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Which Type of Sedentary Behavior Intervention is More Effective at Reducing Body Mass Index in Children? A Meta-Analytic Review

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Abstract

Sedentary behavior is emerging as an independent risk factor for pediatric obesity. Some evidence suggests that limiting sedentary behavior alone could be effective in reducing body mass index (BMI) in children. However, whether adding physical activity and diet-focused components to sedentary behavior reduction interventions could lead to an additive effect is unclear. This meta-analysis aims to assess the overall effect size of sedentary behavior interventions on BMI reduction, and to compare whether interventions that have multiple components (sedentary behavior, physical activity, and diet) have a higher mean effect size than interventions with single (sedentary behavior) component. Included studies (N=25) were randomized controlled trails of children (<18 years) with intervention components aimed to reduce sedentary behavior and measured BMI at pre- and post-intervention. Effect size was calculated as the mean difference in BMI change between children in an intervention and a control group. Results indicated that sedentary behavior interventions had a significant effect on BMI reduction. The pooled effect sizes of multi-components interventions (g=−.060~−.089) did not differ from the single-component interventions (g=−.154), and neither of them had a significant effect size on its own. Future pediatric obesity interventions may consider focusing on developing strategies to decrease multiple screen-related sedentary behaviors.

Keywords

Sedentary behavior; Children; Body mass index; Obesity

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Introduction

Overweight and obesity in childhood are known to have detrimental effects on both physical and psychosocial health. Problems in cardiovascular (e.g., hypercholesterolemia, hypertension) and endocrine functioning (e.g., hyperinsulinism, impaired glucose tolerance, type 2 diabetes mellitus) as well as and mental health concerns (e.g., depression, low self-esteem) are common in obese children and adolescents.[1] These comorbidities will likely persist into adulthood.[2] Moreover, obesity in childhood is known to be an independent risk factor for adult obesity. Being obese in childhood is also believed to be an important early risk factor for adult morbidity and mortality.[3,4] Unfortunately, successful treatments for obesity have been elusive. In addition, only about 10% of obese children seek weight loss treatment.[5] Therefore, much effort has been devoted to developing obesity prevention programs, in the hope that this strategy will be more effective to solve obesity as a public health problem. In fact, prevention in children is viewed as the best approach to reverse the rising global prevalence of obesity.[6]

Interactions between genetic, biological, psychological, sociocultural, and environmental factors are evident in childhood obesity.[1,7] The rapid increase of overweight and obese children during the past two decades suggests that environmental factors may play a greater role than genetic factors.[8] The increasing prevalence of obesity is believed to be a result of an increase in the energy content of dietary intake, decrease in level of physical activity, and increase in sedentary behavior.[9–11] Behavioral methods have been the predominant approach to preventing obesity and often involve dietary modification and efforts to promote physical activity.[12] However, some researchers argue that reducing sedentary behavior alone should lead to a reduction in obesity.[6] A study by Epstein and collegues[13] found that a consistent reduction of daily sedentary time may be as or more important than short periods of vigorous activity for maintaining a long-term energy balance. A recent systematic review on 232 studies done by Tremblay and colleagues[14] revealed a dose-response relation between increased sedentary behavior and negative physical and psychosocial health outcomes. Specifically, more than 2 hours per day of sedentary behavior (assessed primarily as TV viewing) was associated with unfavorable body composition, decreased fitness, lowered self-esteem and decreased academic achievement in children aged 5–17 years. Another systematic review of prospective studies also suggests a moderate evidence (i.e., consisting findings across multiple high- and low-quality studies) for a longitudinal inverse relationship between sedentary time and aerobic fitness during childhood.[15]

In the past years, it was generally believed that the links between sedentary behavior and childhood obesity include displacement of physical activity, increased energy intake due to unhealthy food choices during TV watching, effects of food advertising, and decreased metabolic rate while watching TV.[16–18] However, it is now recognized that one’s level of sedentary behavior may be relatively independent of physical activity level. A cross-national study showed that spending more than 2 hours daily in screen-based sedentary behaviors was not consistently associated with lower level of physical activity among children.[19] Findings from a study by Wong and Leatherdale[20] also support the notion that being highly sedentary is not equivalent to a lack of physical activity among children. These results suggest that there is time for both sedentary and active behaviors through the day for children, and sedentary activity is not simply the lack of physical activity. Moreover, elevated likelihood of being overweight or obese was found in those who were sufficiently active but who had high levels of sedentary behaviors.[21] Therefore, sedentary behavior is emerging as an important risk factor for obesity independent of physical activity.[22]

In recent years, there has been increased interest in understanding the effectiveness of obesity interventions aiming to reduce sedentary time among children. A number of narrative reviews conducted in the past few years concluded that interventions with an emphasis on decreasing sedentary behavior have resulted in positive health behavior change (i.e., decreased sedentary time) and were associated with improvement of weight parameters.[23–25] More recently, several meta-analytic reviews have also been conducted to evaluate the effectiveness of sedentary behavior interventions among children in a more systematic way.[26–29] These studies all found a small but statistically significant effect size for a reduction in sedentary time among the intervention groups, although Wahi et al., found such effect existed only among preschool children. Only two of these meta-analytic reviews [28,29] examined the intervention effects on children's weight parameters (i.e., body mass index [BMI]), which is a more direct indicator of intervention success in terms of obesity prevention. van Grieken et al., found a significant difference in mean BMI change at post-intervention in favor of the intervention groups among the 14 studies reviewed. However, this meta-analysis excluded interventions for overweight and obese children. On the other hand, Wahi et al., failed to find a significant difference in mean BMI change at post-intervention between the intervention and control groups among the 6 studies reviewed. Moreover, this review combined multifaceted interventions aiming to modify several behaviors including dietary habits, physical activity, and sedentary behaviors with interventions that solely focusing on a single behavior, reducing sedentary time. Therefore, it is not clear which behavior change contributed the most to weight improvement, or whether it was additive effect of change in all three behaviors that led to the BMI change. The inconsistent finding in BMI may partly due to the different inclusion/exclusion criteria that the van Grienken et al. and Wahi et al. meta-analytic reviews applied. Meanwhile, since the last literature search cut-off date for the two meta-analyses (April, 2011), results from at least 10 new sedentary intervention studies for children have been published. Inclusion of these new studies may help us to better elucidate the effects of sedentary interventions on BMI change among children.

