Effectiveness of Lifestyle Interventions in Child Obesity: Systematic Review With Meta-analysis

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KEY WORDS
child, adolescent, lifestyle interventions, obesity, weight loss, cardio-metabolic risks, systematic review

ABBREVIATIONS
CI—confidence interval
HDL—high-density lipoprotein
HOMA-IR—homeostasis model assessment of insulin resistance
LDL—low-density lipoprotein
WMD—weighted mean difference

All authors were involved in study conception and design, interpretation of data, critical revision, and final approval of the submitted manuscript; Ms Ho was involved in quality assessment, data extraction, data analysis, and manuscript preparation; Prof Collins, Dr Baur, and Dr Garnett were involved in quality assessment, data extraction and study supervision; and Drs Burrow and Steward were involved in quality assessment and data extraction.

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BACKGROUND AND OBJECTIVES: The effects of lifestyle interventions on cardio-metabolic outcomes in overweight children have not been reviewed systematically. The objective of the study was to examine the impact of lifestyle interventions incorporating a dietary component on both weight change and cardio-metabolic risks in overweight/obese children.

METHODS: English-language articles from 1975 to 2010, available from 7 databases, were used as data sources. Two independent reviewers assessed articles against the following eligibility criteria: randomized controlled trial, participants overweight/obese and ð18 years, comparing lifestyle interventions to no treatment/wait-list control, usual care, or written education materials. Study quality was critically appraised by 2 reviewers using established criteria; Review Manager 5.1 was used for meta-analyses.

RESULTS: Of 38 eligible studies, 33 had complete data for meta-analysis on weight change; 15 reported serum lipids, fasting insulin, or blood pressure. Lifestyle interventions produced significant weight loss compared with no-treatment control conditions: BMI (−1.25kg/m², 95% confidence interval [CI] −2.18 to −0.32) and BMI z score (−0.10, 95% CI −0.18 to −0.02). Studies comparing lifestyle interventions to usual care also resulted in significant immediate (−1.50kg/m², 95% CI −1.58 to −1.03) and posttreatment effects (−0.92 kg/m², 95% CI −1.31 to −0.54) on BMI up to 1 year from baseline. Lifestyle interventions led to significant improvements in low-density lipoprotein cholesterol (−0.30 mmol/L, 95% CI −0.45 to −0.15), triglycerides (−0.15 mmol/L, 95% CI −0.24 to −0.07), fasting insulin (−55.1 pmol/L, 95% CI −71.2 to −39.1) and blood pressure up to 1 year from baseline. No differences were found for high-density lipoprotein cholesterol.

CONCLUSIONS: Lifestyle interventions can lead to improvements in weight and cardio-metabolic outcomes. Further research is needed to determine the optimal length, intensity, and long-term effectiveness of lifestyle interventions. Pediatrics 2012;130:e1647–e1671
Obesity in children and adolescents is a global public health concern and is associated with a range of short- and long-term health complications.\textsuperscript{1–4} Although prevention of obesity is important, so too are effective treatments for those already affected. Lifestyle interventions, involving a combination of diet, exercise, and/or behavior modification, are an essential element of obesity management.\textsuperscript{5–7} Several systematic reviews of childhood obesity have been published and lifestyle interventions targeting treatment of child and adolescent obesity are reported as efficacious in weight loss in the short to medium term.\textsuperscript{8–12} The first specific review of dietary interventions, published in 2006,\textsuperscript{13,14} included studies published up to 2003, and found positive effects of interventions that included a dietary component.\textsuperscript{14,15}

The previously mentioned systematic reviews and others have all presented data on weight change outcomes; however, obese children and adolescents also carry an increased risk for cardio-metabolic complications, including dyslipidemia, insulin resistance, and hypertension.\textsuperscript{15–20} To our knowledge, no systematic review has examined the effects of lifestyle interventions on cardio-metabolic outcomes in overweight children and adolescents. Therefore, the aim of this review was to present the best available evidence from randomized controlled studies of lifestyle interventions incorporating a dietary component to assess their impact on both weight loss and cardio-metabolic risks. This review covers literature published between 1975 and 2010.

METHODS

The protocol and search strategy for this systematic review was based on the previous peer-reviewed protocol\textsuperscript{13} registered with the Joanna Briggs Institute. It involved a 2-stage process. First, a detailed literature search was conducted in September 2010 to identify studies published between 2003 and 2010. Eligible studies from the previous review\textsuperscript{13} covering 1975 and 2003 were then combined in the data synthesis with those from the current search.

Eligibility Criteria

Eligible studies were randomized controlled trials of treatment of overweight and obesity in children and adolescents $\leq$18 years of age comparing the effectiveness of lifestyle intervention programs incorporating a nutrition or dietary component with no treatment or wait-list control, usual care, or minimal advice or written diet and physical activity education materials. Programs that involved the whole family or were directed exclusively at parents of overweight or obese children and adolescents were also included. Additional inclusion criteria were a follow-up period from baseline of at least 2 months, and inclusion of the outcome measures of body weight or body composition. Participants were free living or attending obesity clinical units, community programs, camps, schools, or one-off programs. Studies were excluded if they were targeted at obesity prevention or maintenance of weight loss, were drug trials or interventions that dealt with eating disorders, or if they focused on children with obesity attributable to a secondary or syndromal cause. Studies that were not written in English, or included children who were within the healthy weight range at baseline, were excluded. No restrictions were placed on intervention settings or who delivered the interventions.

Data Source and Search Strategy

The search strategy involved a literature search conducted by a medical librarian of published literature in the English language through CINAHL, Cochrane Reviews, Current Concepts, DARE, Embase, Premedline, and Medline. The Medical Subject Headings of the National Library of Medicine keyword search terms used were dietetic, paediatric (pediatric), child, adolescent, family, parent, school, overweight, obesity, intervention, weight control, weight management, weight loss, and healthy weight (Supplemental Appendix 1). In addition, the reference lists of retrieved articles and key systematic reviews of childhood obesity treatments were scanned for relevant references.\textsuperscript{8,9,11,12}

Study Selection

All studies identified in the database search were assessed for relevance from the title and abstract by 2 independent reviewers. Articles that met, or appeared to meet, the inclusion criteria were retrieved. All retrieved studies were assessed for relevance by 2 independent reviewers. In case of disagreement, a third independent reviewer made the final decision.

