Behavioral Interventions to Prevent Childhood Obesity: A Systematic Review and Metaanalyses of Randomized Trials

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Context: The efficacy of lifestyle interventions to encourage healthy lifestyle behaviors to prevent pediatric obesity remains unclear.

Objective: Our objective was to summarize evidence on the efficacy of interventions aimed at changing lifestyle behaviors (increased physical activity, decreased sedentary activity, increased healthy dietary habits, and decreased unhealthy dietary habits) to prevent obesity.

Data Sources: Data sources included librarian-designed searches of nine electronic databases, references from included studies and reviews (from inception until February 2006), and content expert recommendations.

Study Selection: Eligible studies were randomized trials enrolling children and adolescents assessing the impact of interventions on both lifestyle behaviors and body mass index (BMI).

Data Extraction: Two reviewers independently abstracted data on methodological quality, study characteristics, intervention components, and treatment effects.

Data Analysis: We conducted random-effects metaanalyses, quantified inconsistency using I^2, and conducted planned subgroup analyses for each examined outcome.

Data Synthesis: Regarding target behaviors, the pooled effect size for physical activity (22 comparisons; n = 9891 participants) was 0.12 [95% confidence interval (CI) = 0.04–0.20; I^2 = 63%], for sedentary activity (14 comparisons; n = 3003) was −0.29, (CI = −0.35 to −0.22; I^2 = 0%), for healthy dietary habits (14 comparisons, n = 5468) was 0.00 (CI = −0.20; 0.20; I^2 = 83%), and for unhealthy dietary habits (23 comparisons, n = 9578) was −0.20 (CI = −0.31 to −0.09; I^2 = 34%). The effect of these interventions on BMI (43 comparisons, n = 32,003) was trivial (−0.02; CI = −0.06–0.02; I^2 = 17%) compared with control. Trials with interventions lasting more than 6 months (*vs.* shorter trials) and trials with postintervention outcomes (*vs.* in-treatment outcomes) yielded marginally larger effects.

Conclusion: Pediatric obesity prevention programs caused small changes in target behaviors and no significant effect on BMI compared with control. Trials evaluating promising interventions applied over a long period, using responsive outcomes, with longer measurement timeframes are urgently needed. **(*J Clin Endocrinol Metab* 93: 4606–4615, 2008)**

Obesity is currently considered the most prevalent nutritional disorder of children in the United States. Data from the Centers for Disease Control and Prevention show a 4-fold increase in overweight children [body mass index (BMI) >95th percentile for age] in the 6- to 11-yr-old group over the last three decades and a 3-fold increase in the 12- to 19-yr-old age group

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Abbreviations: BMI, Body mass index; HD, healthy dietary habits; PA, physical activity; RCT, randomized controlled trial; SA, sedentary activity; UD, unhealthy dietary habits.

(1). The prevalence is currently 16% in children of all ages, with the highest prevalence among African-American children. Given the epidemic nature of this condition, and the association between pediatric obesity and adverse health consequences (2), prevention of pediatric obesity is paramount.

Experts have implicated both physical activity (less than necessary with excessive sedentary activity) and dietary behavior (rich in unhealthy food choices and poor in healthy ones) in the causal path to obesity; researchers have consequently targeted these lifestyle behaviors to prevent obesity in children. Previous efforts to summarize the evidence linking interventions to obesity outcomes have been limited by the heterogeneity of the interventions (3–5) and by the selection and measurement of obesity outcomes.

In this systematic review, we have taken a different approach. We examined the extent to which preventive interventions could affect physical activity and dietary behavior as outcomes. Furthermore, we sought to examine the prevention strategies and their components to identify the most effective approaches for changing dietary and physical activity behavior among children and adolescents. A systematic summary of the best available research on the impact of these interventions on targeted behaviors and on obesity outcomes can best inform evidence-based clinical practice guidelines and future obesity prevention trials and programs.

Materials and Methods

Review question

We sought to assess the efficacy of interventions aimed at changing lifestyle behaviors, including increased physical activity (PA), decreased sedentary activity (SA), increased healthy dietary habits (HD), and decreased unhealthy dietary habits (UD) to prevent pediatric obesity. Secondarily, we also sought to assess the effect of these interventions on BMI.

The Endocrine Society's Guidelines Task Force on Pediatric Obesity commissioned the reviews reported in this document. The conduct of this review is consistent with the methods put forth by the Cochrane Collaboration, and this report is in concordance with the Quality of Reporting of Meta-analysis of Randomized Trials (QUOROM) standards.

Study selection

Eligible studies were randomized controlled trials (RCTs) enrolling children and adolescents (ages 2–18 yr) and assessing the impact of interventions on lifestyle behaviors that in turn may impact obesity outcomes. Lifestyle behaviors included 1) dietary changes, *i.e.* increased HD and decreased UD, and 2) changes in physical activity, *i.e.* increased PA and decreased SA. Eligible RCTs included a measure of these lifestyle behaviors, either through self-report or reported by a family member or a responsible adult (*e.g.* school nurse or teacher) or research or healthcare personnel (*e.g.* nurse or study coordinator) or measured using objective measures of the behavior (*e.g.* accelerometer assessment of physical activity). Participants received the interventions at home, school, clinic, or community setting. Healthcare professionals, community members, or health authorities could deliver the interventions. Eligible interventions could be simple or multimodal.

We excluded RCTs of patients with eating disorders or where most participants were adults or where all participants were obese (as defined by the authors of each report). We also excluded RCTs of interventions aimed primarily at reducing cardiovascular risk factors (*e.g.* antihypertensive and antihyperglycemic agents) or other consequences of obesity.