The primary aim of the present meta-analysis was to summarize and compare the effects of three different types of sedentary behavior interventions to reduce body fat in children: (1) interventions solely aiming to reduce sedentary behaviors (SB), (2) interventions aiming to reduce sedentary behaviors in combination with the promotion of physical activity (SB +PA), and (3) interventions aiming to reduce sedentary behaviors, in combination with promoting physical activity and improving dietary habits (SB+PA+diet). Since body mass index (BMI=Kg/m^2) was used most consistently as the primary indicator of body fat in these studies, BMI reduction served as the primary outcome in this meta-analysis. It was hypothesized that interventions targeting multiple behavioral factors (SB+PA+diet) would have a greater effect on reducing BMI than interventions that only target one behavioral factor (SB), given that sedentary behavior, physical activity, and diet are thought to have independent and possibly additive effects on childhood obesity risk.[6,10] The secondary aim of this study was to explore the effects of variables that may potentially moderate the intervention outcomes including (a) demographic characteristics of study participants (e.g., age, weight status); (b) intervention features and design (e.g., type of sedentary behaviors targeted, intervention delivery setting, intervention intensity, intervention duration, retention rate) and (c) outcome reporting features (e.g., format of BMI reported, whether standard deviation of the BMI change was reported). It is anticipated that results from this study will provide promising directions for future childhood obesity prevention research.

Methods

Literature Search Strategy

A literature search was conducted following the recommendations of Lipsey and Wilson.[30] First, a computer search was conducted in Ovid Medline, PsycINFO, Web of Science, and Google Scholar from the first available year to July 2012 and restricted to articles published in the English language only. The following keyword combinations were used: Sedentary Behavior, Sedentary Lifestyle, Physical Inactivity, Television, *or* Screen Time, *and* Obesity *or* Overweight, *and* Children, Youth, Teens *or* Adolescence (see Table S1 for sample full search strategy used for OVID Medline). Titles and abstracts identified through the search process were reviewed to identify relevant articles. A related records search was performed through Web of Science for identified articles. Second, the table of contents for journals that commonly publish articles in the area were reviewed (e.g., *Obesity, American Journal of Preventive Medicine, Journal of Pediatrics*). Finally, bibliographies of narrative reviews and all identified articles were examined to achieve any additional studies.

Inclusion and Exclusion Criteria

Inclusion criteria for this meta-analysis were: (1) all study participants must be children age 18 or younger; (2) the study must be a randomized controlled intervention with a no-treatment control; and (3) the intervention must have components to reduce sedentary behaviors such as watching TV/DVD/VCR, playing sedentary video/computer games, and sitting time in general. Studies were included if children were randomly assigned to an intervention and to either an active control group that received some non-obesity prevention related information (e.g., a general parenting skill training, or a fire drill training), or a control group with usual-programming (e.g., standard physical education classes or any standard school curriculum classes), or an assessment-only control group. Random assignment to condition is crucial because it is the best way to generate a comparison group that is equal on any potential confounding variables at baseline, especially when intervention effects were accessed based on significant differences in change over time across conditions. Studies were excluded if: (1) the intervention used physical activity promotion as a method to reduce sedentary behaviors rather than specifically designed to limit time spent in sedentary behaviors, (2) the study did not report measurement of BMI before and after the intervention separately for the intervention and control groups, and (3) if the study only reported adjusted (for covariates such as baseline BMI, ethnicity, and household income) BMI at post-intervention.

The outcome variable for this meta-analysis was defined as the intervention vs. control group difference in BMI change scores before and after the intervention period. The predictor variable was the sedentary behavior intervention type: SB only intervention, SB +PA intervention, or SB+PA+diet intervention.

Data Extraction

A coding form was developed for data extraction and analysis purposes. The following information was extracted from each study by two reviewers independently: (a) study identification information (e.g., authors, year of publication, publication form); (b) sample characteristics (e.g., mean and range of age, country participants live in, gender composition of the sample, percent overweight at baseline of the sample); (c) study characteristics (e.g., type of intervention, intervention delivery setting, type of sedentary behaviors targeted, duration of intervention, frequency of intervention sessions, type of control group, attrition rate, presence of study follow-up) and (d) effect size information (e.g., format of reported BMI, mean BMI and standard deviation for each group at each time point). Agreement among reviewers for each item ranged from 90% to 100%, and all discrepancies were resolved through discussions that led to a consensus.

Risk of Bias Assessment

The Quality Assessment Tool for Quantitative Studies was used to assess study quality.[31] For each study, six domains were scored with high, moderate, or low for risk of bias: selection bias, study design, confounders, blinding, data collection methods, and withdrawals and drop-outs. An overall rating of the study quality was then assigned based on scores from these six domains. The quality assessment was performed independently by two reviewers and the findings were compared and discussed until consensus was achieved.

Effect Size Calculation

Effect sizes were computed as *d* indices and expressed the difference in mean of the BMI change between children in an intervention and a control group, with negative values indicating a better outcome (a greater BMI decrease) for the intervention group. The *d* indices were calculated from the means and standard deviation of the BMI change scores (the difference between pre-intervention and post-intervention). When the standard deviation of the change score was not reported, the pooled standard deviation of the pre- and post-intervention was estimated by assuming the correlation between the two was equal to .90. When BMI change scores and standard deviation were only reported by subgroups (e.g., by gender), a combined effect across subgroups was computed.[32] Effect sizes were corrected for small-sample bias by transforming the standardized mean difference, *d*, to Hedge's *g* before analysis.[30] Each effect size was weighed by the inverse of its variance to provide a more efficient estimation of true population effects by giving greater weight to studies with larger samples.

Summary of Meta-Analytic Data Analyses

The data analyses included (a) calculation of weighted effect sizes and 95% confidence intervals; (b) use of homogeneity analysis to test effect sizes variation; and if significant heterogeneity exists, an exploration of potential moderators; and (c) examination of potential publication bias. All meta-analytic tests were analyzed using a random-effects model, which assumes an underlying distribution of true effect sizes from which the included studies are drawn, and accounts for variability in effect sizes caused by both sampling error and true differences in effect sizes between studies.[33]

The homogeneity of mean corrected effect sizes was examined to determine if the variability in outcomes was greater than expected from sampling error and measurement artifacts. Q-statistics and I-squared were used to determine heterogeneity among studies. A significant Q-statistic (within-group) indicates heterogeneity of effects. I-square reports the extent of such heterogeneity. Potential moderators were determined a priori and included participants' mean age, population (general population vs. overweight/obese children only), type of sedentary behaviors targeted (TV viewing only vs. multiple sedentary behaviors), intervention delivery setting (school-, home-, clinic-based, vs. mixed), intervention intensity (average sessions per week), intervention duration (in weeks), retention rate, format of BMI reported (raw scores vs. standardized z-score) and whether standard deviation of the BMI change score was reported or estimated. Moderators were examined using an omnibus test of between-group difference in mean effects (Q_b). In addition, to explore the relationship among moderators (e.g., what type of intervention features might co-exist), bivariate correlation test was also performed.

