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The Effect of Childhood Obesity Prevention Programs on Blood Lipids: A Systematic Review and Meta-analysis

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Summary

Aim—We aimed to assess the effects of childhood obesity prevention programs on blood lipids in high-income countries.

Methods—We searched MEDLINE®, Embase, PsychInfo, CINAHL®, clinicaltrials.gov, and the Cochrane Library up to April 22, 2013 for relevant randomized controlled trials, quasi-experimental studies, and natural experiments published in English. Studies were included if they implemented diet and/or physical activity intervention(s) with one year follow up (or six months for school-based intervention studies) in 2 to 18 years old, and were excluded if they targeted only overweight/obese children, or those with a pre-existing medical condition.

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Conflict of interest statement: We declare that we have no conflict of interest.

Author contributions

Youfa Wang and Li Cai had full access to all the data in this study and take responsibility for the integrity of the data and the accuracy of the data analysis. Youfa Wang had final responsibility for the decision to submit for publication.

Study concept and design: Youfa Wang, Li Cai.

Acquisition of data: All authors.

Analysis and interpretation of data: All authors.

Drafting of the manuscript: Li Cai, Youfa Wang.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Li Cai.

Administrative, technical, or material support: Youfa Wang, Renee Wilson.

Study supervision: Youfa Wang.

Results—Seventeen studies were finally included. For total cholesterol, the pooled intervention effect was -0.97 mg/dL (95% CI: -3.26 , 1.32 ; $P=0.408$); for low density lipoprotein-cholesterol (LDL-C), -6.06 mg/dL (95% CI: -11.09 , -1.02 ; $P=0.018$); for high density lipoprotein-cholesterol (HDL-C), 1.87 mg/dL (95% CI: 0.39 , 3.34 ; $P=0.013$); and for triglycerides, -1.95 mg/dL (95% CI: -4.94 , 1.04 ; $P=0.202$). Most interventions (70%) showed similar significant or no effects on adiposity- and lipids outcomes: 15% interventions improved both adiposity- and lipids outcomes; 55% had no significant effects on either.

Conclusions—Childhood obesity prevention programs had a significant desirable effect on LDL-C and HDL-C. Two-thirds of interventions showed similar significant or no effects in adiposity- and lipids outcomes. Assessing lipids outcomes provide additional useful information on obesity prevention program benefits.

Keywords

child; obesity; prevention; lipids; intervention

Introduction

Dyslipidemia is an important modifiable risk factor for cardiovascular diseases. As serum lipid concentrations in childhood are associated with serum lipid concentrations in adulthood (1), improving childhood lipid profiles is an important public health concern (2). A growing body of evidence suggests that childhood obesity is associated with dyslipidemias. As the prevalence of childhood obesity has been increasing markedly over the last few decades, much attention has been given to preventing obesity in children. Obesity prevention programs involving a diet and/or physical activity (PA) intervention have been conducted in many high income countries. A recent systematic review suggested that lifestyle interventions incorporating a dietary component along with an exercise and/or behavioral component result in improvements in weight and cardio-metabolic outcomes, including blood lipids (3). Another meta-analysis, assessing the effectiveness of physical exercise interventions on the lipid profile, also found favorable intervention effects (4). These two recent systematic reviews included a small number of studies, also studied the evidence of effectiveness of lifestyle interventions on blood lipids in overweight or/and obese children. One reviewed the effects of lifestyle interventions in already overweight and obese children (3). Pooling from five studies, it found that lifestyle interventions resulted in a significant reduction in TC (-3.5 mg/dL), LDL-C (-11.6 mg/dL), and TG (-13.3 mg/dL), but a non-significant improvement in HDL-C (3.9 mg/dL). The other review assessed the effectiveness of different PA interventions in obese children (4). It included four studies of aerobic exercise alone, and three studies of combined exercise, and showed that aerobic exercise alone had a small, but significant effect on LDL-C (-0.49 mg/dL) and TG (-0.55 mg/dL), while combined exercise had a significant effect on HDL-C (0.50 mg/dL).

These two prior reviews focused only on already overweight or obese children. Little is known about how childhood obesity prevention programs affect blood lipids, and whether this effect is modified by adiposity measures in the general population of children.