Quality Assessment

Full copies of all included studies were assessed for methodological quality by 2 independent reviewers using the Joanna Briggs Institute critical appraisal of study quality tool (Supplemental Appendix 2). Studies were rated as positive, negative, or neutral based on responses to 10 items. Discrepancies were resolved by discussion or consultation with a third reviewer to achieve consensus.

Data Extraction

Data in relation to methodology, intervention effect, compliance, and intensity were extracted by the first reviewer by using a standardized form developed specifically for this review. This was verified by a second reviewer for accuracy and a consensus reached.
where disagreement existed. Data describing interventions that were reported in more than 1 article were extracted together.

**Data Synthesis**

Review Manager (RevMan5.1, The Cochrane Collaboration, Oxford, England) was used for meta-analyses. All the outcomes in this review were continuous outcomes and a weighted mean difference (WMD) was calculated if the same measurement scale was used. When different outcome measurement scales were reported, we conducted the meta-analysis by using the standardized mean difference approach. Heterogeneity was assessed by $I^2$ statistics. Heterogeneity is considered to be low if $I^2$ is $\leq 40\%$, and high if $I^2$ is $\geq 75\%$. We used a random effects model for meta-analysis if there was significant heterogeneity ($I^2 > 40\%$), and fixed effects for homogeneous ($I^2 \leq 40\%$). BMI and BMI z score were used as the primary weight loss outcomes. We also examined the effects of interventions on body composition by using percentage body fat. By using the last time point of weight loss measurement for each study, we performed meta-analyses among subgroups by age (child defined as mean age at baseline $\leq 12$ years and adolescent as $>12$ years), and the length of the follow-up from baseline. Where key details or data were missing, authors were contacted, or data imputed based on methods described in the Cochrane Handbook. The following cardio-metabolic outcomes were examined:

- serum lipids, including total cholesterol, low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) cholesterol, and triglycerides;
- fasting glucose, fasting insulin, and insulin resistance as determined by the homeostasis model assessment of insulin resistance (HOMA-IR); and
- systolic and diastolic blood pressures.

Where outcomes could not be quantitatively combined in a meta-analysis, they are described in a narrative summary. For forest plots with sufficient studies included ($>10$), we generated funnel plots to examine for the publication bias.

**RESULTS**

**Search Result**

The literature search identified 4713 references (Fig 1), and 434 full articles were retrieved. Forty-one articles relating to 30 different studies met all inclusion criteria. Eight additional studies (12 articles) from the previous review that met the comparison criteria were also included. The total number of studies included in this review is 38.

**Description of Included Studies**

Study characteristics and weight-related outcomes are summarized in Table 1. Nearly half of the studies were conducted in the United States ($n = 18$), 22-24,29,33,41,46-49,50,63,64,66-69 5 in Australia, 25,30,35-37 and the others in Israel ($n = 3$), 38-41 Germany ($n = 2$), 32-34 the United Kingdom ($n = 2$), 34,40 Belgium, 28 China, 28 Finland, 42 Iran, 45 Korea, 31 Mexico, 38 Taiwan, 46 and Tunisia. 23 Eighteen studies targeted obese children exclusively, 22,23,26,28,29,31,33,38,40-42,44,46,51,64-66,71 whereas the others targeted both overweight and obese children. Most studies ($n = 14$) were conducted in a hospital environment, 22,25,29,32,36,38,40-41,43-44,46,63,66,68 followed by the community ($n = 6$), 25,27,30-35,51 school ($n = 6$), 26,42,48-50,64 and primary care setting ($n = 6$). 30,37,39,47,67,69 Thirteen studies were conducted in children, 25,30,33-35,37,40-42,44,47,50,68 in adolescents, 22-24,28,29,31,36 and others enrolled both children and adolescents. 26,27,32,38,39,43,45,46,48,51 Only 1 study included children aged $<5$ years. 35 Four adolescent studies specifically targeted girls, 24,29,31,45 The sample size of included studies ranged from 16 to 258, with a median of 72 participants per study. Twenty-seven studies had 2 study arms, 9 had 3 study arms, and 2 had 4 study arms (Table 1). Among the no treatment or wait-list control comparisons ($n = 22$) (Table 1), the intervention lengths varied from 1 month ($n = 1$) to 2 years. Twelve studies did not follow the participants after the intervention program ended, 22-24,26,28,29,31,32,36,63,64,68 For the comparison of lifestyle intervention with usual care ($n = 11$), the intervention lengths varied from 3 months to 1 year, and 6 studies conducted subsequent follow-up, 41-43,45,65,69 ranging from 2 months to 4 years from the end of the active intervention component. Among the 5 written information studies, 1 had a varied intervention length, 2 had an intervention length of 6 months, 48,49 and another 2 were 1-year $^{50,51}$ intervention programs with the outcome evaluation at the end of the intervention.

**Methodological Quality**

No studies fulfilled all requirements listed in the study quality critical appraisal tool, although 8 studies met 8 of the 10 requirements. 25,27,30,32,37,40,48,69 (Table 2). Twenty-four studies did not specify the method of randomization 22-24,26,28,29,31,32,36,40,42,45,46,48-51,63-68,71 Details of allocation concealment 22,24,26,28,29,31,33,34,41,43-44,46,50,51,63-68,71 and study blinding 22,24,27-31,35,36,37,38,40-42,45,48,50,51,63-68,71 were not adequately reported for most studies. Blinding of participants in dietary and lifestyle interventions is usually not possible. Only 5 studies reported that outcome assessors were blinded to participants’ treatment allocation, 25,30,37,38,40 Overall, retention rates for all included studies ranged from 38% to 100%. Most studies (29/38) had a retention rate of $\geq 70\%$ at 6 months or $>60\%$ at 1 year. Only 9 studies used intention-to-treat analysis. 32,41,44,46,47,62,67-69 Six studies did not report dropout rates and it was therefore not clear if they used an intention-to-treat analysis. 25,36,35,45,46,63
Dietary Interventions