Publication bias was examined using Egger's test of the regression intercept and funnel plots. If either a small-study effect or an asymmetric shape of funnel plot was present, possible publication bias was suspected and trim and fill method was used to adjust the estimates.[32] Effect size calculation and publication bias tests were conducted using Stata (Version 12), and meta-regression was run using SPSS (Version 17.0).

Results

Sample Characteristics

A total of 25 unique studies were included in this meta-analysis: five were SB only interventions,[34–38] ten were SB+PA interventions,[39–48] and ten were SB+PA+diet interventions.[49–58] Figure 1 shows the flowchart for retrieving the articles. Table 1 summarizes the general characteristics of the final 25 studies. All studies were published in peer-reviewed journals, and five were results from pilot studies. Most of the studies were published fairly recently (16 were published between year 2008 and year 2012). Table 2 provides more details for each intervention study.

Risk of Bias Assessment

Table 3 shows the results of the quality assessment for each study. Selection bias was low (rating of strong) for studies where participants were randomly selected from a comprehensive list of individuals and participation rate was high (>80%). Selection bias was high (rating of weak) for studies where participants were self-referred or the selection of participants was not described adequately. Since our search criteria only included randomized control trails, all of the included studies were strong in study design. However, only 11 of the 25 studies reported sequence generation of the randomization. Most of the studies (88%) had comparable intervention and control groups on key demographic variables and study outcomes at baseline (rating of strong on confounders). Seven studies reported that the outcome assessors were not aware of the group assignment, four studies reported the opposite, and the rest of the studies did not describe the blinding of the outcome assessor. Only one study reported that the study participants were not aware of the primary research question, two studies reported the opposite, and the rest of the study did not describe such information. All studies used valid and reliable data collection methods. Furthermore, most studies (92%) had good retention rate (at least 80%) post-intervention. Overall, ten studies were rated strong for study quality, four studies were rated weak, and the others were rated moderate.

Mean Effect Sizes for SB only vs. SB+PA vs. SB+PA+diet Interventions

Across all studies, the total number of participants (intervention + control group) with complete data was 389 for SB only interventions, 2,805 for SB+PA interventions, and 3,851 for SB+PA+diet interventions. When the three types of intervention studies were combined together, the pooled effect size from all 25 studies was significant ($g = -.073$, $p = .021$), indicating an overall effect of sedentary behavior intervention on BMI reduction among children (see Table 3). This effect size indicates that the mean BMI reduction for the intervention groups was .10 (kg/m^2) greater compared to the control groups. However, when examined separately, the effect sizes were not significantly different from zero for SB only interventions ($g = -.154$, $p = .129$), SB+PA interventions ($g = -.089$, $p = .125$), and SB+PA +diet interventions ($g = -.060$, $p = .214$). No significant difference was found for mean effect size among SB interventions, SB+PA interventions, and SB+PA+diet interventions ($Q_b = 32.05$, $p = .126$). Figure 2 shows the adjusted effect size for each study by intervention type.

Heterogeneity and Moderator Analyses

Table 3 shows that the effects of studies were homogeneous within SB interventions (Q = 1.19, $p = .879$), SB+PA interventions ($Q = 15.18$, $p = .086$), and SB+PA+diet interventions ($Q = 14.17$, $p = .117$) in the random-effects model. The heterogeneity observed in the pooled estimate was low ($I^2 = 25\%$, $p = .126$; see Figure 2). Since insignificant heterogeneity was observed, the moderator analyses set a priori to explain heterogeneity were not explored. Bivariate correlations showed that only intervention delivery setting was significantly associated with intervention type (Spearman's R*ho* = .565, $p = .003$). All of the clinic-based intervention studies had multiple components (SB+PA+diet). Most (80%) of the school-based interventions were SB+PA type. Among the moderators, participants' age was associated with type of sedentary behaviors targeted (r = .568, $p = .004$). Interventions with older participants were more likely to target multiple sedentary behaviors. Intervention delivery setting was associated with intervention intensity (r = −.809, $p < .001$). The clinic-based interventions had the lowest intensity (i.e., less than one session per week).

Publication Bias

The Egger's regression test showed small-study effects (i.e., small studies produce larger effect size) for the 25 studies ($b_0 = -.887$, $p = .037$). The funnel plot of effect size from each study is in general symmetrical (see Figure 3), suggests the absence of publication bias. A further trimmed-and-filled analysis also confirmed that there was no publication bias.

Discussion

Results from this meta-analysis of 25 studies suggest that interventions seeking to decrease sedentary behaviors among children significantly reduced BMI when compared to children in control groups. Although the observed magnitude of BMI mean differences ($g = -.073$, $p = .021$) between intervention and control groups at post-intervention may not achieve a level considered to be clinically significant (a minimum of .25 standardized BMI unit reduction) for the treatment of obese children,[59] it may be approaching the magnitude of change required to achieve population-level public health significance in obesity prevention interventions among non-obese children, which is not entirely known.

When looking at each type of intervention studies (SB, SB+PA, and SB+PA+diet) separately, none had a significant effect in BMI reduction. Further, contrary to our hypothesis, multi-components interventions (SB+PA or SB+PA+diet) were not more effective in BMI reduction than SB only interventions in this sample of studies. This result is consistent with van Grieken's[28] findings. However, another meta-analytic study of the obesity interventions for children showed that the mean effect sizes for three- or four-component intervention were much greater than the one- or two-component interventions.[60] In this review, there was only one study with four intervention components (physical activity, nutrition, counseling, and medication) among the 40 studies under examination, and the difference between one- and two-component interventions was not significant. Our results also showed that the SB only interventions had a larger mean effect size ($g = -.154$) than the SB+PA ($g = -.089$) and SB+PA+diet ($g = -.060$) interventions, although none of the subgroup effect sizes was statistically significant. This finding is similar to a narrative review article examining obesity prevention programs in children, which suggested that intervention studies focusing on single behavior change had a stronger impact on BMI than those focused on multiple behavior changes.[10] It is possible that for children, altering one behavior is easier to accomplish than altering two or more behaviors at the same time. In fact, most multiple health behavior change interventions in children failed to achieve significant changes, and the successful ones were all found among adults.[61] Thus, multi-component obesity interventions might not be more effective than a single-component intervention among children. However, it is important to note that in the present meta-analysis, the effect of the interventions on targeted behavior change (i.e., sedentary behavior, physical activity, dietary intake) was not evaluated. Therefore, it is not clear whether the BMI reduction in multi-component interventions was a result of a decrease in sedentary behaviors, an increase in physical activity, an improvement in diet, or any combination thereof. Furthermore, it is also possible that we were not able to detect a significant difference between the three types of interventions due to limited power.