The present study was conducted based on a recent systematic review project funded by the Agency for Healthcare Research and Quality (AHRQ) (5), which assessed the general effectiveness of childhood obesity prevention programs in high-income countries by different settings. Combining all the settings, this study aimed to: 1) assess the effects of childhood obesity prevention programs on blood lipids in high-income countries; 2) examine the potential effects of the intervention on adiposity measures and blood lipids.

Methods

Literature Search

Methods were specified in advance and documented in a protocol (5). In brief, we searched MEDLINE®, EMBASE®, PsychInfo, CINAHL®, and the Cochrane Library for relevant studies with publication dates through April 22, 2013. We developed a search strategy for MEDLINE based on medical subject headings (MeSH®) terms and text words of key articles that we identified *a priori*. Search terms and text words were described in the full report (5). We also reviewed the reference lists of all included articles and relevant review articles to identify studies that the database searches might have missed. We uploaded the articles into DistillerSR (Evidence Partners, Ottawa, Ontario, Canada), a Web-based software package developed for systematic review and data management. We also conducted a grey literature search using the same inclusion criteria in ClinicalTrials.gov to identify unpublished research that was relevant to our review up to July 23, 2012, so as to check publication bias.

Selection criteria

We identified studies conducted in high-income countries (with a very high Human Development Index defined in the United Nations' Human Development Report (6)), that described the effects of interventions to prevent obesity (or "excessive weight gain") in children and adolescents aged 2 to 18 years. Studies needed to include adiposity measures, although the interventions did not necessarily focus specifically on obesity. We included only randomized controlled trials (RCTs), quasi-experimental studies, and natural experiments. The studies needed to test interventions targeting diet, PA, or a combination of the two in any setting, or combinations of settings (e.g., school, home, community, primary care, and child care) for one year, or for six months for school-based intervention studies (considering the length of the school year). We only included articles published in English, but reviewed the abstracts of non-English language articles to assess agreement with the results published in English.

Studies were excluded if they did not report on the attained differences between the intervention and control groups in blood lipids, or if they targeted only overweight or obese children, or those with a pre-existing medical condition like heart disease or diabetes.

Data extraction and quality assessment

Two reviewers independently conducted title scans and abstract reviews, and reviewed the full articles to assess eligibility for inclusion. Standardized forms were created for data extraction. Each article also received a double review for data abstraction; the second

reviewer checked the first reviewer's data abstraction for completeness and accuracy. Reviewers extracted information on study characteristics, study participants, eligibility criteria, intervention components, outcome measures, method of ascertainment, and outcomes. A third reviewer (the first author) double checked the adiposity measures and blood lipids for all included studies.

Two independent reviewers used the Downs & Black Checklist for Measuring Quality to assess the quality of included studies (7). Studies were classified as having low, moderate, or high risk of bias (ROB). Studies were classified as having a low ROB only when they fulfilled all of the following criteria: investigators randomized all subjects, concealed the intervention assignment until recruitment was complete, stated the study's objective clearly, described the characteristics of the enrolled subjects, described the interventions clearly, described the main findings and outcomes. Further, the study must have at least partially described the distributions of (potential) confounders. If a study did not fulfill any one of the above criteria, or if fulfilling the criteria could not be verified, it was rated as having a moderate ROB; if a study did not fulfill two or more of these criteria, it was rated as having a high ROB.

Data analysis and meta-analysis

The primary outcome measures were mean changes in total cholesterol (TC), low density lipoprotein-cholesterol (LDL-C), high density lipoprotein-cholesterol (HDL-C), or triglyceride (TG). Studies were included in the meta-analysis if sufficient data were available to calculate the net change in blood lipids and their variance. For each study, we calculated the net changes as the difference in the mean changes in blood lipids (mean changes in blood lipids in the intervention group minus mean changes in the control group). The variances for net changes in blood lipids were not reported directly in some studies. Therefore, they were calculated from confidence intervals (CIs) for intervention and control groups using standard methods⁸. For studies that reported blood lipids data before and after the intervention, we calculated the variance in the mean changes in blood lipids using correlation coefficient methods (8). We combined two subgroups into a single group if the study presented the outcomes separately for boys and girls in each of the intervention groups (9). One study (10) had five intervention groups: one used a PA intervention, one used a combined intervention, and three used different diet intervention approaches, respectively. We combined the three diet intervention groups into a single diet group. As the study still had more than one intervention group (10), we chose the combined intervention group and the control group for the meta-analysis to avoid double counting the control group. Results were similar when the PA or diet intervention group was used in the meta-analysis.