Ten studies used the Traffic Light or modified Traffic Light diet as their dietary intervention.27,28,32,38,40,41,48,49,66,69 The Traffic Light diet is a calorie-controlled approach in which foods in each category are color-coded according to their calorie density per average serving: green for low-calorie foods that can be eaten freely; yellow for moderate-calorie foods that can be eaten occasionally; and red for high-calorie foods that should be eaten rarely. Four studies used a hypocaloric diet or a calorie restriction approach.22 One-fifth of the included studies inadequately described the details of dietary interventions.31,33,36,39,48,50,71 Other studies provided general healthy eating advice (Table 1). A dietitian was reported to be involved in the delivery of the dietary interventions in 13 studies.25,35,38,40,42–47,51,63,67

Exercise Interventions

Nineteen studies conducted supervised physical activity sessions or exercise training as part of the intervention.22–26,31,32,34,42–46,48,49,50,71 The intensity and variety varied. The total duration of physical activity sessions ranged from 20 minutes per month25 to 6 hours per week,23 most providing ~1.5 to 2.0 hours of training each week (Table 1). Three studies used pedometers to promote physical activity.27,33,36

Effects of Lifestyle Intervention Compared With No Treatment or Wait-Listed Control

Eighteen of the 22 studies that compared lifestyle intervention with no treatment or a wait-listed control group reported a positive effect on weight loss22,23,25–28,31,32,34–36,63,64,66–69,71 (Table 1). In the meta-analysis, which included 19 studies (24 comparisons) and 1234 participants, there was a significantly larger effect on weight and body composition (standardized