We did not observe a significant heterogeneity among the studies in this analysis. Only 25% of the variation in the overall effect size was attributable to between-studies heterogeneity (p-value n.s.). Nevertheless, the studies included in our analysis encompass interventions of different characteristics and purposes. For example, we included both prevention studies (interventions that targeted the general population) and treatment studies (interventions that were exclusively for overweight and obese children). Inclusion of both prevention and treatment studies could attenuate the observed effect of BMI reduction since the effect size is generally higher in treatment studies.[60] Indeed, the two studies that had a significant effect size in BMI reduction in our sample were both treatment programs targeting overweight and obese children.[48,49] However, the primary focus of our meta analysis was to assess the overall effect of sedentary behavior interventions (regardless of prevention or treatment orientation) on BMI reduction, and how such effect sizes may differ between single- versus multi-component interventions.

A particularly interesting finding from our analysis was that all of the clinic-based interventions included three components (SB+PA+diet). It is possible that given the short contact period (total intervention sessions raged from 4 to 11 times, with an average of meeting once every three weeks) with children, practitioners tried to give out as much helpful information as they could during each encounter. It is also possible that medical practice emphasizes the provision of all available evidence-based strategies for BMI reduction to patients. However, since results from the current meta-analysis suggest that the multi-component interventions did not exceed (and the mean effect size was even lower than) the single-component interventions on BMI reduction, and given the limited contact time, clinical health practitioners might want to consider focusing solely on limiting sedentary behaviors to reduce BMI for their pediatric patients.

Several limitations of the current study need to be noted. BMI reduction was the only parameter used to evaluate the effectiveness of interventions in this study. It is possible that an intervention may successfully reduce children's time spent in sedentary behaviors in the absence of significant BMI change. Also, the intervention effect on BMI reduction was assessed by comparing the BMI change scores between the intervention and control group. It is possible that children in both intervention and control groups have increased BMI, but the intervention group has a smaller increase than the control group. In this case, the intervention is effective in slowing down the increase of BMI (rather than reducing BMI in children), and attenuating the rate of BMI increase in children also has health benefits.[62] Children in this sample of studies were relatively young (participants for most studies aged from 4–12 years). Therefore, findings from this study may not be applied to children in older age groups. Moreover, demographic features of study participants, such as ethnicity and socioeconomic status, were often not reported in the primary studies; make it difficult to know how results generalize to other populations. Almost all of the studies included in the present meta-analysis were interventions carried out in developed countries within North America and Europe. Childhood obesity is a global problem, and the prevalence rate has been increasing steadily in some developing countries.[63,64] Children's lifestyles may be quite different across countries and cultures. Therefore, lifestyle interventions to prevent childhood obesity, such as sedentary behavior interventions, may not be universally effective. Lastly, we used the unadjusted mean BMI scores to calculate effect size, and excluded studies that only reported adjusted post-intervention outcomes. Although adjusting for covariates (e.g., demographic variables, baseline BMI) is a preferred way to present intervention results since it controls for potential cofounders, these adjusted results would not be comparable to the other majority studies that reported unadjusted results.

In summary, interventions that target to reduce sedentary behaviors among children are effective in reducing BMI. However, adding a physical activity promotion and diet improvement component to the intervention program did not appear to have an additive effect. A comprehensive sedentary behavior intervention that targets to reduce multiple sedentary activities may be as effective as multi-component programs in BMI reduction, and could be a promising way to prevent obesity in children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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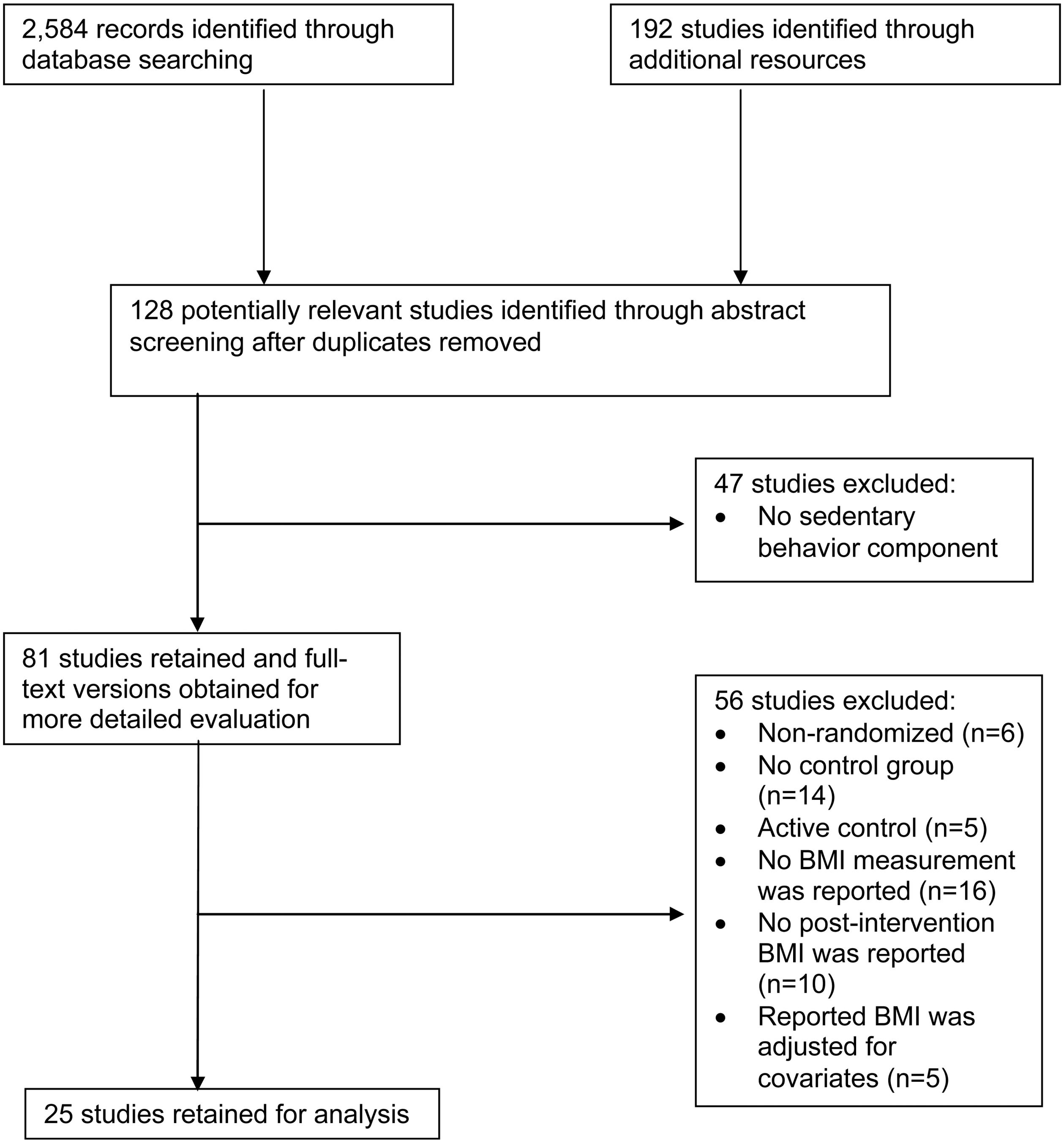

Figure 1.
Flowchart for literature search.