To calculate the pooled mean net changes in blood lipids, each comparison was weighted by the reciprocal of its variance. The I^2 statistic was used to assess the heterogeneity of effect size across interventions. A value greater than 50% was considered evidence of heterogeneity. The random effects model was applied in our meta-analysis because there was significant heterogeneity among the studies. Pre-specified stratified analyses were performed to assess the impacts of various study design on outcomes. A pre-specified

sensitivity analysis was conducted to investigate the influence of a single study on the overall pool estimate by omitting one study in each turn.

The potential publication bias was examined by Begg's rank correlation test, and Egger's linear regression test. The funnel plot was performed when 10 or more studies were pooled. All analyses were conducted in STATA (version 11.0; Stata Corp., College Station, Texas, USA).

We also summarized and compared the intervention effects on adiposity measures and blood lipids for all the included studies.

Results

Literature search and study characteristics

Figure 1 is a flow chart of the literature search. We identified 48844 potentially relevant articles, and 677 full articles were retrieved. Overall, 17 unique studies (9–25) were included in this review, and 15 provided adequate data for meta-analysis.

Table 1 details characteristics of the 17 studies (including 13136 participants). The studies were published between 1985 and 2012. Twelve (71.0%) were RCTs. Eight were conducted in Europe, seven in the US, and one each in Canada and Australia. The studies varied in sample size from 58 to 3714, with a median of 502. Sixteen studies included both boys and girls and one study focused on girls. Mean baseline ages of the subjects in studies ranged from 6.0 to 13.9 years. Fourteen studies reported the baseline mean body mass index (BMI), ranging from 16.0 to 22.6 kg/m²; the sample size-weighted mean BMI was 18.0 kg/m². Five studies (9, 16, 20, 21, 24) reported the baseline prevalence of overweight and obesity, ranging from 13% to 40.4%. Three studies were low ROB, 10 moderate ROB, and four high ROB.

Interventions—These 17 studies assessed 20 interventions (some studies had more than one intervention group). Nineteen of the interventions (95%) involved a school setting: 13 in a school-only setting, six in combined school and home settings; and one in combined community and home settings (Table 2). Ten used a combination of diet and PA interventions, eight applied a PA-only intervention, and only two used a diet-only intervention. The follow-up time varied from six to 72 months, with a median of 12 months.

Comparison of the effects of the interventions on adiposity measures and blood lipids

Four interventions resulted in significant improvements in adiposity measures (Table 2). Four out of 18 interventions resulted in significant improvements, and two led to increases in TC. Three interventions resulted in significant improvements in LDL-C and HDL-C. One intervention led to a significant increase in TG.

Most of the interventions (14, or 70%) had a similar effect on adiposity measures and blood lipids, as three of them showed significantly desirable effects (Tables 2). Three interventions showed a significantly desirable effect on blood lipids, but not on adiposity measures. One intervention having a significantly desirable effect on adiposity measures showed non-

significant effects on blood lipids. Five studies (17, 22–25) (six interventions) reported and showed a non-significant effect on waist circumference. Four (17, 24, 25) of these six interventions also showed non-significant effects on lipids outcomes and two (22, 23) show significant improvements.

Meta-analysis: Intervention effects on blood lipids

As shown in Table 3 and Figure 2, 15 studies (15 interventions) were included in the meta-analyses (13 for TC, five for LDL-C, 10 for HDL-C, and eight for TG). Compared with control, intervention was associated with an average net change of -0.97 mg/dl (95% CI: $-3.26, 1.32$; $P=0.408$) for TC, -6.06 mg/dl (95% CI: $-11.09, -1.02$; $P=0.018$) for LDL-C, 1.87 mg/dl (95% CI: $0.39, 3.34$; $P=0.013$) for HDL-C, and -1.95 mg/dl (95% CI: $-4.94, 1.04$; $P=0.202$) for TG, respectively.