FIGURE 1
<table>
<thead>
<tr>
<th>Study Name</th>
<th>Participants</th>
<th>Intervention</th>
<th>Study Arms and Study Components</th>
<th>Interventions</th>
<th>Retention Rate</th>
<th>Weight-Related Outcome Reported</th>
<th>Significance Difference Between Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botvin 1979</td>
<td>119 F+M</td>
<td>Obese (120% of their ideal BW)</td>
<td>10 wk, 10 wk</td>
<td>(1) Control</td>
<td>74%</td>
<td>≥130% and &lt;130% of ideal weight</td>
<td>Yes: Significant decrease in % overweight of the intervention (P &lt; .05) No significant change in % overweight of the control group</td>
</tr>
<tr>
<td>Epstein 1984</td>
<td>53 families F+M</td>
<td>Obese (≥20% overweight and triceps skinfolds &gt;85th percentile)</td>
<td>6 mo, 1, 5, and 10 y</td>
<td>(1) Wait-list control</td>
<td>94% at 1 y</td>
<td>% overweight: Yes (3 &gt; 1 at 6 mo)</td>
<td></td>
</tr>
<tr>
<td>Kirshenbaum 1984</td>
<td>40 families F+M</td>
<td>Obese (≥20% overweight)</td>
<td>9 wk, 3 and 12 mo</td>
<td>(1) Wait-list control</td>
<td>Overall: 84% Change in relative weight</td>
<td>% overweight: Yes (2 &gt; 1)</td>
<td></td>
</tr>
<tr>
<td>Mellin 1987</td>
<td>68 F+M</td>
<td>Overweight and obese (113% to 213% relative weight)</td>
<td>3 mo, 6 and 15 mo</td>
<td>(1) Control</td>
<td>Overall: 84% Change in relative weight</td>
<td>% overweight: Yes (2 &gt; 1)</td>
<td></td>
</tr>
<tr>
<td>Becque 1988</td>
<td>36 F+M</td>
<td>Overweight and obese (BW and triceps skinfold &gt;75th percentile)</td>
<td>20 wk, 20 wk</td>
<td>(1) Control</td>
<td>NR</td>
<td>% body fat (hydrostatic weighing)</td>
<td>% body fat: Yes (3 &gt; 1)</td>
</tr>
<tr>
<td>Study, Program Name (When Applicable), Setting, Country</td>
<td>Participants</td>
<td>Intervention Length, Follow-up From Baseline</td>
<td>Study Arms and Study Components</td>
<td>Interventions</td>
<td>Retention Rate</td>
<td>Weight-Related Outcome Reported</td>
<td>Significance Difference Between Groups</td>
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<tr>
<td>Rocchini 1988&lt;sup&gt;,68&lt;/sup&gt;, Hospital environment, USA</td>
<td>72 F+M</td>
<td>10 to 17</td>
<td>Overweight and obese (Weight for height &gt;75th percentile; triceps and subscapular skin folds &gt;80th percentile) 20 wk, 20 wk</td>
<td>(1) Control (2) DA + BM&lt;sup&gt;e&lt;/sup&gt; (3) DA + PA + BM</td>
<td>(1) 82% (2) 85% (3) 92%</td>
<td>% body fat (hydrostatic weighing)</td>
<td>% body fat: Yes (3&gt;1)</td>
</tr>
<tr>
<td>Balagopal 2003&lt;sup&gt;,22&lt;/sup&gt;, Hospital environment, USA</td>
<td>16 F+M</td>
<td>14 to 18</td>
<td>Obese (BMI ≥30) 3 mo, 3 mo</td>
<td>(1) No-treatment control (2) DA+PA+SB+BM</td>
<td>Overall: 95%</td>
<td>BMI, % body fat (DXA)</td>
<td>BMI and % body fat: Yes (2&gt;1)</td>
</tr>
<tr>
<td>Jiang 2005&lt;sup&gt;,28&lt;/sup&gt;, Family, China</td>
<td>75 families F+M</td>
<td>7th to 9th grade</td>
<td>Obese (Chinese references weight for height ≥120%) 2 y, 2 y</td>
<td>(1) No-treatment control (2) DA+PA+SB+BM</td>
<td>(1) 90% (2) 92%</td>
<td>BMI</td>
<td>BMI: Yes (2&gt;1)</td>
</tr>
<tr>
<td>Rooney 2005&lt;sup&gt;,33&lt;/sup&gt;, “Growing Healthy Family study”, Community, USA</td>
<td>98 families, 333 people F+M</td>
<td>5 to 12</td>
<td>Overweight and obese (CDC Growth Chart BMI ≥84th percentile) 12 wk, 1 y</td>
<td>(1) No-treatment control (2) DA + PA</td>
<td>Overall: 89%</td>
<td>BMI percentile</td>
<td>No</td>
</tr>
<tr>
<td>Golley 2007&lt;sup&gt;,35,34&lt;/sup&gt;, Hospital environment, Australia</td>
<td>111 F+M</td>
<td>6 to 9</td>
<td>Overweight and obese (IOTF cut-off and BMI z score ≤ 3.5) 6 mo, 12 mo</td>
<td>(1) Wait-list control (2) PS (parents only)&lt;sup&gt;1&lt;/sup&gt; (3) PS + DA + PA</td>
<td>(1) 86% (2) 78% (3) 82%</td>
<td>BMI z score, WC z score</td>
<td>BMI z score: No WC z score: Yes (2&gt;1; 3&gt;1)</td>
</tr>
<tr>
<td>Study, Program Name (When Applicable), Setting, Country</td>
<td>Participants</td>
<td>Intervention Length, Follow-up From Baseline</td>
<td>Study Arms and Study Components</td>
<td>Interventions</td>
<td>Retention Rate</td>
<td>Weight-Related Outcome Reported</td>
<td>Significance Difference Between Groups</td>
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<tr>
<td>Huang 2007,26 School, Taiwan</td>
<td>120 F+M</td>
<td>12 wk, 12 wk</td>
<td>(1) No-treatment control</td>
<td>nutrition</td>
<td>NR</td>
<td>BMI, % body fat</td>
<td>BMI and % body fat: Yes (2&gt;1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2) DA children received 30-min nutrition instruction twice/wk at school</td>
<td></td>
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<td></td>
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<td>PA: 40-min classroom-based noncompetitive aerobic activities 3 times/wk</td>
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<tr>
<td>McCallum 2007,30,58 “LEAP trial,” Primary care, Australia</td>
<td>163 F+M</td>
<td>12 wk, 9 mo, 15 mo</td>
<td>(1) No-treatment control</td>
<td>(2) 4 standard consultations by general practitioners assisted by a 20-page “family folder” written at a 12-y-old reading level, targeting change in nutrition, physical activity, and sedentary behavior</td>
<td>(1) 85%</td>
<td>BMI, BMI z score</td>
<td>No</td>
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<td></td>
<td></td>
<td></td>
<td>(2) DA+PA+SB</td>
<td></td>
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<tr>
<td>Park 2007,31 Setting: unclear, Korea</td>
<td>44 F</td>
<td>12 wk, 12 wk</td>
<td>(1) No-treatment control</td>
<td>(2) Lifestyle education offered by a trained counselor once/wk. DA general advice PA: walking 6 d/wk (10 min for 3 d and 30 to 40 min for 3 d)</td>
<td>(1) 95%</td>
<td>BMI, % body fat (BIA), WC and weight/hip ratio</td>
<td>BMI, % body fat and waist/hip ratio: Yes (2&gt;1)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(2) DA+PA+BM</td>
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<tr>
<td>Shelton 2007,35 Community, Australia</td>
<td>43 F+M</td>
<td>4 wk, 3 mo</td>
<td>(1) Wait-list control</td>
<td>BMI z score</td>
<td>NR</td>
<td>BMI</td>
<td>BMI: Yes (2&gt;1)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(2) DA+PA+BM (parent only)</td>
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<tr>
<td>Janicke 2008,27,55,56 “Project STORY”, Community (rural setting), USA</td>
<td>93 F+M</td>
<td>4 mo, 10 mo</td>
<td>(1) Wait-list control</td>
<td>BMI z score</td>
<td>(1) 81%</td>
<td>BMI z score: Yes (2&gt;1, 3&gt;1)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(2) DA+PA</td>
<td></td>
<td>(2) 73%</td>
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<td></td>
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<td></td>
<td>(3) DA+PA (parents only)</td>
<td></td>
<td>(3) 77%</td>
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<tr>
<td>Tsios 2008,20 “Choose Health program,” Hospital environment, Australia</td>
<td>47 F+M</td>
<td>20 wk, 20 wk</td>
<td>(1) No-treatment control</td>
<td>BMI, WC, body fat (DXA)</td>
<td>Overall: 38%</td>
<td>BMI, body fat and abdominal fat: Yes (2&gt;1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2) DA+PA+BM+CBT</td>
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</tr>
</tbody>
</table>

**TABLE 1 Continued**

**Gender:** F = female, M = male, F+M = female and male

**Selection Criteria:** Overweight and obese (IOTF cut-off and BMI z score

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**Study Arms and Study Components:**

- **No-treatment control**
- **DA:** children received 30-min nutrition instruction twice/wk at school
- **PA:** 40-min classroom-based noncompetitive aerobic activities 3 times/wk
- **DA+PA:** lifestyle education offered by a trained counselor once/wk. DA general advice PA: walking 6 d/wk (10 min for 3 d and 30 to 40 min for 3 d)
- **DA+PA+BM:** lifestyle education offered by a trained counselor once/wk. DA general advice PA: walking 6 d/wk (10 min for 3 d and 30 to 40 min for 3 d)
- **DA+PA+BM+CBT:** lifestyle education offered by a trained counselor once/wk. DA general advice PA: walking 6 d/wk (10 min for 3 d and 30 to 40 min for 3 d)

**Interventions:**

- **Nutrition**
- **BMI, % body fat**
- **BMI z score**
- **Waist/hip ratio**
- **Overall: 38%**
- **BMI, WC, body fat (DXA)**
- **BMI, body fat and abdominal fat: Yes (2>1)**

