
Student (<i>n</i> = 5)	2 (3)
Disabled (<i>n</i> = 5)	0 (0)
Language, M % (SD)	
English (<i>n</i> = 13)	54 (42)
Non-English (<i>n</i> = 14)	23 (30)
English+other language (<i>n</i> = 13)	28 (40)
BMI status, M % (SD)	
Underweight (<i>n</i> = 18)	<1 (1)
Normal weight (<i>n</i> = 18)	12 (11)
Overweight (<i>n</i> = 14)	27 (11)
Obesity (<i>n</i> = 14)	57 (16)
Facilitator ^a characteristics	
Facilitators for children	
Facilitators, median (range), (<i>n</i> = 36)	1 (0–3)
Type of facilitators, %, (<i>n</i> = 45)	
Not reported	7
No facilitators	4
Preschool/child care teachers, assistants, or staff	40
Research staff (BA/MA)	2
Parent peers	7
Paraprofessional	9
Research Staff (BA/MA)+Para	4
Research Staff (BA/MA)+Prof	9
Para+Prof	7
Multiple	11
Language, M % (SD), (<i>n</i> = 13)	
English	38 (51)
Non-English	0 (0)
English+other language	62 (51)
Facilitators for parents/caregivers	
Facilitators, median (range), (<i>n</i> = 36)	1 (0–5)
Type of facilitators, %, (<i>n</i> = 46)	
Not reported	7
No facilitators	22

continued

Table 2. Childhood Obesity Evidence Base Project Study, Sample, and Intervention Characteristics of the 51 Studies (58 Interventions) Included in the Childhood Obesity Prevention Meta-Analysis *continued*

Preschool/child care teachers, assistants, or staff	9
Research staff (BA/MA)	7
Parent peers	9
Paraprofessional	20
Professional	4
Research staff (BA/MA)+Para	7
Research staff (BA/MA)+Prof	4
Para+Prof	11
Multiple	2
Language, M % (SD), (<i>n</i> = 12)	
English	28 (42)
Non-English	2 (6)
English+other language	70 (46)
Facilitators for facilitators	
Facilitators, median (range), (<i>n</i> = 10)	1 (0–1)
Type of facilitators, %, (<i>n</i> = 39)	
Not reported	40
Paraprofessional	31
Professional	23
Para+Prof	6
Language, M % (<i>n</i> = 2)	
English	0
Non-English	0
English+other language	100
Intervention characteristics	
Theory/model	
% SCT/SLT	51
SEM	9
Other	16
Multiple	24
Delivery setting, %	
Child care/preschool	41
Clinical practice	10
Community	12
Home	12

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Table 2. Childhood Obesity Evidence Base Project Study, Sample, and Intervention Characteristics of the 51 Studies (58 Interventions) Included in the Childhood Obesity Prevention Meta-Analysis *continued*

Multiple/other	24
Recipient, %	
Child	83
Parent/caregiver	90
Child care provider	33
Physician/health care provider	16
Content focus, %	
Diet	14
Physical Activity	5
Diet and Physical Activity	48
Multicomponent/Other	33
Duration (months), median (range)	6 (2–36)
Child	
No. of sessions, median (range), <i>k</i> = 42	21 (1–626)
Total dose (in minutes), median, <i>k</i> = 30	1100
Parent	
No. of sessions, median (range), <i>k</i> = 46	9 (1–75)
Total dose (in minutes), median, <i>k</i> = 30	540
Facilitator	
No. of sessions, median (range), <i>k</i> = 27	1 (1–35)
Total dose (in minutes), median, <i>k</i> = 22	420
Controls	
Type of control, %	
Wait-list	16
No treatment	31
Education only	10
Irrelevant content, matched	4
Irrelevant content, not matched	23
Relevant content, matched	2
Relevant content, not matched	14
Active controls, % (<i>n</i> = 51)	43

^aFacilitator refers to the individual(s) who delivers the intervention content (e.g., research assistant, teacher, physician) to the children, caregiver, or facilitator.

BA/MA, bachelor or master's degree; *k*, number of interventions; M, mean; matched, for time or contact; *n*, number of studies reporting on the specified characteristic; Para, paraprofessional; Prof, professional; SCT/SLT, Social Cognitive Theory/Social Learning Theory; SD, standard deviation; SEM, socioecological model.

The mean number of components identified across the interventions was 20 (SD = 6, range = 7–34). The 5 most commonly reported components across the 58 interventions included were: (1) used research-based approaches or curriculum (84%); (2) provided written resources to caregivers (60%); (3) provided initial or one-time training opportunities for facilitators (59%); (4) provided education about nutrition and healthy eating patterns to caregivers (53%); and (5) provided curricular materials to facilitators (50%). (A list of the intervention components can be found in Table 3.)