Stratified analyses and sensitivity analysis: Intervention effects on blood lipids

Interventions in multiple settings led to greater improvements in TC, LDL-C, and TG (Table 3), while a significantly greater improvement in HDL-C was shown in interventions taking place in a single (school-only) setting. The combined diet and PA interventions had greater effects on HDL-C, compared to the PA-only interventions. RCTs had a greater improvement in HDL-C but a smaller improvement in LDL-C when comparing to non-RCTs. Those interventions having a significant desirable effect on adiposity measures resulted in a significantly greater improvement in LDL-C, HDL-C, and TG than those did not improve adiposity measures. When interventions were stratified by mean baseline age, the improvements in LDL-C and HDL-C were greater in children aged <11 years. In the sensitivity analyses, none of the interventions omitted in turn seemed to substantially influence the intervention effect (data not shown).

Publication bias

There was no indication of publication bias for TC and HDL-C through examination of funnel plots (plots not shown). Egger's and Begg's tests yielded similar results to funnel plots: TC (Egger $P=0.57$; Begg $P=0.43$), LDL-C (Egger $P=0.41$; Begg $P=0.46$), HDL-C (Egger $P=0.17$; Begg $P=0.47$) and TG (Egger $P=0.65$; Begg $P=0.90$).

Discussion

To our knowledge, this is the first systematic, quantitative analysis of the effect of childhood obesity prevention programs on blood lipids. We also are the first to systematically compare the effects of obesity prevention programs on lipids with the effects on adiposity measures. We found that childhood obesity prevention programs targeting diet and/or PA significantly improved lipid profiles in children, with a mean reduction of -6.06 mg/dL in LDL-C, and increase of 1.87 mg/dL in HDL-C, and non-significant reductions in TC and TG. Most of the interventions had a similar effect on adiposity measures and blood lipids, but nearly one-third did not. Those interventions that resulted in significant improvement in adiposity measures also resulted in significantly greater improvement in LDL-C, HDL-C and TG than studies which did not improve adiposity measures.

Our results extend the evidence that childhood obesity prevention programs with a diet and/or a PA component are effective at improving LDL-C and HDL-C in the general population of children (including normal weight children). It has been estimated that every 1% population decrease in LDL-C would decrease the 12- year incidence of coronary heart disease by 1% (26). Thus, though the improvement in blood lipids we found was small at the individual level, our findings have significant public health implications.

The observed favorable effects of childhood obesity prevention programs on blood lipids are biologically plausible, although some of the effect might be due to improved diet or increased PA, rather than a reduction in adiposity measures. It has been reported that obesity is associated with an increased cholesterol synthesis rate, equal to about 20 mg/day for each kilogram of body fat (27). BMI was shown to be positively correlated with TG and LDL-C, and negatively with HDL-C (28); and overweight/obesity is positively associated with the prevalence of dyslipidemia in adolescents (29). Our review finds that 70% of the interventions had a similar effect on adiposity measures and blood lipids; interventions having a significant desirable effect on adiposity measures led to a significantly greater improvement in LDL-C, HDL-C and TG. These findings suggest that improvement in adiposity measures generally seem to contribute to improvements in blood lipids.

Similar to our results in children, a meta-analysis of adults undergoing diet and aerobic exercise interventions found that greater reductions in both TC and LDL-C were associated with decreases in body weight (30). This meta-analysis concluded that diet, especially diet combined with aerobic exercise, was superior to aerobic exercise alone for improving selected lipids and lipoproteins in adults (30). In our review, only two diet-only intervention studies were identified. One of them found a significant improvement in TC and LDL-C, but a non-significant effect on HDL-C and TG. The other study reported a significant increase in TC, but did not assess TG. Improvement in HDL-C was significant and more prominent in studies using combined diet and PA interventions. However, because of limited study data, the effect of combined diet and PA interventions on LDL-C and TG were unclear. More studies need to be conducted before a definite conclusion can be drawn regarding the potential differential effects of diet and/or PA interventions on blood lipids in children. It is a debatable issue whether the effectiveness of interventions in children is different depending on gender. Unfortunately, we do not have enough data to investigate any gender difference that may exist.