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**Note:** The table continues with more studies and interventions, but is truncated for brevity.
<table>
<thead>
<tr>
<th>Study, Program Name (When Applicable), Setting, Country</th>
<th>Study Name</th>
<th>N&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Gender</th>
<th>Age, y</th>
<th>Selection Criteria&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Intervention Length, Follow-up From Baseline</th>
<th>Study Arms and Study Components</th>
<th>Interventions</th>
<th>Retention Rate&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Weight-Related Outcome Reported</th>
<th>Significance Difference Between Groups&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis 2009,24 Setting: unclear, USA</td>
<td>Davis</td>
<td>50</td>
<td>F</td>
<td>14 to18</td>
<td>Overweight and obese (CDC growth chart BMI &gt;84th percentile)</td>
<td>16 wk, 16 wk</td>
<td>(1) No-treatment control</td>
<td>(2) Weekly 90-min dietary session plus 4 motivational interview sessions</td>
<td>Overall: 82%</td>
<td>BMI, BMI z-scores, BMI percentile and fat mass (DXA)</td>
<td>BMI: Yes (1&gt;3, 1 = 4) BMI z-score and fat mass: No</td>
</tr>
<tr>
<td>Kitzman-Ulrich 2009,29 Hospital environment, USA</td>
<td>Kitzman-Ulrich</td>
<td>42</td>
<td>F</td>
<td>12 to 15</td>
<td>Obese (CDC growth chart BMI &gt;95th percentile)</td>
<td>4 mo, 4 mo</td>
<td>(1) Wait-list control</td>
<td>(2) DA Food Guide Pyramid PA: general advice (3) as group 2 plus attended a 45-min multifamily therapy group.</td>
<td>Overall: 83%</td>
<td>BMI z-score</td>
<td>No</td>
</tr>
<tr>
<td>Wake 2009,37 “LEAP 2 trial,” Primary care, Australia</td>
<td>Wake</td>
<td>258</td>
<td>F+M</td>
<td>5 to 9.99</td>
<td>Overweight and obese (IOTF cut-off and BMI z-score &lt;3.0)</td>
<td>12 wk, 6 mo, 12 mo</td>
<td>(1) No-treatment control</td>
<td>(2) 4 standard consultations by general practitioners assisted by a 16-page “family folder” written at a 12-year old reading level, targeting change in nutrition, physical activity, and sedentary behavior.</td>
<td>(1) 98%</td>
<td>BMI</td>
<td>No</td>
</tr>
<tr>
<td>Ben Ounis 2010,23 Community, Tunisia</td>
<td>Ben Ounis</td>
<td>28</td>
<td>F+M</td>
<td>Mean age 13.1±0.8</td>
<td>Obese (BMI &gt;97th percentile, reference not specified)</td>
<td>8 wk, 8 wk</td>
<td>(1) No-treatment control</td>
<td>(2) Nutrition education program 4 h/wk (1) calorie restriction (500 kcal less than the reported energy intake at baseline, 15% energy from protein, 55% carbohydrate, 30% fat) PA: supervised exercise training 4 times/wk (30 min each)</td>
<td>NR</td>
<td>BMI, % body fat (skin fold)</td>
<td>BMI and % body fat: Yes (2&gt;1)</td>
</tr>
<tr>
<td>Reinehr 2010,32 “Obeldicks Light” Program, Hospital environment, Germany</td>
<td>Reinehr</td>
<td>71</td>
<td>F+M</td>
<td>8 to 16</td>
<td>Overweight and obese (Germany reference BMI 90th to 97th percentile)</td>
<td>6 mo, 6 mo</td>
<td>(1) Wait-list control</td>
<td>(2) Intensive phase (3 mo): 6 nutrition groups (1.5 h each) education session for children (stratified by gender and age) plus 6 parent evening sessions (1.5 h) plus 30 min individual dietary counseling. Establishing phase (3 mo): 1 individual nutrition counseling session plus 3 counseling sessions. DA: Optimized mixed diet (food-based dietary guideline) and Traffic Light system PA: weekly physical activity training (1.5 h each, mainly aerobic exercise) for 6 mo SB: general advice</td>
<td>(1) 84%</td>
<td>BMI, BMI z-score, WC, % body fat (YA)</td>
<td>BMI z-score, WC and % body fat: Yes (2&gt;1)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Numbers refer to unique studies.

<sup>b</sup> Selection criteria are based on age, height, weight, body mass index (BMI), or other obesity-related parameters.

<sup>c</sup> Retention rate indicates the percentage of participants who completed the study.