Search strategy

An experienced reference librarian (P.J.E.) designed and conducted an electronic search of all published literature indexed in the electronic databases MEDLINE, ERIC, EMBASE, CINHAL, PSYCInfo, DISSERTATION abstracts, Science Citation Index, Social Science Citation Index, and the Cochrane CENTRAL Database of controlled clinical trials, from each database's inception until February 2006. We used terms (both words and terms in the controlled vocabulary of each database) to cover the following concepts: overweight and obesity in children, behavioral modification, nonpharmacological treatments, prevention, and randomized trials (detailed search strategies are available from authors upon request).

We supplemented the database search with manual review of the reference lists of included articles, review articles, and expert suggestions. Two reviewers (L.M. and C.C.K.), working in duplicate and independently, screened all abstracts and titles as well as all full text publications for eligibility. In cases of disagreement between the reviewers, a third member of the research team not involved in the initial assessment (V.M.M.) adjudicated the study after reviewing the stated reasons for the initial assessment and the full text of the report. For the prevention review, we excluded studies focused exclusively on obese children; these studies were included in the accompanying treatment review (6). Otherwise, these two reviews share common search and selection processes but no common analyses.

Quality assessment

Working independently and in duplicate, reviewers ascertained the reported quality of eligible RCTs. We assessed the adequacy of concealment of allocation (chance-adjusted interobserver agreement; $\kappa = 0.73$), blinding of patients to allocation ($\kappa = 1.0$) or to the study hypotheses ($\kappa = 1.0$) as well as blinding of health-care providers ($\kappa = 0.86$) and data collectors ($\kappa = 0.83$). We also assessed whether the analyses were based on the intention to treat principle ($\kappa = 1.0$) and the extent of loss of follow-up, *i.e.* proportion of patients in whom the investigators were not able to ascertain outcomes.

Data abstraction

Working in duplicate and using a standard abstraction form, we abstracted the following data from each study: year and journal of publication, description of the study including setting and location, eligibility criteria, duration of study, and elapsed time from subject randomization to assessment of outcomes. We also collected information on participants, including sex, ethnicity, age, and other relevant demographic details and abstracted details on the nature of intervention and control.

We extracted the interventional components/strategies underlying each intervention as described in each trial according to a predefined framework. Specifically, we identified which of informational, cognitive, behavioral, environmental, or social support components (Table 1) were included in the description of the interventions.

Informational components included passive information ($\kappa = 0.82$) and education ($\kappa = 0.89$). Cognitive components included general cognitive strategies ($\kappa = 0.82$), goal setting ($\kappa = 0.85$), and problem solving/relapse prevention ($\kappa = 0.84$). Behavioral components included reminders and prompts for desired behaviors ($\kappa = 0.82$), skill building, practice and rehearsal ($\kappa = 0.95$), monitoring and feedback ($\kappa = 0.66$), and reinforcement for behavior ($\kappa = 1.0$). Environmental components consist of actual physical changes made to facilitate desired changes in behavior and to inhibit undesired changes by changing the environment of the home ($\kappa = 0.55$), school ($\kappa = 0.95$), and community ($\kappa = 0.71$). Parental support strategy components reflected the active involvement of primary parents but also included other significant caregivers in the delivery of the intervention ($\kappa = 0.73$).

Finally, we collected outcome data [end of study (preferred) or change from baseline] on each lifestyle variable and BMI for the longest period of follow-up for which data were available and where there was not excessive (>20%) loss to follow-up and where patients were still exposed to treatment or control. We calculated missing data using stan-

TABLE 1. Table of definition and distribution of intervention components and behavioral targets across studies

Strategies	Examples of intervention strategies	Baranowski (9)	Bayne-Smith (10)	Bush (32)	Caballero (11)	Dennison (27)	Epstein (29)	Fitzgibbon (12)	Going (13)	Gortmaker (14)	Hopper (34)	James (30)	Lauer (45)	Luepker (35)	Neumark-Sztainer (25)	Obarzanek (37)	Pate (16)	Patrick (17)	Robinson (18)	Robinson (19)	Roemmich (28)	Sahota (23)	Sallis (20)	Sallis (21)	Simon (24)	Story (22)	Tershakovec (36)	Walter (33)	Warren (26)	Vandongen (31)
Information and Education		■	■	□	■	■	■	□	□	■	□	■	■	□	■	□	□	■	□	□	□	□	□	■	■	■	■	□	■	□
Information	Lists of low-fat lunch ideas printed in newsletter; health information on internet or in pamphlet																													
Education	Facilitated instruction in the healthy food guide pyramid; health classes																													
Cognitive		■		■	□	■	■		□	■			■	□	■	■	■	■		□			■		□	■	□	□	□	
General cognitive strategies (Includes strategies to enhance or change attitudes, perceptions, self-efficacy, decision-making, and perceived control)	Recognizing triggers to unhealthy eating, addressing perceptions of health risks, identifying the pros and cons of a health behavior																													
Goal-setting	Setting goals toward eating healthy snacks or reducing television time																													
Problem-solving	Preparing for challenging situations and working around barriers to healthy behavior (*e.g.* what to do when only fast food options are available)																													
Behavioral		■	■	■	□	■	■	□	□	■	■	□	□	■	□	□	■	■	□	□	■	□	■	□		■		■	■	■
Reminders and prompts	Teacher cues to complete activities																													
Skill building, practice & rehearsal	Guided play during recess, snack preparation																													
Monitoring, feedback	Recording of activity time, tracking eating patterns																													
Reinforcement for behavior	Healthy lunch contests with opportunity to earn raffle tickets																													
Environmental				□	□					□		□		□			□		□	□	□	□	□	□	□	□	□		□	
Home environment	Equipment at home limiting television and video game use; increased availability of fruits and vegetables in the home																													
School environment	Cafeteria recipe modification and ingredient substitution																													
Parental/social support	Parent and child collaboration in completing activity packets; family fun nights at school	□		□	□	□	□	□			□		□	□			□	□	□	□	□	□	□	□		□	□	□	□	□
Behavioral targets examined	Increased PA	•			•			•	•	•				•	•		•	•	•	•	•		•	•	•	•			•	
	Decreased SA					•		•		•					•			•	•	•	•	•		•	•		•				
	Increased HD	•	•				•	•		•		•	•		•			•				•		•			•			•	•
	Decreased UD			•	•		•	•		•	•	•		•	•	•		•	•	•		•		•		•	•	•	•	•	•

■, More than one component; □, at least one component; •, target behavior included in study.