Synthesis of Results

All studies assessed BMI at the end of treatment except for one study,⁵⁹ which did not include an immediate post-test; sixteen studies assessed BMI at a longer-follow-up (median = 52 weeks, range = 18–143 weeks). Hedge's *g* (and homogeneity statistics) for each BMI outcome by assessment interval is presented in Supplementary Table S3. Analyses indicated that children in the intervention group had a smaller BMI increase at the immediate post-test ($g = 0.10$, 95% CI = 0.02–0.18; $k = 55$; 0 weeks) and at the last follow-up ($g = 0.17$, 95% CI = 0.04–0.30; $k = 14$; range = 18–143 weeks) relative to the comparison group.* [Extreme outliers were detected at both the immediate post-test (2 out of 57 ES) and last follow-up (2 out of 16 ES) assessment and were removed from the analyses; see Supplementary Table S3.] The hypothesis of homogeneity was supported for BMI [immediate post-test: $Q(54) = 67.08$, $p = 0.109$; $I^2 = 20$, 95% CI = 0–43; last follow-up: $Q(13) = 11.91$, $p = 0.535$; $I^2 = 0$, 95% CI = 0–74], but uncertainty limits were wide at the last follow-up and exceeded the 50% threshold. (Forest plots of the overall BMI at the immediate post-test and last follow-up are found in Figs. 2 and 3.)

When pooling the separate BMI metrics, analyses showed that children in the intervention group had a lower BMI percentile at the immediate post-test ($g = 0.15$, 95% CI = 0.04–0.26; $k = 19$) and last follow-up ($g = 0.59$, 95% CI = 0.14–1.13; $k = 6$) and a lower BMI z-score at last follow-up ($g = 0.20$, 95% CI = 0.06–0.34; $k = 12$) relative to the comparison group. Intervention children also had a lower weight at the immediate post-test ($g = 0.35$, 95% CI = 0.16–0.55; $k = 16$) and last follow-up ($g = 0.26$, 95% CI = 0.05–0.48; $k = 11$) assessment compared with the comparison group. The hypothesis of homogeneity was not supported for weight [immediate post-test: $Q(15) = 109.93$, $p < 0.001$; $I^2 = 86$, 95% CI = 79–90; last follow-up: $Q(11) = 45.06$, $p < 0.001$; $I^2 = 78$, 95% CI = 61–88], and uncertainty limits exceeded the 75% threshold.

*Sensitivity analyses showed that excluding studies in which multiple interventions were compared with a single control condition did not change the magnitude or direction of the findings at the immediate post-test ($g = 0.10$, 95% CI = 0.07–0.13; $k = 42$; 0 weeks) but weakened the findings at the last follow-up ($g = 0.13$, 95% CI = –0.01–0.27; $k = 10$; range = 18–143 weeks).

Table 3. Childhood Obesity Evidence Base Project Taxonomy of Components Identified, Frequency, and Impact on the Overall BMI across the 58 Interventions Included in the Analyses

Intervention components	%	Impact on BMI			
		Immediate		Final	
		B (SE)	p	B (SE)	p
Activities to support behavior change		0.03 (0.01)	0.024	0.01 (0.02)	0.743
Implement structures of accountability	28	0.06 (0.04)	0.117	0.09 (0.09)	0.334
Incorporate implementation of self-reflection strategies	19	0.02 (0.05)	0.678	-0.03 (0.08)	0.723
Implement media campaigns	2	0.18 (0.11)	0.098	-0.03 (0.10)	0.781
Incorporate financial incentives	19	0.03 (0.04)	0.446	0.03 (0.08)	0.663
Engage caregivers in praise/encouragement for positive behavior	22	0.09 (0.05)	0.049	0.34 (0.19)	0.092
Engage caregivers in goal setting	31	0.07 (0.04)	0.122	-0.03 (0.08)	0.689
Engage caregivers to serve as role models for children	19	0.05 (0.04)	0.234	—	—
Engage facilitators in praise/encouragement for positive behavior	9	-0.03 (0.05)	0.476	—	—
Instructional strategies		-0.01 (0.01)	0.286	-0.01 (0.02)	0.486
Provide toys/books/games/stickers for child engagement	34	-0.04 (0.04)	0.308	-0.11 (0.08)	0.187
Utilize arts and music	24	-0.01 (0.04)	0.840	-0.06 (0.07)	0.421
Utilize games, imaginative play, or storytelling	29	0.01 (0.04)	0.809	-0.08 (0.07)	0.311
Utilize a stepped-intensity approach	14	-0.03 (0.07)	0.732	0.08 (0.08)	0.381
Utilize written activities	10	-0.00 (0.05)	0.924	-0.04 (0.08)	0.626
Utilize modeling/demonstration	22	0.06 (0.04)	0.116	0.12 (0.12)	0.342
Utilize media for instruction	16	-0.07 (0.06)	0.287	-0.08 (0.11)	0.452
Utilize hands-on approach	34	-0.06 (0.03)	0.069	-0.11 (0.08)	0.203
Utilize reflective listening	7	-0.00 (0.07)	0.988	-0.02 (0.09)	0.860
Utilize discussion	24	-0.05 (0.04)	0.207	-0.01 (0.08)	0.895
Utilize role-playing for instruction	12	-0.05 (0.06)	0.428	0.04 (0.13)	0.782
Utilize group instruction	41	-0.03 (0.03)	0.354	0.09 (0.08)	0.248
Utilize telephone calls	19	0.06 (0.05)	0.187	-0.03 (0.08)	0.689
Utilize dual language instruction/materials	26	-0.06 (0.03)	0.100	0.02 (0.07)	0.818
Utilize field trips/site visits	16	-0.02 (0.06)	0.729	-0.02 (0.09)	0.860
Activities for supporting caregivers		0.01 (0.01)	0.447	0.00 (0.01)	0.914
Engage experts to provide technical assistance to caregivers	16	0.00 (0.05)	0.980	—	—
Provide audiovisual media resources to caregivers	5	-0.11 (0.12)	0.366	-0.12 (0.16)	0.465
Provide materials to support healthy eating patterns to caregivers	28	0.02 (0.04)	0.710	0.05 (0.08)	0.532
Provide materials to support screen time reduction to caregivers	14	0.04 (0.05)	0.441	-0.03 (0.08)	0.723
Provide written resources to caregivers	60	-0.05 (0.04)	0.170	-0.09 (0.09)	0.331
Provide access to social media platforms/websites to caregivers	10	-0.01 (0.06)	0.873	-0.05 (0.08)	0.537
Provide education about obesity risk/awareness to caregivers	10	-0.07 (0.06)	0.268	—	—
Provide education about physical activity to caregivers	38	0.06 (0.04)	0.148	0.01 (0.08)	0.858
Provide education about healthy sleep patterns to caregivers	12	-0.08 (0.06)	0.211	-0.01 (0.09)	0.938
Provide education about the importance of routines to caregivers	14	-0.04 (0.08)	0.603	0.15 (0.15)	0.338