<sup>d</sup> Significance difference between groups indicates whether there were significant differences in outcomes between intervention groups.
<table>
<thead>
<tr>
<th>Study, Program Name (When Applicable), Setting, Country</th>
<th>Participants</th>
<th>Intervention Length, Follow-up From Baseline</th>
<th>Study Arms and Study Components</th>
<th>Interventions</th>
<th>Retention Rate</th>
<th>Weight-Related Outcome Reported</th>
<th>Significance Difference Between Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacher 2010, MEND program, Community, United Kingdom</td>
<td>116 F+M</td>
<td>Obese (UK 1990 reference BMI &gt;98th percentile) 6 mo, 12 mo</td>
<td>(1) Wait-list control (2) DA+PA+BM+12-wk free family swim pass</td>
<td>(1) 18, 2-h biweekly sessions for children and their parents and siblings. DA: 8 sessions, general nutrition education and nondieting approach PA: 16 sessions (1 each), noncompetitive group play</td>
<td>(1) 68% (2) 70%</td>
<td>BMI and BMI z score</td>
<td>BMI and BMI z score: Yes (2&gt;1)</td>
</tr>
<tr>
<td>Lifestyle intervention program compared with usual care or minimal advice</td>
<td>259 children (1 y follow-up study) 136 children (4.6 y follow-up study) F+M</td>
<td>Obese (≥20% overweight) Varied, 1.0 and 4.6 y</td>
<td>(1) Minimal therapeutic contact: DA, PA (2) Individual treatment: CBT, DA, PA (3) Group treatment: CBT, DA, PA (4) Summer camp training: CBT, DA, PA</td>
<td>(1) Advice in 1 session (3 h) and given treatment manual for parents and workbook for children (2) Received the same information packages as group 1 plus children received 7 sessions of 90 min (twice/mo) and 7 monthly family follow-up sessions on an individual basis. DA: Healthy eating + 3 mid-meal snacks. Unhealthy meals limited to 1/mo or small amount weekly. No kcal counting. PA: moderate exercise 30 min/d (3) same as group 2 but on a group approach (4) 10-d summer camp: Balanced healthy food 1500 kcal/d plus daily lifestyle exercises 5 h/d and families encouraged to attend monthly follow-up sessions for 1 y</td>
<td>Overall: 81% at 1 y 80% at 4.6 y</td>
<td>1 y follow-up paper: Mean % weight loss 4.8 y follow-up paper: % overweight and mean % weight loss</td>
<td>No: Significant decrease in % overweight in all groups at 3, 6 mo, 1.0 and 4.6 y</td>
</tr>
<tr>
<td>Braet 1997, Hospital environment, Belgium</td>
<td>44 F+M</td>
<td>Overweight and obese (20% to 100% above the median for BMI) 4 mo, 7 mo</td>
<td>(1) Typical care: DA, PA (2) Intensive follow-up: DA BM, PA, SB</td>
<td>(1) Single appointment with a pediatrician at baseline (nontailored counseling session) DA: Food Guide Pyramid PA: 60 min/d (2) Computer-based program: assessment of eating, PA and SB. At baseline, a pediatrician provided tailored counseling session based on the computer-generated individualized action plan. Weekly telephone counseling for 8 wk then biweekly until 14 to 16 wk. Also received behavior modification manual DA: 1200–1500 kcal/d and weekly goal of 40 green (&lt;1 g fat, &lt;150 kcal and nutrient dense) and &lt;15 red foods (5 g or more fat or diet versions of high-fat foods) PA: ≥60 min moderate intensity exercise 5 d/wk SB: general advice</td>
<td>(1) 90% (2) 78%</td>
<td>BMI, % overweight BMI: Yes (2&gt;1)</td>
<td></td>
</tr>
<tr>
<td>Study, Program Name (When Applicable), Setting, Country</td>
<td>Participants</td>
<td>N&lt;sup&gt;a&lt;/sup&gt; Gender</td>
<td>Age, y</td>
<td>Selection Criteria&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Intervention Length, Follow-up From Baseline</td>
<td>Study Arms and Study Components</td>
<td>Interventions</td>
</tr>
<tr>
<td>---------------------------------------------------------</td>
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</tr>
<tr>
<td>Nemet 2005,&lt;sup&gt;43,40&lt;/sup&gt; Hospital environment, Israel</td>
<td>54 F+M</td>
<td>6 to 16 NR</td>
<td>3 mo, 1 y</td>
<td>(1) Minimal advice: DA, PA (2) Lifestyle program: DA, PA</td>
<td>(1) At least 1 ambulatory nutritional consultation plus general exercise advice. (2) DA hypocaloric diet (30% deficient based on reported intake or 15% less than estimated daily requirement). Met dietitian 6 times in 3 mo (2.5 h in total). PA: twice-weekly training (mostly endurance training. 1 h/session)</td>
<td>(1) 67% (2) 83%</td>
<td>BMI, % body fat (skin fold), BMI percentile</td>
</tr>
<tr>
<td>Gillis 2007,&lt;sup&gt;39&lt;/sup&gt; Primary care, Israel</td>
<td>27 F+M</td>
<td>7 to 16 Overweight and obese (BMI ≥90th percentile, reference not specified)</td>
<td>6 mo, 6 mo</td>
<td>(1) Minimal advice: DA, PA (2) Lifestyle program: DA, PA</td>
<td>(1) A 0.5-h talk on exercise and diet at baseline (2) Talks of 0.5 h at baseline and 3 mo, plus weekly follow up phone calls. Also, instructed to record diet and exercise on 1 day of each wk</td>
<td>(1) 54% (2) 79%</td>
<td>BMI z score</td>
</tr>
<tr>
<td>Kalavainen 2007,&lt;sup&gt;42,59&lt;/sup&gt; School, Finland</td>
<td>70 F+M</td>
<td>7 to 9 Obese (Finnish reference weight for height 120% to 200%)</td>
<td>6 mo, 12 mo</td>
<td>(1) Routine Program: DA (2) Lifestyle program: DA, PA, SB, BM, CBT</td>
<td>(1) 2 individual counseling sessions by school nurse (30 min each) plus information booklets for family (2) Family-based group treatment, 15 sessions (60 min each) with separate sessions for parents and children and 1 joint session. First 10 sessions were held weekly and then fortnightly. DA: general healthy eating PA: noncompetitive activities</td>
<td>(1) 100% (2) 97%</td>
<td>BMI and BMI z score</td>
</tr>
<tr>
<td>Savoye 2007,&lt;sup&gt;46,61&lt;/sup&gt; “Yale Bright Bodies Weight Management Program”, Hospital environment, USA</td>
<td>209 F+M</td>
<td>8 to 16 Obese (CDC growth chart BMI &gt;95th percentile)</td>
<td>1 y, 1 y</td>
<td>(1) Standard care: DA (2) Lifestyle program: DA, PA, BM</td>
<td>(1) Met dietitian every 6 mo, general healthy eating and physical activity advice. (2) Intensive family-based nutrition and behavior modification (weekly 40 min for the first 6 mo then every other wk). DA: a nondieting approach, focused on better food choices PA: twice 50-min sessions of high-intensity aerobic exercise for the first 6 mo followed by 100 min twice/month. Plus encouraged to exercise 3 additional days at home per wk</td>
<td>(1) 64% (2) 71%</td>
<td>BMI and % body fat (BMI)</td>
</tr>
<tr>
<td>Study, Program Name (When Applicable), Setting, Country</td>
<td>Participants</td>
<td>Intervention Length, Follow-up From Baseline</td>
<td>Study Arms and Study Components</td>
<td>Interventions</td>
<td>Retention Rate</td>
<td>Weight-Related Outcome Reported</td>
<td>Significance Difference Between Groups</td>
</tr>
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</tr>
<tr>
<td>Hughes 2008, 40, 57 &quot;SCOTT,&quot; Hospital environment, United Kingdom</td>
<td>134 F+M</td>
<td>5 to 11 Obese (UK reference BMI ≥98th percentile)</td>
<td>12 mo, 12 mo</td>
<td>(1) Standard care: DA (2) Lifestyle program: DA, PA, BM</td>
<td>(1) 3 to 4 appointments with dietitian over 8 to 10 mo (1.5 h in total). DA: general healthy eating and mainly directed toward parents. (2) Family-centered lifestyle intervention program, 8 appointments over 26 wk (5 h in total). DA: modified Traffic Light guide PA: not specified SB: ≤ 2 h per day</td>
<td>63% (2) 65%</td>
<td>BMI z score, WC z score</td>
</tr>
<tr>
<td>Nemet 2008, 44 Hospital environment, Israel</td>
<td>22 F+M</td>
<td>8 to 11 Obese (CDC growth chart BMI &gt; 95th percentile)</td>
<td>3 mo, 3 mo</td>
<td>(1) Minimal advice: DA, PA (2) Lifestyle program: DA, PA, BM</td>
<td>(1) At least 1 ambulatory nutritional consultation plus general exercise advice. (2) DA: hypocaloric diet (30% deficient based on reported intake or 15% less than estimated daily requirement). The children met with the dietitian weekly and the parents met separately with the dietitian biweekly. PA: twice-weekly 1-h training (mostly endurance training)</td>
<td>Overall: 100%</td>
<td>BMI, % body fat (BIA), BMI percentile</td>
</tr>
<tr>
<td>Kalarchian 2009, 41 Hospital environment, USA</td>
<td>192 F+M</td>
<td>8 to 12 Obese (CDC growth chart BMI &gt; 97th percentile)</td>
<td>6 mo, 12 mo, 18 mo</td>
<td>(1) Usual care: DA (2) Lifestyle program: DA, PA, SB, BM</td>
<td>(1) 2 nutrition sessions based on Stop Light eating plan (2) First 3 mo: 20 group meetings (80 min each). Parents and children in separate group, then joined to set weekly goals 6 to 12 mo: 3 group sessions plus 3 telephone follow-up 12–18 mo: no contacts DA: modified Stop Light eating plan SB: &lt; 15 h/wk</td>
<td>85.3% (2) 85.5%</td>
<td>BMI, WC, and % body fat (DXA)</td>
</tr>
<tr>
<td>Sarvestani 2009, 45, 46 Setting: unclear, Iran</td>
<td>60 F</td>
<td>11 to 15 NR</td>
<td>18 wk, 6 mo</td>
<td>(1) Standard care: DA, PA, BM (2) Lifestyle program: DA, PA, BM</td>
<td>(1) 3 behavioral modification intervention sessions (same program as group 2). (2) 16 behavioral modification intervention sessions (2 h behavior modification or dietary instruction plus 2 h yoga therapy). Plus 4 individual diet sessions and required to keep 24-h food records.</td>
<td>NR</td>
<td>BMI</td>
</tr>
<tr>
<td>Study, Program Name (When Applicable), Setting, Country</td>
<td>Participants</td>
<td>Intervention Length, Follow-up From Baseline</td>
<td>Study Arms and Study Components</td>
<td>Interventions</td>
<td>Retention Rate</td>
<td>Weight-Related Outcome Reported</td>
<td>Significance Difference Between Groups</td>
</tr>
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<td>--------------------------------------------------------</td>
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</tr>
<tr>
<td>Diaz 2010, 38 Shapedown Program, Hospital environment, Mexico</td>
<td>76 F+M</td>
<td>9 to 17 Obese (CDC growth chart BMI &gt;95th percentile or BMI &gt;90th percentile with WC &gt;90th percentile)</td>
<td>12 mo, 12 mo</td>
<td>(1) Usual care: DA (2) Lifestyle program: DA, PA, SB, BM</td>
<td>(1) 58% (2) 55%</td>
<td>BW, BMI, BMI z score, WC, and body fat: Yes (2&gt;1)</td>
<td></td>
</tr>
<tr>
<td>Face-to-face education compared with written education materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Fullerton 2007, 48 School, USA</td>
<td>80 F+M</td>
<td>6th and 7th graders Obese (CDC growth chart BMI ≥85th percentile)</td>
<td>6 mo, 6 mo</td>
<td>(1) Written materials (2) Intensive instructor-led intervention group: DA, PA, BM</td>
<td></td>
<td>BMI z score: Yes (2&gt;1)</td>
<td></td>
</tr>
<tr>
<td>Johnston 2007, 49, 62 School, USA</td>
<td>71 F+M</td>
<td>10 to 14 Obese (CDC growth chart BMI ≥85th percentile)</td>
<td>6 mo, 6 mo</td>
<td>(1) Written materials (2) Intensive instructor-led intervention group: DA, PA, BM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study Program Name (When Applicable), Setting, Country</td>
<td>Participants</td>
<td>Intervention Length, Follow-up From Baseline</td>
<td>Study Arms and Study Components</td>
<td>Interventions</td>
<td>Retention Rate</td>
<td>Weight-Related Outcome Reported</td>
<td>Significance Difference Between Groups</td>
</tr>
<tr>
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</tr>
<tr>
<td>Weigel 2008, Community, Germany</td>
<td>73</td>
<td>7 to 15 Obese (WHO growth standard)</td>
<td>1 y</td>
<td>(1) Written dietary advice: DA (2) Group sessions: DA, PA, BM</td>
<td>(1) 83% (2) 97%</td>
<td>BMI, BMI z score and BMI: z score and BMI: Yes (2 &gt;1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F+M</td>
<td></td>
<td>1 y</td>
<td>(1) Written advice (Food Guide Pyramid) from a pediatrician during an outpatient visit at baseline and 6 mo. (2) Children received weekly group nutrition education (adapted from the Food Guide Pyramid fruit and vegetable template, 45–60 min/session) and coping strategy training. Parents received monthly 2 h support sessions. PA weekly session, alternating swimming and indoor sports</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DA food groups were labeled “safety” (most fruits and nonstarchy vegetables), “caution” (low-fat meat, low-fat dairy and complex carbohydrate) and “danger” (≥ 5 grams of fat or ≥ 15 grams of sugar per serving) zone food.