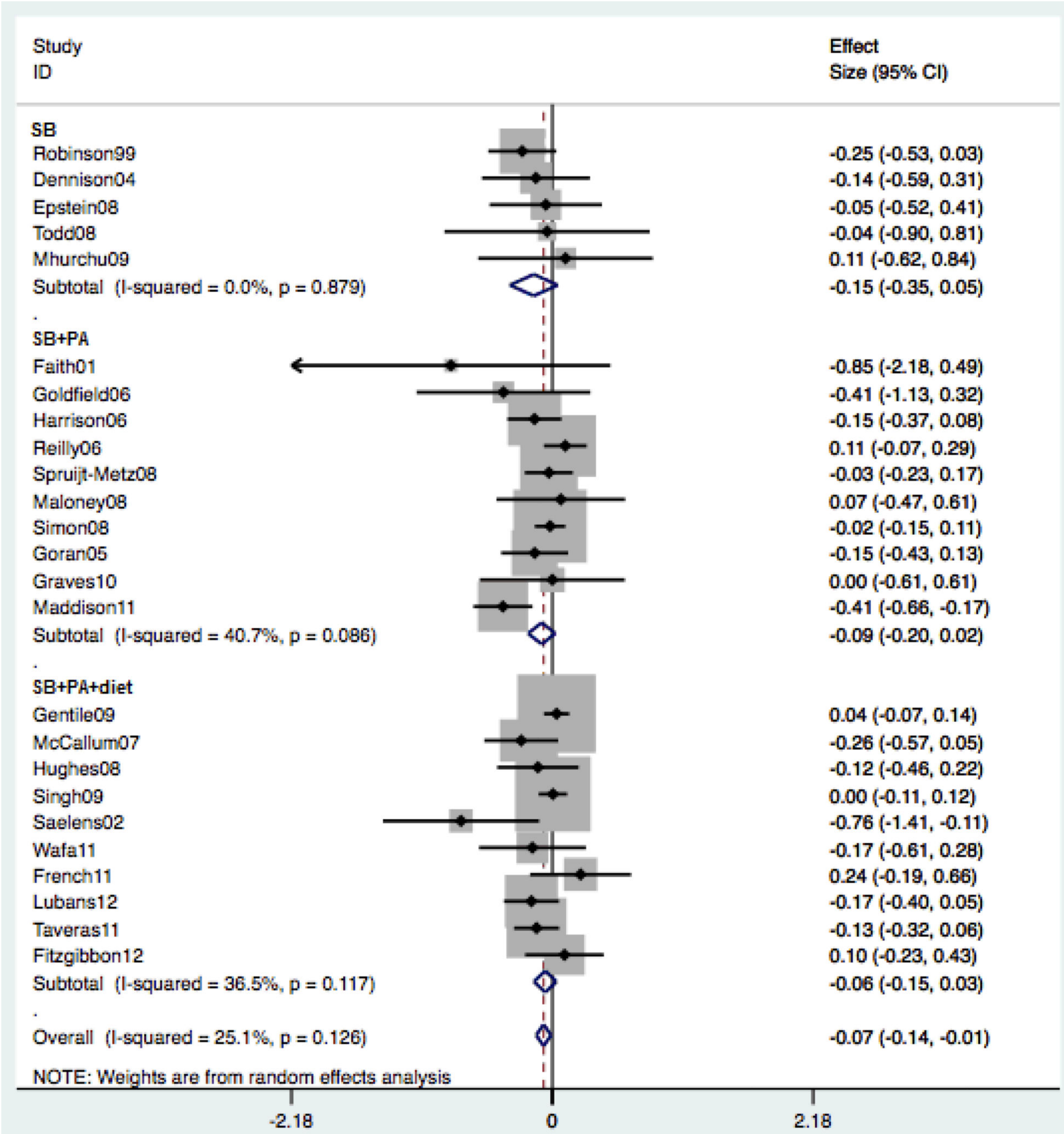

Figure 2.

Effect size on BMI reduction by intervention type.

Note: I-square – the variation in pooled effect size attributable to heterogeneity within that group.

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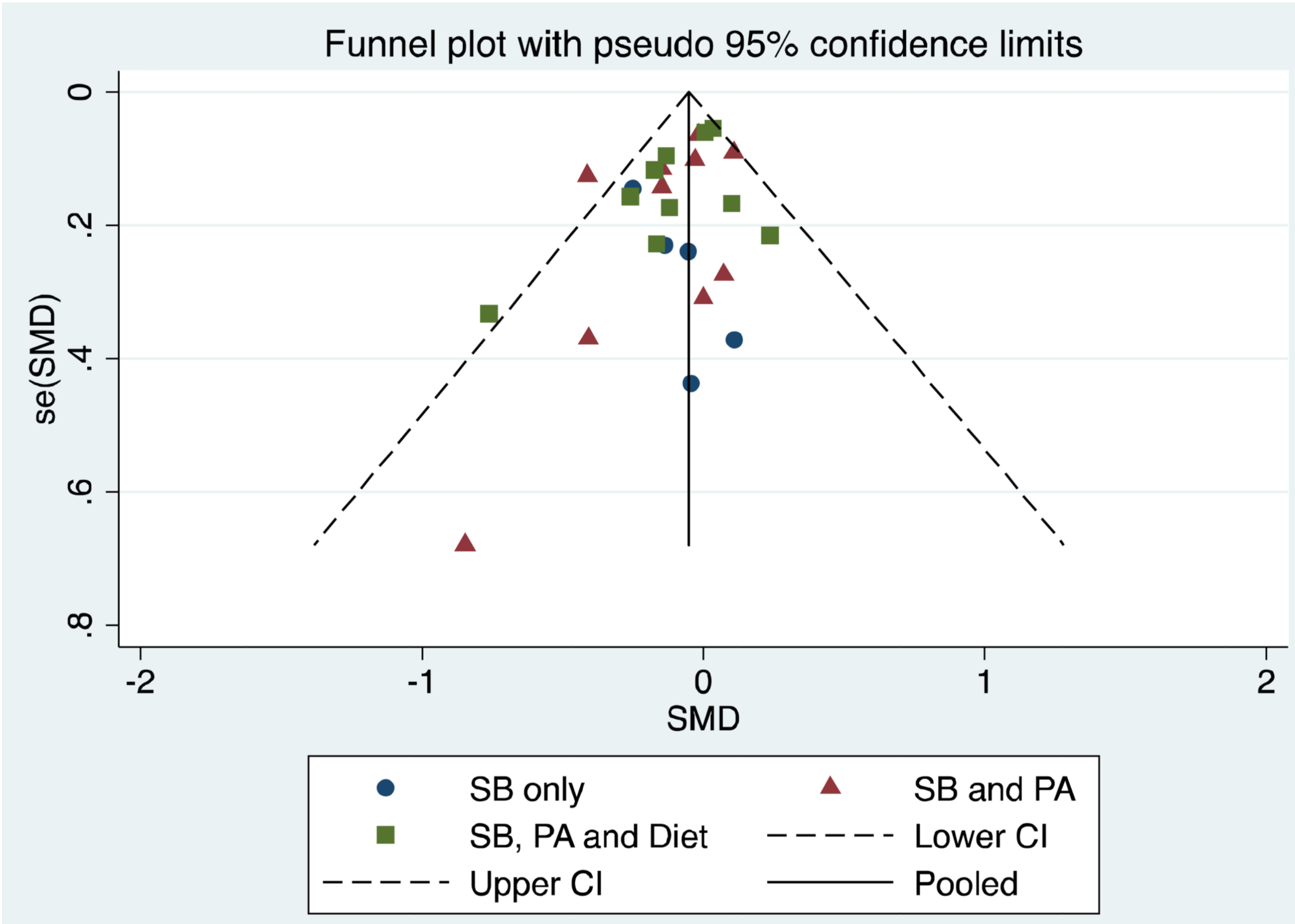