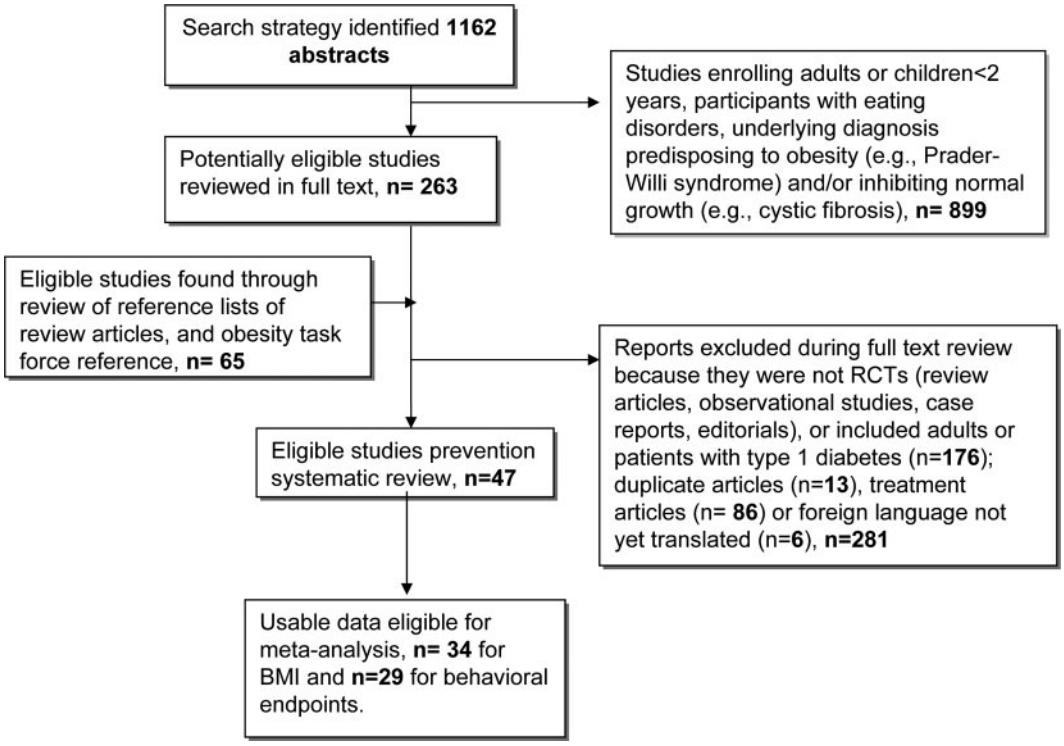

FIG. 1. Flow chart of the study selection process.

dard procedures recommended in the Cochrane Handbook (7). We contacted authors and requested information when data were measured but not adequately reported. Response rate from author contact was approximately 30%.

Quantitative data synthesis

We determined the effect sizes (standardized mean differences) and 95% CI for the difference between arms (treatment *vs.* control) for each of the four behavioral targets and for BMI by dividing the mean difference by the pooled SD between arms with adjustment for small samples (Hedges g), as implemented in Review Manager (RevMan) version 4.2 for Windows (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). When data were in the form of odds ratios or counts, we conducted metaanalyses using the generic inverse variance method as implemented in RevMan. We quantified the extent of the variability observed that could be accounted by true between-study differences rather than chance using the I^2 statistic (8).

Subgroup analyses

We explored preplanned subgroup analyses by grouping RCTs by quality (loss to follow-up <20%), by the age (child or adolescent) and sex of the study population, by whether the trial was described as pilot feasibility or not, by study duration (<3 months, 3–6 months, and >6 months), by outcome measured during treatment or during maintenance, and by whether the intervention was school based. Additional preplanned subgroup analyses explored treatment-subgroup interactions with the type of intervention (cognitive: multiple components or single/no components and goal setting; behavioral: multiple components or single/no components, reinforcement/rewards, social support, and environmental changes) and whether researchers measured outcomes objectively and with high quality. An example of an objective measure for physical activity would be accelerometer data; an example of high-quality measurement would be moderate to vigorous activity, minutes per week *vs.* frequency of physical activity in the last week. Subgroup analyses, although planned, were exploratory; we did not apply adjustments for multiple comparisons.

Results

Search results

The search yielded 1162 potentially eligible abstracts (Fig. 1). We also considered 64 additional articles from review of reference lists from relevant reviews and guidelines and from input from the Pediatric Obesity Task Force members. We found 36 eligible RCTs; of these, three reported on population reported in another included RCT, and two were deemed ineligible after author contact and clarification. Of the remaining RCTs, we were able to obtain complete data from 34 RCTs for BMI, of which 29 RCTs had complete data for at least one of the behavioral endpoints.

Study characteristics

Methodological quality

Table 2 describes the methodological quality of included prevention trials. Most reports were unclear on the quality dimensions we sought to extract, and none satisfied all quality criteria. Of the 34 included, only four (12%) studies had allocation concealment, one (3%) had participant or provider blinding, five (14%) had blinding of data collectors, and 11 (32%) had loss to follow-up over 20%. Studies focusing on physical activity interventions alone performed the worst in terms of methodological quality.