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Table 3. Childhood Obesity Evidence Base Project Taxonomy of Components Identified, Frequency, and Impact on the Overall BMI across the 58 Interventions Included in the Analyses *continued*

Intervention components	%	Impact on BMI			
		Immediate		Final	
		B (SE)	p	B (SE)	p
Provide education about nutrition and healthy eating patterns to caregivers	53	0.01 (0.04)	0.861	-0.05 (0.08)	0.545
Provide education about child behavior management to caregivers	31	0.08 (0.05)	0.092	0.06 (0.08)	0.437
Provide education about modeling healthy behaviors to caregivers	16	0.00 (0.04)	0.971	-0.05 (0.09)	0.563
Provide education about sources of stress and coping strategies to caregivers	9	-0.11 (0.08)	0.167	0.04 (0.19)	0.849
Provide education about social and emotional skills to caregiver	12	0.06 (0.05)	0.228	—	—
Provide education about the importance of built environment to caregiver	14	0.05 (0.05)	0.328	0.01 (0.09)	0.947
Provide education about health and wellness content to caregivers	10	-0.01 (0.05)	0.920	-0.02 (0.09)	0.860
Include activities to promote problem-solving to caregivers	17	0.02 (0.07)	0.824	0.23 (0.12)	0.074
Provide education about the importance of screen time reduction to caregivers	31	0.13 (0.04)	0.002	0.10 (0.08)	0.267
Implement personalized support for caregiver	29	0.05 (0.04)	0.235	0.00 (0.08)	0.992
Implement follow-up support for caregivers	21	-0.00 (0.05)	0.928	-0.08 (0.13)	0.566
Implement support groups for caregivers	2	0.01 (0.27)	0.972	—	—
Provide materials to support self-control in children	0	—	—	—	—
Facilitator training activities		-0.01 (0.01)	0.575	-0.12 (0.06)	0.091
Use a train-the-trainer model	22	0.02 (0.04)	0.620	-0.02 (0.09)	0.860
Provide curricular materials to facilitators	50	-0.02 (0.04)	0.650	0.01 (0.07)	0.929
Provide regular training opportunities for facilitators	31	-0.01 (0.04)	0.738	-0.12 (0.09)	0.860
Provide initial or one-time training opportunities for facilitators	59	-0.01 (0.04)	0.831	-0.05 (0.08)	0.488
Provide physical activity education and training to facilitators	21	-0.03 (0.03)	0.334	—	—
Provide healthy eating education and training to facilitators	7	-0.00 (0.06)	0.994	—	—
Provide food preparation education and training to facilitators	3	-0.12 (0.16)	0.434	—	—
Provide nutrition education and training to facilitators	17	-0.03 (0.04)	0.493	-0.11 (0.17)	0.540
Engagement of facilitators		0.02 (0.02)	0.213	-0.01 (0.06)	0.893
Engage pediatricians/health care providers	17	0.11 (0.04)	0.012	-0.05 (0.08)	0.541
Engage child care providers	14	0.07 (0.04)	0.076	-0.00 (0.12)	0.975
Engage families	29	-0.01 (0.04)	0.819	0.04 (0.19)	0.849
Engage community organizations	22	-0.03 (0.04)	0.442	-0.01 (0.08)	0.864
Policy-based strategies		-0.01 (0.01)	0.196	—	—
Implement nutrition standards	19	-0.04 (0.03)	0.220	—	—
Implement earned income tax credit	0	—	—	—	—
Implement policies regulating food/beverage costs	0	—	—	—	—
Implement policies for regulation of food/beverage access	10	-0.03 (0.04)	0.414	—	—
Implement SNAP/WIC policies	3	-0.06 (0.04)	0.159	—	—
Implement policies for increasing physical activity	16	-0.04 (0.04)	0.344	—	—

continued on page 36

Table 3. Childhood Obesity Evidence Base Project Taxonomy of Components Identified, Frequency, and Impact on the Overall BMI across the 58 Interventions Included in the Analyses *continued*