Figure 3.
Funnel plot for BMI reduction, by intervention type.

Table 1

General Characteristics of Included Studies

Characteristics	Number of Studies
Publication Year	
Prior to 2000	1
2001–2005	4
2006–2010	14
2011–2012	6
Country of Study	
North America (U.S. or Canada)	14
Europe	6
Australia and New Zealand	4
Asia	1
Mean Age of Study Sample	
< 6 years	5
6–12 years	15
> 12 years	5
Targeted Sample	
General population	16
Overweight or obese children only	9
Setting of Intervention	
School-based	5
Home-based	9
Clinic-based	5
Mixed[a]	6
Sedentary Behaviors Targeted	
TV viewing only	10
TV viewing and other screen-related activities	15
Duration of Intervention	
< 3 months	8
3 months – 6 months	9
> 6 months	8
Intervention Follow-up[b]	
Has follow-up	9
No follow-up	16
Format of BMI Reported	
Raw BMI score	14
Age/gender standardized *z*-BMI score	11

Note:

[a]Interventions that had both school/clinic component and home component.

[b]Studies that had follow-up measurements of height and weight after the end of intervention.

Table 2

Characteristics of the Interventions

Study	Intervention Type	Participants	Intervention	Control	Duration (weeks)	Follow-up Measurement[a]	Effects on BMI
Dennison et al., 2004	SB	N=222 Age range: 2.5–5.5 Mean age (year): 4 Sex: 49% male Race: mostly white General population	School and home-based. No behavior change theories specified; intervention aimed to show preschool staff and parents the positive alternative activities to TV viewing, such as improved literacy skills and enhanced social skills. Children attended a 7-session program to be educated to reduce TV-viewing time. After each class, materials and activities were sent home to foster discussion between parents and children.	No treatment	39	None	No significant difference in BMI raw score and BMI z-score change between intervention and control groups.
Robinson et al., 1999	SB	N=198 Age range: 8–10 Mean age (year): 9.9 Sex: 53% male Race: mostly white General population	School and home-based. Based on social cognitive theory, children were educated to budget TV watching time (self-monitoring and self-reporting strategies), newsletters were sent to parents to help children stay within budget. Each household also received an electronic television time manager to help with budgeting.	No treatment	25	None	Children in the intervention group had a significant decrease in raw BMI as compared with the control group.
Todd et al., 2008	SB	N=22 Age range: 8–11 Mean age (year): 9.9 Sex: all male Race: mostly (>80%) white General population	Home-based. No behavior change theories specified; intervention aimed to enhance awareness of electronic media use and to set goals to minimize use. Children and parents attended family-centered interactive session designed to reduce TV-viewing time and increase awareness to minimize electronic media use. TV and computer-locking devices were installed to help monitoring and limiting children's TV and computer use. Follow-up newsletters were sent to home.	No treatment	20	None	No significant change in BMI raw score between intervention and control groups.
Epstein et al., 2008	SB	N=70 Age range: 4–7 Mean age (year): 6 Sex: 53% male Race: mostly white Children BMI at or above 75th BMI percentile	Home-based. No behavior change theories specified; a reward system was set up based on children's TV-viewing time. TV allowance was set up to budget children's TV-viewing time. Children earned $0.25 for each half hour under budget, up to $2.00 per week. Parents praised children for reduced TV-viewing time and for engaging in alternative behaviors. Monthly newsletters were sent to parents with information about how to rearrange home environment.	No treatment	104	None	Children in the intervention group had a significant decrease in BMI z-score as compared with the control group.
Mhurchu et al, 2009	SB	N=29 Age range: 9–12 Mean age: 10.4 Sex: 62% male Race: 65% European Obese population	Home-based. No behavior change theories specified; TV time monitor was provided to limit children's access to TV. Parents had the control of the time budget, and were encouraged to restrict TV watching to 1 hour per day or less for their children.	Only receive verbal advice on general strategies to decrease TV watching; no TV time monitor was provided	6	None	No significant difference in BMI raw score and BMI z-score change between intervention and control groups.