Childhood obesity prevention programs in many countries have primarily focused on schools. In our review, 16 out of 17 studies involved schools, with six of them also incorporating a home component. We found that interventions taking place in a school-only setting had a significant favorable effect on HDL-C, while interventions taking place in multiple settings (e.g., school, home, and community) had a significant and favorable effect on LDL-C and TG. This inconsistency may be attributed to the small number of studies that were pooled for analysis. Thus, the evidence is insufficient to draw conclusions about the optimal intervention setting(s). More studies are needed to address the broader issues of the overall food and PA environment, including families, communities and other environments.

Numerous studies have shown that cardiovascular disease begins early in life, and the initial stages are associated with adverse blood lipids in children (1, 31). Elevated levels of LDL-C in childhood tend to persist, progressing to adult dyslipidemias (1); more than 70% of children with abnormal blood lipids continued to have dyslipidemias in adult life (32); lipid levels drawn before puberty have a high correlation with adult levels and are stable, unlike levels drawn during puberty (33). In this review, we found that the improvements in LDL-C and HDL-C were greater in children aged <11 years. In addition, data supports that the mean reduction in BMI z-score in lifestyle interventions for children with obesity had better results in young children (34). These evidences highlight the importance of measurements early in life, and early introduction of preventive and intervention programs aimed at fostering healthful lifestyles (1).

Our study has several strengths. A systematic approach to identify the relevant literature and a sequence of screening procedures were used. The review process also benefited at various stages from input from a number of experts in the field. Only experimental studies, natural experiments, and quasi-experimental studies were included in this study, minimizing problems with confounding. In addition, this study is the first to quantify the effect of obesity prevention programs on blood lipids in the general population of children (including normal weight children).

Limitations of this study should be noted. First, only studies conducted in high income countries were included, though this choice can help enhance the comparability of the studies for pooled analysis. Second, some studies that did not focus specifically on obesity, but focused more broadly on cardiovascular risk reduction were included. We included these studies because they targeted diet and PA, and reported adiposity measures and blood lipids. Third, we only included articles published in English. Fourth, publication bias is possible, though no evidence for this was identified. Fifth, the included studies used different study designs, eligibility criteria, follow-up times, and intervention approaches, which led to a moderate-to-large amount of heterogeneity for the lipid outcomes. Sixth, methodological problems in the design, conduct, or reporting of included studies may affect results. Furthermore, a relatively small number of studies were available and included in our review. Thus, caution in generalizing these results is advisable. While, when available we used better indicators of childhood obesity like BMI z-scores and % body fat, some studies only reported BMI, which may be less valid for children. Given the above limitations, future research should focus on using standardized study designs and measures to reduce heterogeneity and increase confidence in the findings.

In conclusion, we report the first systematic, quantitative analysis of the effect of childhood obesity prevention programs on blood lipids, and found that childhood obesity prevention programs had a significant, desirable effect on LDL-C and HDL-C in the general population of children in high income countries. Although most of the interventions had a similar effect on both adiposity measures and blood lipids, nearly one third did not. Those interventions that had a significant desirable effect on adiposity measures resulted in significantly greater improvements in LDL-C, HDL-C, and TG. Thus, when it is feasible to gather blood samples, we recommend assessment of blood lipids in future studies to fully capture the effects of childhood obesity prevention programs. Our findings also lend support to

emphasizing the relationship between adiposity measures and lipids in clinical settings, and draws attention to the potential benefits to be obtained by focusing on diet and physical activity among children.

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Figure 1.

Flow chart of the childhood obesity prevention studies identified and evaluated in the review and meta-analysis

* Sum of excluded abstracts exceeds 660 because the two reviewers might have different reasons for excluding the same study. "Other" reasons of article exclusion includes abstract only, does not apply to research question, no original data, not a country of interest. TC, total cholesterol; LDL-C, low density lipoprotein-cholesterol; HDL-C, high density lipoprotein-cholesterol; TG, triglyceride.

(A) TC (mg/dL)

(B) LDL-C (mg/dL)

(C) HDL-C (mg/dL)

(D) TG (mg/dL)

Figure 2. Meta-analysis of the effect of changes in blood lipids between the control and intervention groups

(A) TC (mg/dL)

(B) LDL-C (mg/dL)

(C) HDL-C (mg/dL)

(D)TG (mg/dL)

TC, total cholesterol; LDL-C, low density lipoprotein-cholesterol; HDL-C, high density lipoprotein-cholesterol; TG, triglyceride; WMD, Weighted mean difference.