Included RCTs

Table 3 describes RCT characteristics demonstrating considerable heterogeneity in terms of participants, interventions, delivery methods, and outcome measures.

TABLE 2. Methodological quality of included studies

	Allocation concealment	Blinding of participants	Blinding of providers	Blinding of data collectors	Loss to follow-up >20%
All prevention studies (n = 34)	4 (12%)	1 (3%)	1 (3%)	5 (14%)	11 (32%)
Combined lifestyle interventions (n = 20)	2 (1%)	0 (0%)	1 (5%)	3 (15%)	7 (35%)
PA interventions (n = 7)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (43%)
Dietary interventions (n = 7)	2 (29%)	1 (14%)	0 (0%)	2 (29%)	1 (14%)

Interventions

Table 1 describes the distribution of interventional components and behavioral endpoints across the included RCTs. Informational components (passive information and/or education) were part of every intervention. Interventions included behavioral components more often than cognitive components and social support. Notably, only half of the RCTs used environmental strategies.

Most RCTs targeted more than one behavior; with dietary behavior (HD and UD) targeted slightly more often than physical activity (PA and SA). Six studies targeted all four lifestyle behaviors. PA was typically targeted along with HD and UD; SA was the least targeted behavior.

Quantitative data synthesis

Effects of interventions to increase physical activity

We found 18 reports (9–26) of interventions to increase physical activity. Four of these (14, 17, 20, 21, 24) contributed additional comparisons because each sex group was examined separately. Metaanalysis of these 22 RCTs including 9891 participants showed a small but statistically significant increase in physical activity (0.12; CI = 0.04–0.20) with moderate inconsistency across trials (I^2 = 63%; Fig. 2). We found no significant treatment × subgroup interactions that could explain this inconsistency. There was a trend favoring multiple cognitive components (0.15; CI = 0.05–0.24; *vs.* one or no cognitive components, 0.00; CI = 0.13–0.13; $P = 0.06$) and interventions including reinforcement (0.24; CI = 0.06–0.41; *vs.* no reinforcement, −0.07; CI = −0.01–0.15; $P = 0.07$).

Effects of interventions to decrease sedentary activity

We found 10 reports (12, 14, 17–19, 21, 24, 25, 27, 28) of interventions to reduce sedentary behavior. Metaanalysis of the 14 RCTs including 3003 participants showed a small but statistically significant reduction of sedentary activity (−0.29; CI = −0.35 to −0.22), with high consistency in results across studies ($I^2 = 0\%$; Fig.

TABLE 3. Methodological Quality of Included Studies

Study	Allocation concealment	Participant's blinding status	Provider's blinding status	Data collector's blinding status	Intention to treat analysis	Loss to Follow-up
Baranowski, T et al., 2003 (9)	yes	unclear	unclear	unclear	yes	0.11
Bayne-Smith, M et al., 2004 (10)	no description	unclear	not blinded	unclear	unclear	0.12
Bush et al., 1989 (32)	no description	unclear	unclear	unclear	no	0.34
Caballero, B et al., 2003 (11)	no description	unclear	not blinded	presumed blinded	yes	0.17
Dennison, BA et al., 2004 (27)	unclear	unclear	not blinded	unclear	unclear	0.07
Epstein, LH et al., 2001 (29)	unclear	unclear	unclear	unclear	yes	0.15
Fitzgibbon MN 2004 (12)	unclear	unclear	unclear	presumed blinded	unclear	0.36
Going, S et al., 2003 (13)	unclear	unclear	unclear	unclear	unclear	0.04
Gortmaker, SL et al., 1999 (14)	unclear	unclear	not blinded	unclear	yes	0.05
Hopper CA et al., 1992 (34)	no description	not blinded	unclear	not blinded	unclear	0.06
James, J et al., 2004 (30)	yes	blinded	not blinded	clearly blinded	unclear	0.11
Lauer, RM et al., 2000 (45)	yes	unclear	unclear	clearly blinded	yes	0.10
Luepker et al., 1996 (35)	no description	unclear	unclear	clearly blinded	yes	0.21
Neumark-Sztainer, D et al., 2003 (25)	no description	not blinded	not blinded	unclear	unclear	0.10
Obarzanek E et al., 2001 (37)	yes	unclear	unclear	clearly blinded	yes	0.13
Pate RR et al., 2005 (16)	no description	unclear	unclear	unclear	unclear	0.23
Patrick et al., 2006 (17)	no description	not blinded	not blinded	unclear	yes	0
Robinson TN 1999 (18)	no description	not blinded	not blinded	clearly blinded	yes	0.15
Robinson TN 2003 (19)	no description	unclear	blinded	clearly blinded	yes	0.03
Roemmich et al., 2004 (28)	no description	unclear	unclear	unclear	yes	0.28
Sahota P et al., 2001 (23)	yes	unclear	not blinded	unclear	unclear	0.07
Sallis JF et al., 1997 (20)	no description	unclear	not blinded	unclear	unclear	0.38
Sallis, JF et al., 2003 (21)	no description	unclear	not blinded	unclear	unclear	0.15
Simon et al., 2004 (24)	no description	unclear	not blinded	unclear	unclear	0.10
Story, M et al., 2003 (22)	no description	unclear	not blinded	unclear	unclear	0.02
Tershakovec et al., 1998 (36)	no description	not blinded	not blinded	unclear	unclear	NA
Walter HJ et al., 1988 (33)	no description	unclear	unclear	unclear	unclear	0.17
Warren, JM et al., 2003 (26)	no description	unclear	not blinded	unclear	unclear	NA
Vandongen et al., 1995 (31)	no description	not blinded	not blinded	not blinded	unclear	0.17

NA, Not applicable.