Study	Intervention Type	Participants	Intervention	Control	Duration (weeks)	Follow-up Measurement[a]	Effects on BMI
Reilly et al., 2006	SB+PA	N=545 Age range: 4–5 Mean age (year): 4.2 Sex: 50% male Race: mostly white General population	School and home based. No behavior change theories specified; intervention components included enhanced physical activity program in nursery (three 30-min sessions a week over 24 weeks) plus home-based health education aimed at increasing physical activity through play and reducing TV viewing time.	No treatment	24	Week 28	No significant difference in BMI raw score change between intervention and control groups.
Maloney et al., 2008	SB+PA	N=60 Age range: 7–8 Mean age (year): 7.5 Sex: 50% male Race: mostly white General population	Home-based. No behavior change theories specified; written physician prescription was given to children to play 120 minutes per week of Dance Dance Revolution and daily minutes of Dance Dance Revolution play was recorded, supervised by parents.	No treatment	10	Week 18	Children in the intervention group had a significant decrease in BMI raw score as compared with the control group.
Graves et al., 2010	SB+PA	N=58, Age range: 8–10 Mean age: 9.2 Sex: 67% male Race: mostly white General population	Home-based. No behavior change theories specified; a peripheral device (jOG), a step-powered video game, was given to children to encourage light-to-moderate intensity activity and reduce sedentary time.	No treatment	12	None	No significant difference in BMI raw score change between control and intervention groups.
Goran et al., 2005	SB+PA	N=209 Age range: 8.8–11.1 Mean age (year): 9.4 Sex: 40% male Race: mostly Hispanic General population	School-based. Based on social cognitive theory, eight CD-ROM interactive animated lessons, four classroom lessons, and four family-based assignments were delivered over 8 weeks. Each lesson incorporated elements of social cognitive theory including outcome expectancies, behavioral capability and modeling, goal setting, self-monitoring, reinforcement, self-efficacy, and environmental aspects aiming to increase levels of physical activity, decrease sedentary behavior, and alter psychosocial variables related to physical activity.	No treatment	8	None	No significant difference in BMI raw score and BMI z-score change between intervention and control groups. Female students in the intervention group had a significantly larger decrease in BMI z-score as compared with the control group.
Harrison et al., 2006	SB+PA	N=312 Age range: 9–11 Mean age (year): 10.2 Sex: 57% male Race: mostly white General population	School-based. Based on social cognitive theory, the 10-lesson, teacher-led intervention emphasized on self-control, self-monitoring, and goal setting skills.	No treatment	16	None	No significant difference in BMI raw score change between control and intervention groups.
Simon et al., 2008	SB+PA	N=954 Age range: 9.9–13.8 Mean age (year): 11.6 Sex: 46.7% male Race: mostly white General population	School-based. A multilevel program aimed to affect the intrapersonal, social and certain environmental determinants of physical activity with three principal targets: (1) knowledge, attitudes, beliefs and motivation towards physical activity; (2) social support; and (3) environmental conditions. The intervention included an educational components focusing on physical activity and sedentary behavior and opportunities for physical activity were provided at lunchtime and after school hours.	No treatment	208	None	Children in the intervention group had a significant smaller increase in BMI z-score as compared with the control group.
Spruijt-Metz et al., 2008	SB+PA	N=459 Age range: 12–13 Mean age (year): 12.5	School-based. Based on the self determination theory and the theory of meanings of behavior, the intervention aimed to increase positive meanings and	No treatment	1	Week 13	No significant difference of BMI z-score change between

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Study	Intervention Type	Participants	Intervention	Control	Duration (weeks)	Follow-up Measurement[a]	Effects on BMI
		Sex: all female Race: mostly Hispanic General population	promote intrinsic motivation for physical activity. Students received information about media-based physical activity and TV-viewing and other sedentary behaviors classroom education and participated in learning activities that supported engagement in physical activity and TV-viewing time.				intervention and control groups.
Faith et al., 2001	SB+PA	N=10 Age range: 8–12 Mean age (year): 10 Sex: 70% male Race: no info Obese population	Home-based. Intervention was based on the behavioral theory of reinforcement. Children pedaled on the electronically braked cycle ergometer to activate power of TV.	No treatment	10	None	Children in the intervention group had a decrease in raw BMI whereas children in the control group had an increase in raw BMI.
Goldfield et al., 2006	SB+PA	N=30 Age range: 8–12 Mean age (year): 10.5 Sex: 43% male Race: mostly white Overweight and obese population	Home-based. Intervention was based on the behavioral theory of reinforcement, with an open-loop feedback system. Children accumulated 400 counts of physical activity on pedometers earned 1 hour of TV/VCR/DVD time. Parents reviewed the physical activity amount and implemented the contingencies (the open-loop feedback feature).	No treatment	8	None	Children in the intervention group had a significant decrease in BMI raw score as compared with the control group.
Maddison et al., 2011	SB+PA	N=322, Age range: 10–14 Mean age (year): 11.6 Sex: 73% male; Race: 57% European Overweight or obese population	Home-based. No behavior change theories specified; active video games were given to children to encourage them to increase physical activity and decrease screening time.	No treatment	24	None	Children in the control group had a significant increase in BMI z-score as compared with the intervention group.
Gentile et al., 2009	SB+PA+diet	N=1323; Age range: 6.1–12.7 Mean age (year): 9.6 Sex: 47% Race: 90% white General population	School and home-based. Based on the social ecological framework, the intervention targeted families as the primary leverage point, and school-based reinforcement and incentives as well as community support as the secondary leverage points. Children were encouraged to adapt to healthy lifestyle by using self-rewards, school education, family-planned meals, and creating short-term and long-term goals of healthy active lifestyle.	No treatment	30	Week 26	No significant difference in BMI raw score change between intervention and control groups.
Fitzgibbon et al., 2012	SB+PA+diet	N=128; Age range: 3–5 Mean age (year): 4.5 Sex: 50% male Race: Hispanic General population	School and home-based. Based on social cognitive theory, and relevant components of the health belief model and self-determination theory were also incorporated. Intervention curriculum included nutrition instruction and physical activity session, both supplemented by a Spanish language CD. Child component targeted specific child behaviors to increase consumption of fruits, vegetables, and fiber; decrease fat intake; reduce television viewing; and increase the duration and level of daily physical activity.	Weekly general health education	14	Week 52	Both the intervention and control groups decreased BMI raw score and BMI z-score. No significant difference in BMI raw score and BMI z-score change between intervention and control groups.
Lubans et al., 2012	SB+PA+diet	N=357, Age range: 12–14 Mean age (year): 13.2	School and home-based. Based on social cognitive theory, the intervention targeted psychological, behavioral, and environmental influences on physical	No treatment	52	None	No significant difference in BMI raw score and BMI z-score change between