Intervention components	%	Impact on BMI			
		Immediate		Final	
		B (SE)	p	B (SE)	p
Activities related to physical activity/environment		-0.00 (0.01)	0.946	-0.03 (0.03)	0.350
Focus on physical activity education	22	-0.02 (0.04)	0.609	-0.04 (0.10)	0.695
Focus on importance of reduced screen time	26	-0.03 (0.04)	0.431	-0.08 (0.08)	0.321
Provide materials/space to support physical activity to caregivers	24	-0.05 (0.04)	0.231	0.04 (0.19)	0.849
Provide materials/space to support physical activity to facilitators	16	-0.03 (0.05)	0.572	-0.16 (0.18)	0.393
Engage caregivers in supporting physical activities	26	0.07 (0.04)	0.067	0.03 (0.08)	0.707
Engage child care providers in supporting physical activity	17	0.03 (0.04)	0.428	—	—
Implement reduction of sedentary behaviors	24	-0.03 (0.04)	0.465	-0.10 (0.17)	0.540
Implement “fun” physical activities to engage children	28	0.02 (0.04)	0.568	-0.05 (0.07)	0.501
Include structured physical activities	36	0.01 (0.04)	0.841	0.00 (0.08)	0.996
Include free play	9	0.02 (0.06)	0.683	—	—
Activities related to food/food environment		0.01 (0.01)	0.383	0.00 (0.03)	0.965
Focus on food preparation education	9	0.06 (0.05)	0.256	-0.10 (0.09)	0.264
Focus on nutrition-related education	47	0.01 (0.04)	0.851	0.02 (0.07)	0.830
Provide food to encourage healthy eating to children	24	-0.04 (0.04)	0.247	-0.12 (0.07)	0.139
Provide healthy recipes/shopping lists/menus to caregivers	16	0.07 (0.05)	0.115	-0.02 (0.10)	0.781
Engage child care providers in facilitating healthy eating patterns	17	0.01 (0.05)	0.746	0.19 (0.11)	0.108
Decrease less healthy food options	26	0.02 (0.04)	0.519	-0.05 (0.08)	0.511
Increase healthy food options	19	0.02 (0.04)	0.623	-0.02 (0.09)	0.860
Include opportunities for children to prepare foods	7	-0.03 (0.07)	0.605	-0.02 (0.09)	0.860
Include opportunities for children to try new foods	22	0.02 (0.04)	0.695	0.15 (0.08)	0.097
Engage caregivers in facilitating healthy eating patterns	48	0.04 (0.04)	0.414	0.06 (0.08)	0.415
Characteristics of the intervention		0.00 (0.01)	0.982	0.02 (0.02)	0.296
Utilized recognized standards or recommendations	47	-0.03 (0.03)	0.426	0.10 (0.07)	0.192
Utilized research-based approaches or curriculum	84	-0.00 (0.06)	0.945	—	—
Used a multi-level approach	33	-0.01 (0.04)	0.676	-0.03 (0.10)	0.781
Used culturally tailored intervention	33	-0.00 (0.04)	0.969	0.02 (0.08)	0.791
Documentation of intervention implementation/quality	34	0.03 (0.04)	0.387	0.14 (0.15)	0.351
Engage caregiver/family in intervention development	17	0.02 (0.05)	0.766	0.01 (0.08)	0.902
Engage child care providers in intervention development	17	-0.03 (0.04)	0.524	0.06 (0.09)	0.493
Engage pediatricians/health care providers in intervention development	9	0.02 (0.06)	0.786	0.06 (0.09)	0.493
Included home-visits	17	0.07 (0.07)	0.322	0.14 (0.15)	0.351

The overall frequency is the proportion of interventions that included the specific component expressed as a percentage. Bold values indicates significant moderator of BMI at the immediate or final post-intervention assessment. Dashes indicate that meta-regression could not be performed due to insufficient cases or when the variable was dropped due to multicollinearity.

SE, standard error.

Synthesis of Moderator Analyses

Meta-regression (using restricted maximum likelihood to estimate the between-study variance) was conducted to examine proposed moderators of BMI (see Moderator Analyses). Interventions that sampled fewer children of low socioeconomic status ($\beta = -0.20$, $p = 0.002$), sampled more children meeting criteria for overweight or obesity ($\beta = 0.23$, $p = 0.009$), recruited samples from clinical practices ($\beta = 0.20$, $p < 0.001$; e.g., pediatrician offices, primary care), and implemented the intervention in a clinical practice ($\beta = 0.24$, $p < 0.001$) were more likely to reduce children's BMI at the immediate post-test.

We also examined whether components of the intervention impacted BMI. Overall, children had a lower BMI at the immediate follow-up when the intervention delivered more, rather than fewer, activities supporting behavior change, $\beta = 0.03$, $p = 0.024$ (total components, see Table 3). Interventions that: (1) engaged caregivers in praise/encouragement for positive health-related behavior ($\beta = 0.09$, $p = 0.049$); (2) provided education about the importance of screen time reduction to caregivers ($\beta = 0.13$, $p = 0.002$); and (3) engaged pediatricians/health care providers in delivering intervention content ($\beta = 0.11$, $p = 0.012$) were more successful than interventions that did not include these components in reducing BMI in children at the immediate post-test.