Table 1

Study populations and intervention approaches in the included childhood obesity prevention studies

Study	RCT	Country	Total N	% girls	Mean age/(Range)	Grade	Baseline BMI	Risk of Bias	Intervention approaches	
									Control	Intervention
Walter, 1985	Yes	US	1563	48.6	9.1	4	NR	Moderate	Usual care	C Incorporated social learning strategies to encourage behavioral change regarding diet and PA (improvement of cardiovascular fitness)
Bush, 1989	Yes	US	1041	54.0	10.5	4-6	NR	Low	Only received results of screening	C Subjects received nutrition, exercise, anti-smoking lessons, health screening, and a "Health Passport". Health newsletters were mailed to parents throughout intervention
Lionis, 1991	No	Greece	171	51.0	(13-14)	NR	20.0	Moderate	Usual care	D School health education curriculum focused on nutrition, physical fitness, and prevention of cigarette smoking; it was taught in the school by the regular class teachers in cooperation with a team from a Health Center.
Vandongen, 1995	Yes	Australia	1147	51.3	(10-12)	6	17.9	Low	Usual care	PA Arm A: Classroom sessions providing rational basis for activity programs. Fitness program included relays, skipping and health hustles. C Arm B: The fitness program as stated in Arm A and a school-based nutrition program, which aimed to improve knowledge, attitudes and eating habits. D Arm C: The school-based nutrition program and/or the home-based nutrition program, which provide educational material for the child and parents.
Nader, 1999	Yes	US	3714	48.0	8.7	3	17.6	Moderate	Usual care	C CATCH intervention: targeted consuming foods low in fat, saturated fat and sodium via a multi-component program that included school environmental changes, and a family component.
Manios, 2002	No	Greece	1046	NR	(5.5-6.5)	1	16.3	Moderate	Usual care	C Educational sessions offered for health and nutritional components. PA component included educational sessions and increased

Study	RCT	Country	Total N	% girls	Mean age(Range)	Grade	Baseline BMI	Risk of Bias	Intervention approaches	
									Control	Intervention
Skybo, 2002	No	US	58	48.3	NR	3	NR	High	Usual care	PA with stretching, fitness stations and aerobic games. PA with stretching, fitness stations and aerobic games. American Heart Association Heart Power! Emphasized nutrition in class discussions as well as importance of PA. Children then engaged in PA such as jumping jacks or running in place.
Hopper, 2005	Yes	US	238	49.0	8.6	3	17.8	Moderate	Usual care	School classroom lessons on nutrition and exercise. Home activities for parents and children to complete.
Yin, 2005	Yes	US	601	52.0	8.7	3	19.4	Moderate	Usual care	Youths were provided healthy snacks during after-school PA sessions along with academic enrichment homework and assistance.
Reed, 2008	Yes	Canada	268	NR	(9–11)	4–5	18.9	Moderate	Usual care	Goal to deliver 15 min of moderate to intensive PA daily for 75 extra min of PA per week in schools. Principals and teachers met with facilitators to design program. Teachers also provide classroom activities such as skipping, dancing and resistance training.
Simon, 2008	Yes	France	954	50.0	11.6	6	18.8	Moderate	Usual care	School education on PA and sedentary behaviors, opportunities for PA were offered. Parents were asked to support the child's physical activity.
Walther, 2009	Yes	Germany	182	51.0	11.7	6	18.1	Moderate	Regular school sports	45 min of PA with 15 min endurance training per school day.
Kriemler, 2010	Yes	Switzerland	502	51	(6–12)	1 and 5	17.1	Low	Usual care	School based stringent PA program and home daily PA homework of about 10 minutes.
Robinson, 2010	Yes	US	261	100	9.4	NR	20.7	High	Usual care	Daily 1-hour homework period and small snack followed by 45 to 60 minutes of learning and practicing dance routines. Home-based screen time reduction intervention designed to incorporate African or African American history and culture.
Salcedo, 2010	Yes	Spain	1044	51.5	(9–11)	4–5	18.5	Moderate	Usual care	Activity program with sports using alternative equipment (pogo sticks, frisbees, parachutes, etc).