Study	Intervention Type	Participants	Intervention	Control	Duration (weeks)	Follow-up Measurement[a]	Effects on BMI
		Sex: all female Race: mostly Australian General population	activity and nutrition behavior change, and focused on promoting lifetime physical activities, reducing sedentary behaviors, and encouraging low-cost healthy eating. Intervention components included enhanced school sport sessions, interactive seminars, nutrition workshops, lunch-time physical activity sessions, handbooks and pedometers, parent newsletters, and text messaging for social support.				intervention and control groups.
Singh et al., 2009	SB+PA+diet	N=1108 Age range: 12–14 Mean age (year): 12.7 Sex: 49.5% male Race: mostly Western/ Dutch General population	School-based. Using an intervention mapping approach, intervention selected multiple theoretical strategies for behavioral change, including self monitoring, self-evaluation, reward, increasing skills, goal setting, environmental changes, social encouragement, social support, information regarding behavior and personalized messages. The intervention consisted of an educational program (individual component), and an environmental component (i.e., changes in and around school cafeterias).	No treatment	35	Week 17 and week 52	No significant difference of BMI raw score change between intervention and control groups.
French et al., 2011	SB+PA+diet	N=90 Age range: 12–17 Mean age (year): 14.7 Sex: 61% male Race: 58% white General population	Home-based. Based on the social ecology framework, the intervention included both household environment and individual-level behavioral components such as placement of TV time-limiting devices, provision of guidelines about food availability, face-to-face group sessions, and monthly newsletters.	No treatment	52	None	No significant difference in BMI z-score change between intervention and control groups.
Taveras et al., 2011	SB+PA+diet	N=475, Age range: 2–6.9 Mean age (years): 4.9 Sex: 52% male; Race: no info; Overweight population	Clinic-based. Based on the chronic care model, the major components of the intervention involved changes to the health care system. Intervention includes primary care restructuring, and families received motivational interviewing by pediatric nurse practitioners regarding TV viewing and fast food and sugar intake.	Usual care which included well-child care visits and follow-up appointments for weight checks with their pediatrician or subspecialist	52	None	No significant difference in raw BMI score and BMI z-score change between intervention and control groups.
McCallum et al., 2007	SB+PA+diet	N=163 Age range: 5–9 Mean age (year): 7.4 Sex: 48% male Race: no info Obese population	Clinic-based. Using an intervention mapping approach, modifiable behavioral determinants of obesity were identified. General practitioners used a brief solution-focused approach to set and record appropriate, healthy lifestyle goals with the family, assisted by a personalized 20-page family folder, which aimed to help improve children's physical activity, TV viewing and other sedentary behaviors and diet.	No treatment	12	Week 39 and week 65	No significant difference in BMI raw score change between intervention and control groups.
Hughes et al., 2008	SB+PA+diet	N=134 Age range: 5–11 Mean age (year): 8.7 Sex: 44% male	Clinic-based. A best-practice, family-centered, behavior change counseling delivered by pediatric dietitians. Used multiple behavioral strategies including exploring motivation to change, exploring	No treatment	26	Week 25 and week 52	No significant difference of BMI z-score change between intervention and control

Study	Intervention Type	Participants	Intervention	Control	Duration (weeks)	Follow-up Measurement[a]	Effects on BMI
		Race: no info Overweight population	pros and cons of change, identifying barriers to change, problem-solving barriers, goal-setting, rewards, self-monitoring, social support, and preventing relapse to modify diet, physical activity, TV viewing and other sedentary behaviors.				groups from baseline to 6 and 12 months.
Wafa et al., 2011	SB+PA+diet	N=107 Age range: 7–11 Mean age (year): 9.8 Sex: 50% male; Race: no info; Obese population	Clinic-based. A parent-centered, dietician-led program based on trans-theoretical model and social cognitive theory. The program included 8 group sessions focused on changing diet, physical activity, and sedentary behavior. Parents also received treatment materials.	No treatment	24	None	No significant difference in BMI z-score change between intervention and control groups.
Saelens et al., 2002	SB+PA+diet	N=44 Age range: 12–16 Mean age (year): 14.2 Sex: 59.1% male Race: 70.5% white Overweight population	Clinic-based. No behavior change theories specified; intervention aimed to address behavioral skills including self-monitoring, goal setting, problem solving, stimulus control, self-reward, and preplanning. Children engaged in a computer-based program on physical activity, diet, and sedentary behavior education. Children also received weekly phone counseling. Parents received information sheets including recommended parental skills.	A single session of physician weight counseling	17	Week 23	Children in the intervention group had a slight decrease in BMI z-score as compared with the control group.

Note:

[a]Indicates the follow-up measurement occurred at post-intervention, if any.

Table 3

Assessment of Risk of Bias of Included Studies

Study	Selection Bias	Study Design	Confounders	Blinding	Data Collection Methods	Withdrawals and Drop-outs	Global Rating
Dennison et al., 2004	Strong	Strong	Strong	Moderate	Strong	Strong	Strong
Robinson et al., 1999	Moderate	Strong	Strong	Strong	Strong	Strong	Strong
Todd et al., 2008	Weak	Strong	Strong	Moderate	Strong	Strong	Moderate
Epstein et al., 2008	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Mhurchu et al., 2009	Weak	Strong	Strong	Moderate	Strong	Strong	Moderate
Reilly et al., 2006	Strong	Strong	Strong	Moderate	Strong	Strong	Strong
Maloney et al., 2008	Weak	Strong	Strong	Moderate	Strong	Strong	Moderate
Graves et al., 2010	Moderate	Strong	Strong	Weak	Strong	Moderate	Moderate
Goran et al., 2005	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong
Harrison et al., 2006	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong
Simon et al., 2008	Strong	Strong	Strong	Moderate	Strong	Strong	Strong
Spruijt-Metz et al., 2008	Strong	Strong	Strong	Moderate	Strong	Strong	Strong
Faith et al., 2001	Weak	Strong	Weak	Moderate	Weak	Strong	Weak
Goldfield et al., 2006	Moderate	Strong	Strong	Moderate	Weak	Strong	Moderate
Maddison et al., 2011	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Gentile et al., 2009	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong
Fitzgibbon et al., 2012	Strong	Strong	Strong	Weak	Strong	Strong	Moderate
Lubans et al., 2012	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong
Singh et al., 2009	Moderate	Strong	Moderate	Weak	Strong	Strong	Moderate
French et al., 2011	Weak	Strong	Weak	Moderate	Strong	Strong	Weak
Taveras et al., 2011	Weak	Strong	Strong	Moderate	Strong	Strong	Moderate
McCallum et al., 2007	Weak	Strong	Strong	Moderate	Strong	Strong	Moderate
Hughes et al., 2008	Moderate	Strong	Strong	Moderate	Strong	Moderate	Moderate
Wafa et al., 2011	Weak	Strong	Strong	Moderate	Strong	Strong	Moderate
Saelens et al., 2002	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong

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Table 4

Effect Size (ES) Summary (Random-Effects Model)

Intervention Type	*k*	Total *N*	Adjusted ES range	Mean ES (*g*)	95% CI	*z*	*p*	Heterogeneity *Q*	*p*
SB	5	389	−.251 – .110	−.154	−.354 – .045	1.52	.129	1.19	.879
SB+PA	10	2,805	−.846 – .108	−.089	−.202 – .025	1.53	.125	15.18	.086
SB+PA+diet	10	3,851	−.762 – .236	−.060	−.154 – .034	1.24	.214	14.17	.117
Overall	25	7.045	−.846 – .236	−.073	−.135 – −.011	2.31	.021	32.05	.126