When the intervention components were simultaneously entered in a multiple meta-regression model, only providing education about the importance of screen time reduction to caregivers emerged as a significant moderator of BMI at the end of the intervention. The model was significant [$F(3, 51) = 4.33$, $p = 0.009$, I^2 residual = 5%] and accounted for 89% of the variance in the change in BMI. Adjusting for multiple testing using the permutation test (5000 permutations) confirmed that interventions providing education about the importance of screen time reduction to caregivers differ on average from interventions that did not include this component (adjusted p -value = 0.048).[†]

[†]We did not include other significant sample or intervention features (Supplementary Table S4) in this model due to multicollinearity and overfitting, but we conducted exploratory analyses to evaluate the significant univariate moderators, controlling for screen time reduction, in separate multiple meta-regression models. Our base model assessed screen time reduction only [$F(1, 53) = 10.76$, $p = 0.002$; I^2 residual = 5%; $\tau^2 = 0.0003$] which was compared with models that also included the significant univariate moderator (model 2). Only one pattern emerged: The model including socioeconomic status provided a better fit to the data, indicating that childhood obesity interventions that sampled fewer children of low socioeconomic status ($\beta = -0.14$, $p = 0.043$), and provided education on screen time reduction ($\beta = 0.09$, $p = 0.038$), were more likely to reduce children's BMI at the immediate assessment [$F(2, 52) = 7.72$, $p = 0.001$; I^2 residual = 0%; $\tau^2 = 0.0002$]. This model accounted for 82% (vs. 75% in model 1) of the variance in the change in BMI. Adjusting for multiple testing using the permutation test (5000 permutations), however, showed weak evidence that socioeconomic status was associated with change in BMI ($p = 0.056$).

None of the hypothesized sample or intervention features (see Moderator Analyses) were associated with BMI at the final assessment (Supplementary Table S4).

Risk of Bias within Studies

The overall risk of bias judgments revealed that most studies were at low risk of bias (40%) or provided insufficient details to determine the quality of the study (35%). Most studies were judged to be at low risk for selection (53%), attrition (49%), or other sources (61%) of bias. The studies were typically judged to be at high risk for bias due to inadequate allocation concealment (51%), performance bias (59%), or detection bias (39%) because concealing the allocation and blinding of participants or personnel was not possible for many of the studies. Reporting biases (i.e., selective reporting) were typically judged as low (43%) or unclear (43%) risk of bias. The risk of bias score was not associated with the overall BMI at the immediate ($p = 0.943$) or final ($p = 0.343$) assessment (data not shown). The overall judgment and ratings for the seven sources of bias can be found in Supplementary Figure S1.

Risk of Bias across Studies

Funnel plots and results of the statistical tests to assess for the possibility of publication bias appear in the online appendix supporting this article, available in the Supplementary Data S2. The graphical and statistical tests revealed asymmetries that might be interpreted as small-study effects for BMI at the last follow-up assessment. Trim-and-fill procedures were used to estimate the number of potentially "missing" studies and the pooled ES (using random-effects procedures) if the presumed to be "missing" studies were included. These tests indicated that three studies may have been omitted. The pooled ES estimate was consistent with the original pooled ES for overall BMI, suggesting that including the "missing" studies would not change the overall conclusion ($g = 0.17$, 95% CI = 0.04–0.30 and estimated $g = 0.13$, 95% CI = 0.04–0.23).

Discussion

The current systematic review and meta-analysis shows that interventions to improve weight status in preschool-aged children are effective in reducing BMI. The overall magnitudes of the ESs are small ($g = 0.10$ at the end of treatment and $g = 0.17$ at the last follow-up) but suggest that 54% and 58% of the children exposed to an intervention had a lower BMI relative to the average for children in the control or comparison group at the immediate and final assessments, respectively. The magnitudes of ESs were likely impacted by our ES adjustments for baseline BMI values in consideration of regression to the mean (i.e., a statistical phenomenon that arises if extreme values observed in a group at baseline are closer to the mean at follow-up). Our findings, however, may be limited to certain settings or populations (e.g., clinical settings, children of low