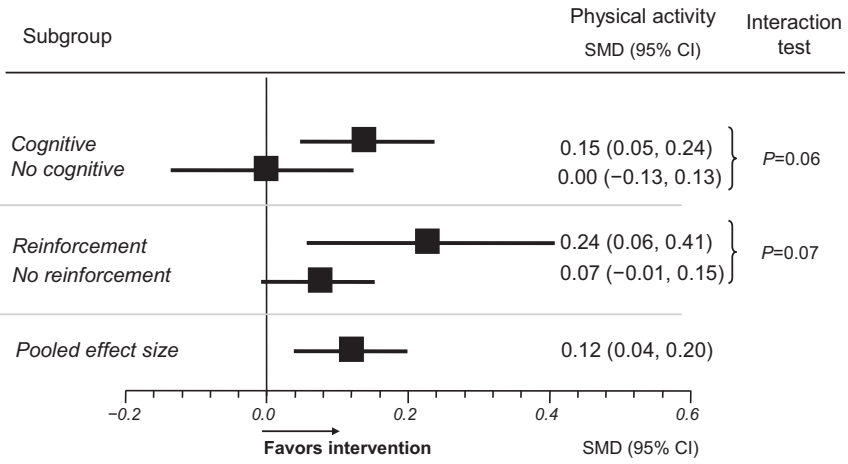

FIG. 2. Metaanalysis: PA outcome. Summary of random-effects metaanalyses of randomized trials of interventions to increase PA to prevent pediatric obesity. Plot shows metaanalytic point estimates (■) and 95% CI (*horizontal lines*) for all studies and selected subgroups. Cognitive indicates one or more cognitive components in intervention; no cognitive, no cognitive component in intervention; reinforcement, one or more reinforcement in intervention; and no reinforcement, no reinforcement component in intervention. *P*, Probability of null hypotheses; SMD, standardized mean differences.

3). We noted several significant treatment × subgroup interactions. There were greater treatment effects when trials measured in-treatment outcomes (−0.32, CI = −0.39 to −0.25; *vs.* outcomes measured after treatment, −0.05; CI = −0.24–0.13; $P = 0.009$), when treatment duration was more than 6 months (−0.31; CI = −0.39 to −0.24; *vs.* briefer trials, −0.05; CI = −0.31–0.20; $P = 0.05$); and when trials enrolled children (−0.31, CI-0.39, −0.24 *vs.* adolescents −0.00, CI = −0.25–0.25; $P = 0.02$). There was a trend favoring interventions that included multiple cognitive components (−0.31; CI = −0.38–0.24; *vs.* one or no cognitive components, −0.09; CI = −0.29–0.11; $P = 0.06$).

Effects of intervention to increase healthy dietary behavior

We found 12 reports (9, 10, 12, 14, 17, 22, 23, 25, 26, 29–31, 45) of interventions to enhance healthy dietary behavior. Metaanalysis of the 14 RCTs including 5468 patients showed a trivial and nonsignificant increase in healthy dietary behavior (0.06; CI = −0.09–0.21), with considerable heterogeneity ($I^2 = 83\%$; Fig. 4). Trials yielded greater treatment effects when interven-