PA 2-stage approach, wk 1 to 6 aimed to develop a basic level of physical fitness; wk 7 to 12 to focus on sport skill development.
<table>
<thead>
<tr>
<th>Study, Program Name (When Applicable), Setting, Country</th>
<th>Participants</th>
<th>Intervention Length, Follow-up From Baseline</th>
<th>Study Arms and Study Components</th>
<th>Interventions</th>
<th>Retention Rate</th>
<th>Weight-Related Outcome Reported</th>
<th>Significance Difference Between Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estabrooks 2009.47 Primary care, USA</td>
<td>220 F+M</td>
<td>Overweight and obese (CDC growth chart BMI ≥85th percentile)</td>
<td>Intervention length varied, follow up at 6 and 12 mo</td>
<td>(1) Written materials: DA, PA, SB (2) Written materials + Group session with dietitian: DA, PA, SB, BM (3) Written materials + Group session with dietitian + interactive voice response technology: DA, PA, SB, BM</td>
<td>(1) 72% (2) 66% (3) 74%</td>
<td>BMI z score</td>
<td>BMI z score: Yes (3 &gt; 1; 1 &gt; 2)</td>
</tr>
<tr>
<td>Resnick 2009.910c CHEER Program, School, USA</td>
<td>46 families F+M</td>
<td>Kindergarten and 5th graders Overweight and obese (CDC growth chart BMI ≥85th percentile)</td>
<td>1 y.</td>
<td>(1) Written materials (2) Written materials + home visit or phone call</td>
<td>(1) 100% (2) 86%</td>
<td>BMI percentile</td>
<td>No: both groups lost weight</td>
</tr>
</tbody>
</table>