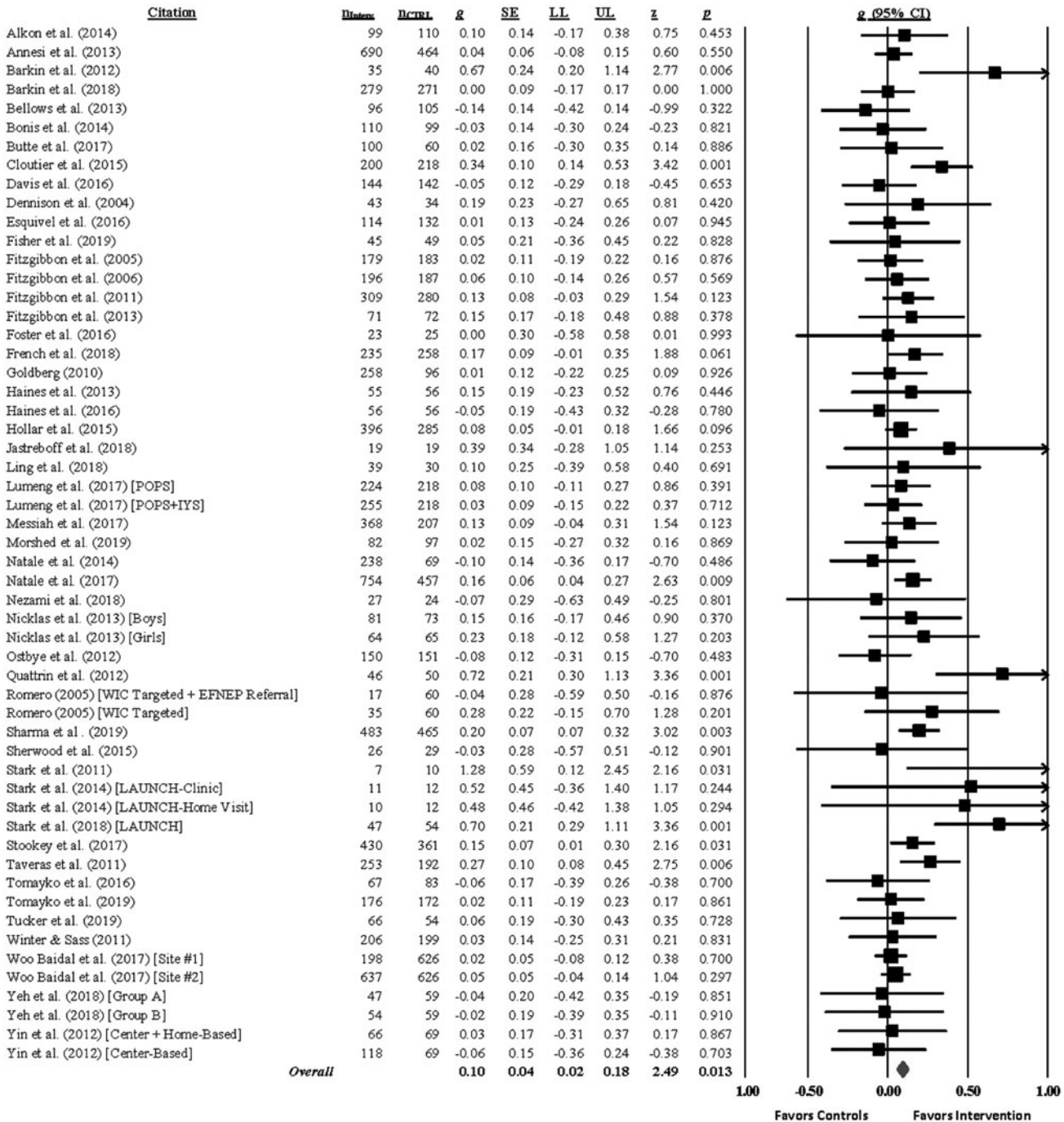


Figure 2. Childhood Obesity Evidence Base Project Forest Plot of the Impact of Child Obesity Interventions on BMI at the Immediate Post-intervention Assessment ($k = 55$).^a ^aRandom effects (full information maximum likelihood) model. The size of the square representing the standardized mean difference for each study is proportional to its weight in the analysis and the line running through the square represents the 95% CI. The diamond represents the overall standardized mean difference and the width of the diamond represents the 95% CI. Heterogeneity: $I^2 = 20\%$ (95% CI = 0–43); $\tau^2 = 0.0303$; $Q (54) = 67.08$, $p = 0.109$. CI, confidence interval.

socioeconomic status) and future meta-analyses should continue to examine which settings or populations benefit most from these interventions as the scientific literature grows. Nevertheless, our findings indicate that children aged 2–5 years who participate in an obesity intervention gain less BMI over time than children in the control or comparison groups. It is important to note that

this outcome is not a prevalence reduction, but it indicates a slowing of obesity in the intervention relative to the comparison condition as measured by lower weight status. The limited heterogeneity observed for overall BMI provides strong clinical evidence supporting the use of obesity prevention interventions for children 2–5 years of age living in the United States.