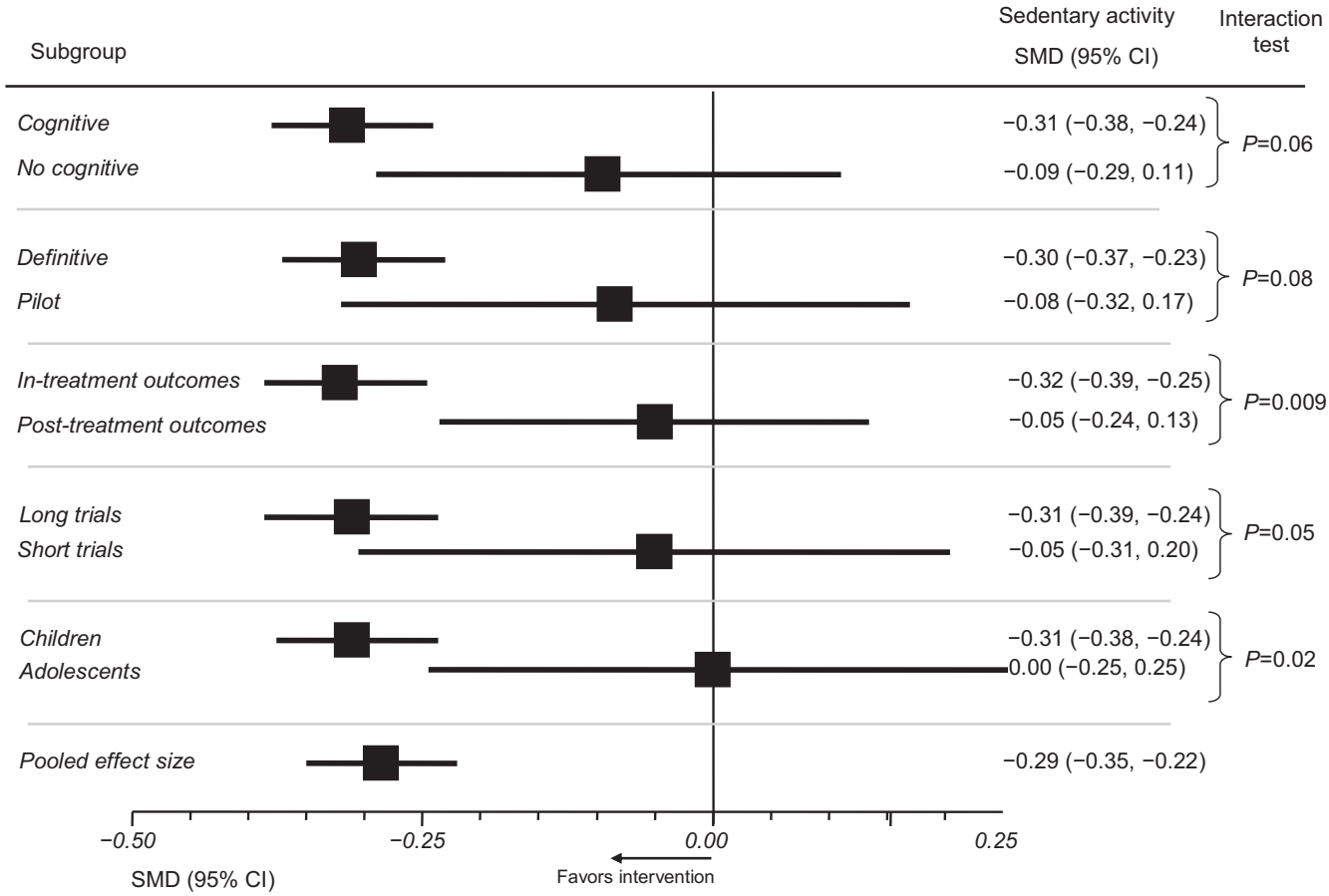

FIG. 3. Metaanalysis: SA outcome. Summary of random-effects metaanalyses of randomized trials of interventions to decrease SA to prevent pediatric obesity. Plot shows metaanalytic point estimates (■) and 95% CI (*horizontal lines*) for all studies and selected subgroups. Cognitive indicates one or more cognitive components in intervention; no cognitive, no cognitive component in intervention; definitive, definitive trial; pilot, pilot or feasibility trial; in-treatment outcomes, outcomes measured within 1 month of termination of trial; posttreatment outcomes, outcomes measured more than 1 month after termination of trial; long trials, trials of duration greater than 6 months; short trials, trials of duration shorter than 6 months; children, trials enrolling subjects 2–11 yr of age; and adolescents, trials enrolling subjects 12–18 yr of age. *P*, Probability of null hypotheses; SMD, standardized mean differences.

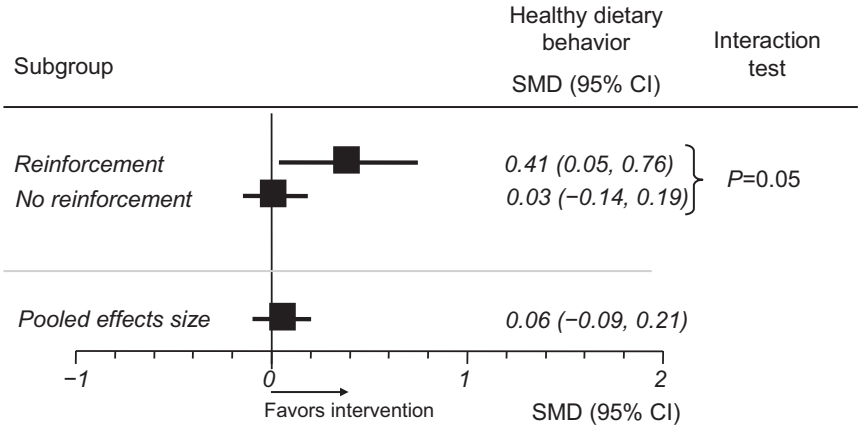

FIG. 4. Metaanalysis: HD behavior outcome. Summary of random-effects metaanalyses of randomized trials of interventions to increase HD to prevent pediatric obesity. Plot shows metaanalytic point estimates (■) and 95% CI (*horizontal lines*) for all studies and selected subgroups. Reinforcement indicates one or more reinforcements in intervention, and no reinforcement indicates no reinforcement component in intervention. *P*, Probability of null hypotheses; SMD, standardized mean differences.

tions included reinforcement (0.41; CI = 0.05–0.76; *vs.* no reinforcement, −0.03; CI = −0.14–0.19; $P = 0.05$). All other planned subgroup analyses were noncontributory.

Effect of interventions to reduce unhealthy dietary behavior

We found 19 reports (11, 12, 14, 17–19, 21–23, 25, 29–37) of interventions to reduce unhealthy dietary behavior. Metaanalysis of the 23 RCTs including 9578 patients showed a small but significant reduction in unhealthy dietary behavior (−0.15; CI = −0.22 to −0.08) but with moderate inconsistency across studies ($I^2 = 34\%$; Fig. 5). Trials yielded greater treatment effects when they studied interventions with briefer training (−0.40; CI = −0.62 to −0.19; *vs.* interventions with longer training, −0.15; CI = −0.22–0.08; $P = 0.02$). All other planned analyses were noncontributory.

Effect of interventions on BMI

Figure 6 summarizes the metaanalyses of 34 trials of lifestyle interventions on BMI. The pooled effect from 43 comparisons including 32,003 participants was insignificant (−0.02; 95% CI = −0.06–0.02; $I^2 = 17\%$).

Planned subgroup analyses found that trials longer than 6 months and trials that measured outcomes after treatment yielded significantly greater treatment effects than brief trials and trials that measured outcomes on treatment (test of interaction, $P = 0.02$ and $P = 0.03$, respectively). In both instances, however, the range of effects in the confidence intervals excluded moderate or large effects on BMI. All modalities of intervention (dietary only, physical activity only, or combined lifestyle interventions) yielded similar trivial to small effects on BMI compared with control (Fig. 6).