Study	RCT	Country	Total N	% girls	Mean age(Range)	Grade	Baseline BMI	Risk of Bias	Intervention approaches	
									Control	Intervention
Burguera, 2011	No	Spain	90	59.7	13.9	7–9	22.6	High	Usual care	C Primary care providers encouraged to focus on behavior Primary care providers encouraged to focus on behavior Primary care providers encouraged to focus on behavior Subjects were offered two nutrition and behavioral modification workshops. Special emphasis on healthy lifestyle and self-responsibility. Opportunities to participate in PA sessions if required.
Resaland, 2011	No	Norway	256	51.2	9.2	4	17.3	High	Usual care	PA 60 min/day of PA conducted by specialist PE teacher for 104 weeks

BMI, body mass index (kg/m²); C, combined diet and physical activity intervention; D, diet-only intervention; NR, not reported; PA, physical activity/ physical activity-only intervention; RCT, randomized control trial; US, United State.

Table 2

Characteristics of childhood obesity prevention programs and results of the included interventions

Intervention	Setting(s)	Type of Interventions	Follow-up time (months)	Effect of intervention on adiposity measures		Effect of intervention on Lipids*			Direction of adiposity measures and blood Lipids [†]
				Index	Effect*	TC	LDL-C	HDL-C	
Walter, 1985	S	C	12	TSF	(+), NS	(+), NS	.	(+), NS	→→
Bush, 1989	S	C	24	TSF	(-), NS	(-), NS	.	(+)	→↑
Lionis, 1991	S-H	D	12	BMI	(+)	(+)	(+)	(-), NS	↑↑
Vandongen, 1995a	S	PA	9	BMI	(-), NS	(-)	.	.	→↓
Vandongen, 1995b	S	C	9	BMI	(-), NS	(-), NS	.	.	→→
Vandongen, 1995c	S-H	D	9	BMI	(-), NS	(-)	.	.	→↓
Nader, 1999	S-H	C	36	BMI	(-), NS	(+), NS	.	(-), NS	→→
Manios, 2002	S	C	72	BMI	(+)	(+)	(+)	(+), NS	↑↑
Skybo, 2002	S	C	9	% body fat	0, NS	(-), NS	.	.	→→
Hopper, 2005	S-H	C	20	BMI	(+), NS	(-), NS	.	.	→→
Yin, 2005	S	C	8	BMI	(+), NS	(+), NS	.	(+), NS	→→
Reed, 2008	S	PA	9	BMI	(+), NS	0, NS	(+), NS	.	→→
Simon, 2008	S-H	PA	48	BMI	(+)	(-), NS	.	(+), NS	↑→
Walther, 2009	S	PA	12	BMI z-score	(+), NS	(-), NS	(-), NS	(+), NS	→→
Salcedo, 2010	S	PA	21	BMI	(+), NS	(+)	.	.	→↑
Kriemler, 2010	S-H	PA	9	BMI	(+)	.	.	(+)	↑↑
Robinson, 2010	Com-H	PA	24	BMI z-score	(-), NS	(+)	(+)	(+), NS	→↑
Burguera, 2011a	S	C	6	BMI z-score	0, NS	(+), NS	(-), NS	(-), NS	→→
Burguera, 2011b	S	C	6	BMI z-score	(-), NS	0, NS	0, NS	(-), NS	→→
Resaland, 2011	S	PA	24	BMI	0, NS	.	.	.	→→

* (+) or (-) = improvement or worsening in outcome in intervention group compared to the control group, respectively.

[†] There are two arrows in each cell; the first one represents weight-related outcome and the second one represents blood lipids outcomes. → = no significant differences between changes in intervention and control groups; ↑ or ↓ = **significant** improvement or worsening in intervention group compared to control group.

BMI, body mass index; C, combined diet and physical activity intervention; Com, community; D, diet-only intervention; H, home; HDL-C, high density lipoprotein-cholesterol; LDL-C, low density lipoprotein-cholesterol; NS, non-significant; PA, physical activity-only intervention; S, school; TC, total cholesterol; TG, triglyceride; TSF, triceps skinfold thickness; "0", no difference between intervention group and control group.