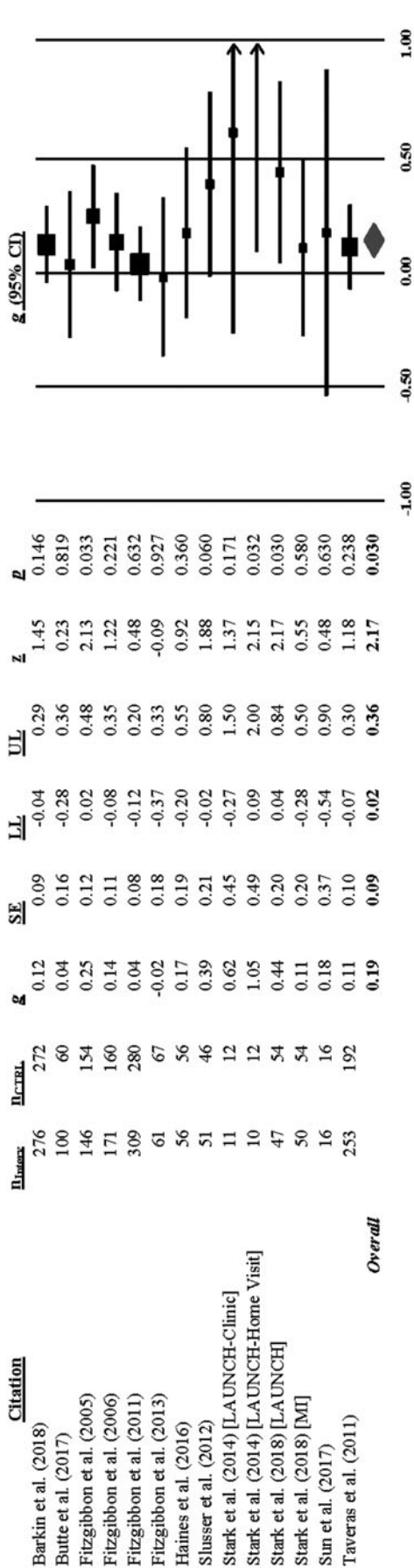


Figure 3. Childhood Obesity Evidence Base Project Forest Plot of the Impact of Child Obesity Interventions on BMI at the Final Post-Intervention Assessment ($k = 14$).^a Random effects (full information maximum likelihood) model. The size of the square representing the standardized mean difference for each study is proportional to its weight in the analysis, and the line running through the square represents the 95% CI. The diamond represents the overall standardized mean difference, and the width of the diamond represents the 95% CI. Heterogeneity: $I^2 = 0\%$ (95% CI = 0–74); $\tau^2 = 0.0297$; $Q(13) = 11.91$, $p = 0.535$.

This meta-analysis represents the first use of a taxonomy approach to identify components used in early childhood obesity interventions. Taxonomic meta-analysis allows for the discovery of components or patterns of components that are critical for behavioral change approaches,⁶⁰ which were included as moderators in this analysis. Four prior systematic reviews in the area of childhood obesity prevention have used a taxonomic approach to identify intervention components but these reviews focused on infant feeding interventions,⁶¹ parent-involved childhood weight control interventions for children 0–12 years of age,⁶² or prevention and management of childhood obesity in children and adolescents aged 1–18 years⁶³ or 2–18 years.⁶⁴ These systematic reviews were limited in scope, reviewing fewer than 24 studies each, and used a pre-existing taxonomy of behavioral change techniques that was not developed specifically to identify intervention components in the area of childhood obesity.^{65,66}

The current systematic review and meta-analysis extended prior research by focusing on any childhood obesity intervention targeted toward children aged 2–5 years, used the grounded theory^{16,17} within the SEM framework to identify the specific components of the intervention,¹⁹ and used meta-regression to identify whether intervention components impacted the efficacy of the findings. The development, refinement, and application of the taxonomy was a collaboration of a multidisciplinary team of experts, and they represent a significant step toward identifying the “active ingredients” of childhood obesity interventions, but ongoing applications will be necessary to optimize reliability, comprehensiveness, and implementation of the taxonomy especially as new studies emerge. Nevertheless, it is noteworthy that the findings from the taxonomic analysis performed in COEB support other taxonomic analyses based on behavior change components expected to affect weight outcomes.^{65,66}

Taxonomic meta-regression analyses identified three components that improved the success of the intervention in lowering children’s BMI at the end of treatment: Engage caregivers in praise or encouragement for positive health-related behavior (*e.g.*, positive affirmation or encouragement to child from caregivers), provide education about the importance of screen time reduction to caregivers, and engage pediatrician or health care providers in delivering all or part of the intervention content. However, when the intervention components were simultaneously entered in a regression model, providing education about the importance of screen time reduction to caregivers was the only significant moderator of BMI change. This model accounted for 89% of the variance in the change of BMI, suggesting the validity of the taxonomy of intervention components.

Exploratory subgroup analyses revealed a small but significant effect in reducing BMI in interventions in which a screen time component was present ($g = 0.23$, 95% CI = 0.10–0.36) versus absent ($g = 0.05$, 95% CI = -0.02 to 0.12) relative to the control or comparison group [$Q_B(1) = 11.24$, $p < 0.001$]. This is an important finding given that screen time habits in children younger than the age

of three are associated with increased screen use at 8 years of age,⁶⁷ and the robustness of research showing that screen time exposure is associated with an increased risk of obesity.⁶⁸ This also highlights the critical role of parents in reducing childhood obesity,⁶⁹ and the need to identify specific strategies and provide skills-training to support parents of preschoolers who often find it challenging to limit screen time exposure.⁷⁰ These findings are consistent with the Community Preventive Services Task Force, which found strong evidence supporting the efficacy of interventions addressing screen time reduction to promote healthy weight in children aged 13 and younger.⁷¹ Promoting screen time reduction could have the additional benefit of improving children's physical activity, diet, and sleep behaviors.⁷² Further, as young children five must receive required vaccinations to attend public school,⁷³ engaging health care teams (*e.g.*, physician, nurse, medical assistant) in delivery of obesity prevention initiatives seems both feasible and pragmatic given that half (53%) of the studies that promoted screen time reduction recruited children from clinical settings. The moderators highlighting the importance of the clinical setting (recruitment and implementation) may have explained additional between-study variance but were not included in the final multiple meta-regression model due to multicollinearity and overfitting of the model.