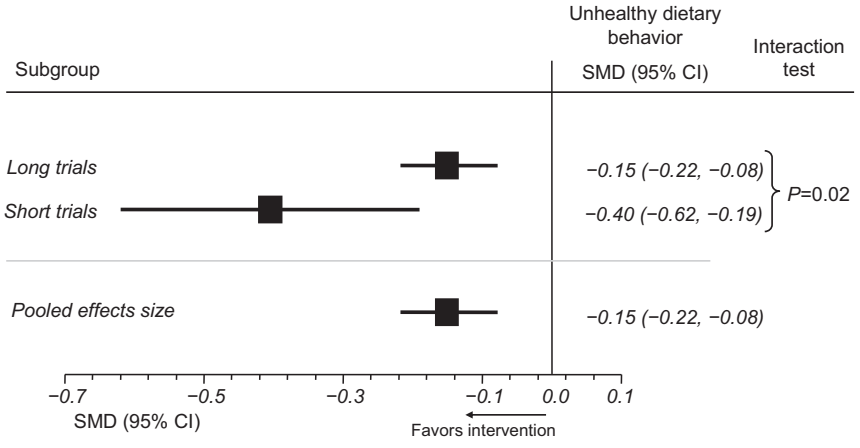

FIG. 5. Metaanalysis: UD behavior outcome. Summary of random effects metaanalyses of randomized trials of interventions to decrease UD to prevent pediatric obesity. Plot shows metaanalytic point estimates (■) and 95% CI (*horizontal lines*) for all studies and selected subgroups. Long trials indicates trials of duration greater than 6 months; short trials, trials of duration shorter than 6 months. *P*, Probability of null hypotheses; SMD, standardized mean differences.

Discussion

Our findings

This systematic review of all available RCTs of programs to prevent pediatric obesity found that these interventions caused small changes on their respective target behaviors and no significant effect on BMI compared with control. Further exploration through hypotheses-generating subgroup analyses found 1) there were no sex-treatment interaction; 2) trials in children found larger reductions in SA than trials in adolescents; 3) trials of long treatments (>6 months) found larger reductions in SA and BMI than shorter trials, which were more effective in reducing UD; and 4) trials measuring outcomes during treatment found larger reductions in SA and smaller reductions in BMI than trials that measured these outcomes after treatment. We found no significant interaction between interventional components and their effect on target behaviors or BMI compared with control.

Limitations and strengths of this systematic review

There are certain limitations to our study that deserve mention. We limited our search to RCTs that measured the impact of interventions on obesity outcomes and on mediating behavior variables. Although our focus was on obesity prevention, our search yielded prevention studies that mostly included a mixed group, a proportion of which was already overweight. It is possible that important and different inferences could result from considering RCTs focused exclusively on non-overweight children and RCTs measuring mediating behavioral outcomes only and from considering RCTs focused on lifestyle interventions to treat pediatric obesity. Despite our comprehensive search, we may have missed eligible studies. We had to rely on limited descriptions of interventions to classify the studies.

We have pooled RCTs many of which have important methodological shortcomings (loss to follow-up, lack of blinding). In-

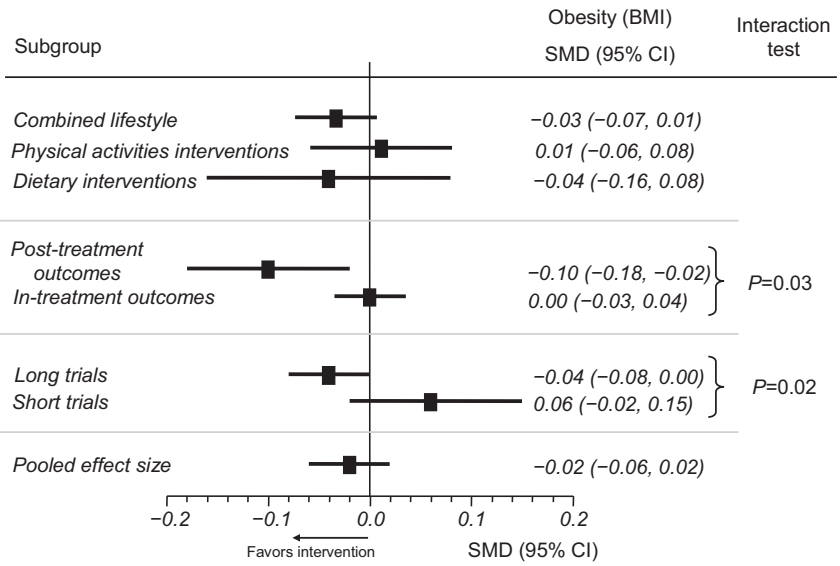

FIG. 6. Metaanalysis: obesity. Summary of random-effects metaanalyses of randomized trials of interventions to increase PA to prevent pediatric obesity. Plot shows metaanalytic point estimates (■) and 95% CI (*horizontal lines*) for all studies and selected subgroups. Combined lifestyle interventions indicates interventions that include dietary changes and PA; PA interventions, interventions focused on increasing PA and/or decreasing SA; dietary interventions, interventions focused on increasing HD and/or decreasing UD; in-treatment outcomes, outcomes measured within 1 month of termination of trial; posttreatment outcomes, outcomes measured more than 1 month after termination of trial; long trials, trials of duration greater than 6 months; and short trials, trials of duration shorter than 6 months. *P*, Probability of null hypotheses; SMD, standardized mean differences.

consistency across RCTs for most of our analyses remains largely unexplained despite a large set of planned subgroup analyses. The inconsistency is likely the result of true heterogeneity in patients and settings, interventions, outcomes, and trial design. We could not explore with greater detail the impact of duration, dose intensity, and other details of the intervention often missing from the primary reports. A consequence of our focus on RCTs is the predominance of clinical rather than population-based or environmental interventions assessing the effect of interventions; however, RCTs yield less biased treatment estimates and should be used to determine the relative merit of interventions targeting communities and environments. BMI as an outcome of these interventions may be relatively insensitive to change, and other outcomes, such as the proportion of participants who became overweight at the end of the study period with and without intervention, which would have been most pertinent to judge the downstream efficacy of the behavioral interventions, were not consistently available. Furthermore, we could not determine the extent to which the effect of behavioral interventions differed between overweight participants (as were members of mixed cohorts) *vs.* those who had not yet received this classification. Thus, the overall quality of the evidence supporting the use of lifestyle interventions to change behavior and impact BMI is low, with inferences weakened by methodological flaws (lack of blinding and excessive loss to follow-up) and unexplained inconsistency.