Table 3

Subgroup meta-analyses of blood lipids by type of childhood obesity prevention program

	TC (mg/dl)			LDL-C (mg/dl)			HDL-C (mg/dl)			TG (mg/dl)		
	N*	Net change (95% CI)	I ² (%)	N ^a	Net change (95% CI)	I ² (%)	N ^a	Net change (95% CI)	I ² (%)	N ^a	Net change (95% CI)	I ² (%)
Total	13	-0.97 (-3.26, 1.32)	74.5	5	-6.06 (-11.09, -1.02)	79.0	10	1.87 (0.39, 3.34)	84.1	8	-1.95 (-4.94, 1.04)	54.5
Setting(s)												
Single setting	9	0.22 (-0.35, 3.49)	69.2	3	-4.29 (-10.62, 2.04)	61.5	5	2.90 (0.61, 5.18)	80.8	4	-2.05 (-8.44, 4.34)	74.0
Multiple settings	4	-2.72 (-6.55, 1.12)	85.6	2	-9.68 (-24.09, 4.74)	92.0	5	0.48 (-0.64, 1.59)	52.3	4	-2.80 (-5.31, -0.30)	0.0
Type of intervention												
Diet-only	1	-17.21 (-25.76, -8.66)	.	1	-17.59 (-25.58, -9.60)	.	1	-0.78 (-3.87, 2.38)	.	1	3.30 (-6.12, 12.72)	.
PA-only	5	-1.16 (-4.39, 2.07)	62.3	3	-2.67 (-4.30, -1.03)	0.0	4	1.59 (-0.50, 3.67)	58.5	6	-2.22 (-5.95, 1.51)	63.7
Combined	7	0.27 (-2.64, 3.18)	69.0	1	-8.49 (-12.77, -4.21)	.	5	2.37 (-0.11, 4.85)	90.9	1	-3.54 (-8.54, 1.37)	.
Follow-up time												
12 months	7	-0.58 (-5.62, 4.47)	76.4	3	-6.75 (-18.35, 4.85)	83.3	5	1.33 (0.25, 2.42)	1.1	3	-2.94 (-7.55, 1.67)	12.3
> 12 months	6	-1.44 (-3.97, 1.09)	75.9	2	-5.31 (-10.80, 0.18)	82.7	5	2.49 (0.06, 4.91)	92.3	5	-1.79 (-5.67, 2.10)	67.6
RCT												
Yes	10	-0.30 (-2.36, 1.75)	64.6	3	-2.67 (-4.30, -1.03)	0.0	8	1.88 (0.24, 3.52)	85.6	5	-1.45 (-5.41, 2.51)	65.1
No	3	-5.23 (-16.65, 6.19)	88.4	2	-12.39 (-21.22, -3.56)	74.2	2	1.68 (-2.86, 6.23)	83.0	3	-3.19 (-7.98, 1.60)	31.2
Adiposity measures												
Non-significant	10	-0.15 (-2.35, 2.05)	66.3	3	-2.67 (-4.30, -1.03)	0.0	6	1.56 (-0.30, 3.42)	88.6	4	-1.73 (-7.72, 4.25)	73.2
Favorable	3	-6.12 (-15.57, 3.34)	89.1	2	-12.39 (-21.22, -3.56)	74.2	4	2.48 (0.40, 4.55)	51.6	4	-3.04 (-5.67, -0.40)	0.0
Mean age												
< 11 year	9	-1.64 (-3.71, 0.42)	63.5	3	-4.98 (-9.25, -0.71)	65.4	7	2.07 (0.35, 3.79)	89.0	5	-2.21 (-6.24, 1.83)	71.0
11 year	4	-0.69 (-8.99, 7.61)	85.7	2	-8.14 (-26.5, 10.2)	91.4	3	0.86 (-1.61, 3.34)	14.1	3	-1.75 (-5.91, 2.42)	0.0

* N, number of interventions. I² >50% was considered evidence of heterogeneity.

Combined, combined diet and physical activity intervention; Diet-only, diet-only intervention; HDL-C, high density lipoprotein-cholesterol; LDL-C, low density lipoprotein-cholesterol; PA-only, physical activity-only intervention; RCT, randomized controlled trial; TC, total cholesterol; TG, triglyceride.