The success of childhood obesity prevention interventions to improve weight status was also associated with the characteristics of the samples. First, consistent with our hypothesis, childhood obesity interventions sampling a greater proportion of children meeting criteria for overweight or obesity were more successful in improving weight status. Other reviews corroborate our findings showing that multi-component obesity interventions can reduce weight status in overweight or obese preschoolers, but this moderator was no longer significant when screen time reduction was included in our exploratory models, suggesting that interventions providing education regarding screen time reduction to caregivers are beneficial for normal weight, overweight, and obese children. This finding is also consistent with the Community Preventive Services Task Force, which showed that interventions to reduce recreational sedentary screen time were effective regardless of weight status.^{71,72}

Second, as hypothesized, childhood obesity interventions sampling children of lower socioeconomic status were less successful in reducing BMI. This is an important and concerning finding given that low socioeconomic status is a critical risk factor for childhood obesity, and early prevention efforts are critical to prevent obesity in children of lower socioeconomic status. Exploratory multiple meta-regression analyses, however, showed weakened evidence that low socioeconomic status is associated with intervention efficacy when adjusting for multiple moderators. These findings suggest that traditional prevention strategies such as reducing screen time may also require content to address upstream (*e.g.*, reducing poverty, increasing access to education) and midstream (*e.g.*, reducing poverty-related stress) risk factors to reduce so-

cioeconomic disparities in obesity,²⁰ and we encourage researchers to conduct future studies evaluating novel intervention strategies to address socioeconomic adversity.

Finally, other hypothesized characteristics of the interventions (implementation in a school-based setting, targeting nutrition and physical activity, and involving caregivers) did not emerge as significant moderators of the intervention efficacy. Some reviews have found moderately strong evidence supporting the efficacy of interventions implemented in a school-based setting, diet combined with physical activity interventions, or those involving caregivers, but these have largely been found in meta-analyses sampling of children from a wider age range (*e.g.*, 2–18 years of age), multiple geographic locations, or limited to specific intervention settings (*e.g.*, schools).^{2–12,74} Such distinctions highlight the utility of a taxonomic meta-analytic approach to more precisely identify the intended recipients, context, and channels of delivery to improve the effectiveness of early childhood obesity interventions.

Limitations

Several limitations should be considered when interpreting the findings from this meta-analysis. First, as with any meta-analysis, identifying relevant studies is limited to the reports included in the electronic bibliographic database, our primary source for retrieving relevant reports. To reduce the possibility of omitting potentially relevant research, we conducted a comprehensive search of multiple bibliographic databases, cross-checked our findings with registries of federal grant funding and clinical trials, and consulted with experts in the field. It remains unclear, however, whether only the most rigorous interventions contributed most of the data, or whether all available data from community-based obesity prevention efforts in this age range were captured by using our search methods.

Second, we intended to include all studies evaluating an intervention to prevent or reduce childhood obesity in this age group but limitations in study design (*e.g.*, no control or comparison condition), sample (*e.g.*, children with a mean age <2 or >5 years of age), or outcomes (*i.e.*, no objective measure of BMI reported) impacted the number of reports available for inclusion. Also, by insisting that BMI be an inclusion criterion, it may be that the sample of studies was not representative of the many community-based intervention programs that focus on policy, system, and environmental changes to influence healthy behavior change. Third, we included studies that provided transformations of BMI (*i.e.*, BMI z-score, BMI percentile) that are known to be weakly associated with other measures of body fat in children with severe obesity and may have obscured changes in BMI in samples with a greater proportion of children in the 95th percentile or greater.⁷⁵

Finally, our moderator tests were limited to the intervention descriptions provided in the studies and supplemental reports. Intervention content is often not described in full detail due to space limitations in journals, and intervention fidelity was only addressed in one-third of the included studies. Further, the length of exposure to specific

intervention components is typically not provided. Therefore, we may have been limited to find effects for some of the intervention components or strategies because those components were not well represented in the interventions or reported fully in the database of included studies (*i.e.*, insufficient statistical power and restriction of range). Methods described in implementation science evaluation schemas can provide guidance for accomplishing this goal.⁷⁶ Replication of this meta-analytic approach by using another age range or targeted outcomes (*e.g.*, improving healthy eating; increasing physical activity; reducing screen time across age groups) will be necessary to demonstrate the robustness of using this taxonomic approach.

Conclusion

This is the first meta-analysis to use a taxonomic approach to identify components used in early childhood obesity interventions. Findings show that early childhood obesity interventions efforts may be successful in reducing the rate of increase in BMI over time, and that these changes may persist for up to 3 years after the intervention. Specific intervention components emerged as promising strategies: Training caregivers in healthy behavior change strategies (*i.e.*, reducing screen time), engaging health care providers directly in the delivery of obesity prevention efforts, and using health care settings were effective. Importantly, educating caregivers about the importance of screen time reduction appears to be the most promising intervention component identified in the current meta-analysis, but future research is needed to determine the benefits of delivering this component for all populations (*e.g.*, children of lower socioeconomic status). In sum, we found that using a taxonomic meta-analytic approach does elucidate promising intervention components and strategies that may accelerate efforts to reduce rates of childhood obesity. The taxonomic approach to meta-analysis of study effects allows evaluation of these questions and adds to the information provided by traditional meta-analysis.

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Author Disclosure Statement

No competing financial interests exist.

Supplementary Material

Supplementary Table S1
 Supplementary Table S2
 Supplementary Table S3
 Supplementary Table S4
 Supplementary Figure S1
 Supplementary Data S1
 Supplementary Data S2

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Address correspondence to:

Lori A.J. Scott-Sheldon, PhD

Centers for Behavioral and Preventive Medicine

The Miriam Hospital

CORO West, Suite 309, 164 Summit Avenue

Providence, RI 02906

USA

E-mail: lori_scott-sheldon@brown.edu