On the other hand, our focused review question, comprehensive and systematic literature search aided by an experienced reference librarian, collaboration of a multidisciplinary team of health behavior specialists, pediatricians, internists, and health researchers, explicit and reproducible eligibility criteria, and focused protocol-driven analyses contribute to the validity of study findings. The extent of agreement between abstractors regarding the assessment and classification of components in interventions increases our confidence in our classifications. We were able to overcome most of the observed reporting bias thanks to the authors who responded to our data queries resulting in our ability to complete most of the missing data from publications after 1995.

Comparison with other systematic reviews

The systematic reviews that focused on either obesity prevention or similar endpoints to ours (3, 5, 38–43) also struggled with unexplained heterogeneity across trials. None of these reviews offered a quantitative synthesis of the evidence on the endpoints of focus for this review, making it difficult to directly compare our results with theirs. Arguably, the lack of pooled estimate in other reviews limits their usefulness to clinicians and policymakers who will undoubtedly seek answers in each of the individual trials falling victim to the random variation in results across trials (*i.e.* random error). Although our review provided the largest number of RCTs focused on the prevention of obesity, the other reviews included studies that also examined the treatment of obesity (3, 39), studies that were controlled but not randomized (42, 43), other nonrandomized designs (5, 38), studies enrolling adults (40), reviews with narrower focus on school-based programs (42, 43), and reviews of papers published in a briefer time span (3, 38, 42, 43).

As the Agency for Healthcare Research and Quality review (3) pointed out, behavioral interventions, which represent expertise-driven approaches using principles to improve behaviors such as diet and physical activity, should be considered conceptually apart from these behaviors in preventing obesity. In most reviews, dietary behavior and physical activity were considered interventions (rather than behavioral outcomes). Except for three reviews (38, 39, 43), none of the other reviews made a distinction between behavioral interventions and behaviors (such as PA, SA, HD, and UD) to prevent obesity; of these, only two summarized the data, but only qualitatively (39, 43). A recently published review (43) focusing only on school-based interventions found that TV watching was the most modifiable behavior, similar to our results. Flynn *et al.* (38) noted that of the 44 studies that included nutritional outcomes, 73% reported a positive change, with more effective results in community and primary school settings. Among the 36 studies including physical activity outcomes, 64% reported positive change. This form of vote counting, however, does not take into account the relative size (precision) of each trial, thus yielding a potentially misleading inference, and cannot offer estimates of the magnitude of the change in behavior afforded.

Implications for practice, research, and policy

This research provides preliminary insight into the impact of interventions on lifestyle behaviors deemed critical in the prevention of pediatric obesity. Interventions intended to prevent obesity in children can indeed have significant effects on physical activity and dietary behaviors. At this time, strategies attempting to reduce unhealthy behaviors (*i.e.* decreasing sedentary behaviors and dietary fat) seem to be more effective than those promoting positive behaviors (*i.e.* increasing physical activity and consumption of fruits and vegetables). If compelling evidence was available showing that decreasing unhealthy behaviors effectively prevented pediatric obesity, these may indeed be the behaviors to specifically target in constructing a cost-effective intervention to prevent pediatric obesity. We think our analyses were underpowered to detect an interaction between the interventional components and the outcomes of interest; this assertion assumes, however, that the size of that interaction was relatively modest. Some trends suggest greater effects on healthy behaviors (PA and HD) associated with reinforcement and beneficial effects on physical activity and sedentary activity with multiple-component cognitive techniques. These and other inferences from subgroup analyses remain tentative.

The link between lifestyle behaviors and obesity must be established within the right framework and methodological technique. Do they serve as moderating or mediating influences of behavioral interventions to prevent obesity? Do they interact with each other? Are the positive and negative dimensions of behaviors substitutable for each other or do they have complementary effects? For example, do interventions that increase physical activity also encourage increased intake of both healthy and unhealthy food? These behaviors are likely to interact when impacting obesity to the extent that we believe obesity to result from an imbalance between energy expenditure and consumption. Effective change in more than one behavior, therefore, could have a synergistic effect on obesity prevention.

The long-term impact of behavioral interventions on maintenance of target behaviors needs further exploration along with methodological rigor in the definition and measurement of the target behaviors. Given the considerable heterogeneity across pediatric obesity prevention studies, in terms of specific interventions used (*e.g.* number, type, and duration of interventional strategies), behavioral targets of the interventions, and the measurement of outcomes, it is necessary for authors to make available sufficient detail about their treatment strategies, about the theoretical basis and components of interventions, and of the dose and intensity of the interventions, including any implementation and evaluation of treatment fidelity (44). Furthermore, we suggest that future systematic reviews of obesity prevention trials attempt to systematically categorize intervention strategies to allow for comparisons of intervention types across studies, similar to our classification (Table 1). Finally, we did not examine the adverse effects of behavioral interventions or the targeted behaviors. Although unlikely, behaviors that are most amenable to change may also cause the most harm to child wellbeing (*i.e.* dietary restrictions may lead to poor child growth and development).

In summary, metaanalyses of the available trials of interventions to prevent pediatric obesity found small beneficial changes on the target behaviors and no significant effect on BMI compared with control.

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