a Number of participants at randomization.

b Classification of overweight and obesity standardized using the following definitions: Overweight = BMI 85th to 95th percentile for age and sex; obese = BMI ≥95th percentile for age and gender or weight ≥120% of average weight for height.

c Retention rates reported post intervention if no follow-up, or at latest point of follow-up.

d > 1 means group 2 had a greater reduction than group 1 (P < .05).

e Not included in the meta-analyses.
Lifestyle interventions compared with no-treatment/wait-list control, n = 22 studies

Effects of Lifestyle Intervention Program Compared With Usual Care or Minimal Intervention

Eight of the 11 studies reported a positive effect of the lifestyle intervention as compared with usual care or minimal interventions. The overall effect size in the meta-analysis, which included 7 studies (586 participants), was a decrease in BMI of 1.30 kg/m² at the end of active intervention (95% CI: 1.03–1.58, I² = 0%–48%) (Fig 3A). Studies with longer intervention periods (>6 months) showed greater weight loss compared with shorter term interventions. Four studies followed up participants at 7 months to 1 year from baseline and the pooled results indicate that weight loss was sustained after program completion (Fig 3B). Similar observations were obtained for percentage body fat change, with the lifestyle intervention group losing 3.2% more body fat (95% CI: 1.39–5.01) than the usual care group at the end of active intervention (Supplemental Fig 9A). The fat loss effect was sustained at 1 year postintervention (Supplemental Fig 9B). Four studies reported BMI z score change after the active intervention, with the pooled weight loss being 0.09 BMI z score greater (0.02 to 0.15, I² < 40%) in the lifestyle intervention compared with usual care (Supplemental Fig 9C).

Effects of Lifestyle Intervention Program Compared With Written Educational Materials

Two of the 5 studies reported BMI and 3 reported BMI z score. There was a 2.52 kg/m² greater reduction in pooled BMI (95% CI: 0.91–5.95, I² = 97%) and 0.06 greater reduction in pooled BMI z score (95% CI: 0.02–0.10, I² = 99%) for the lifestyle intervention programs compared with written educational materials only over 1 year (Fig 4A and B).

Effects of Lifestyle Interventions on Cardio-metabolic Outcomes

Table 3 summarizes the metabolic outcomes reported by each study. Fifteen of the 38 studies reported at least 1 cardio-metabolic outcome. All except 2 small studies (with 7 to 15 participants in each study arm) reported a positive weight loss effect of lifestyle interventions compared with control groups. Eight studies reported blood lipids results; 6 studies reported results of fasting glucose, fasting insulin, or HOMA-IR; and 12 studies reported blood pressure findings.

Total Cholesterol and Triglycerides

Meta-analysis of 5 studies including 440 participants between 8 and 16 years old (Supplemental Fig 10) showed that lifestyle intervention had a significantly greater impact on total cholesterol improvement compared with no treatment/wait-list control, usual care, or written educational materials, both in the short-term (WMD = –0.40 mmol/L, 95% CI: –0.51 to –0.30, I² = 0% study length: 4 to 6
A  Outcome: Change in BMI (kg/m²) at the latest point of follow-up

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Lifestyle intervention</th>
<th>Control</th>
<th>Weight</th>
<th>Mean Difference IV, Random, 95% CI</th>
<th>Mean Difference IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>1.2.1 Children*</td>
<td>1.2</td>
<td>1.22</td>
<td>70</td>
<td>0.4</td>
<td>0.89</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>356</td>
<td>343</td>
<td>46.5%</td>
<td>1.00  [-1.91, -0.08]</td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 1.22; Chi² = 129.39, df = 5 (P < .00001), I² = 98%
Test for overall effect Z = 2.13 (P = .03)

1.2.2 Adolescents*  

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Lifestyle intervention</th>
<th>Control</th>
<th>Weight</th>
<th>Mean Difference IV, Random, 95% CI</th>
<th>Mean Difference IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>107</td>
<td>93</td>
<td>53.5%</td>
<td>-1.45 [-3.02, 0.12]</td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 4.38; Chi² = 266.38, df = 6 (P < .00001), I² = 98%
Test for overall effect Z = 1.81 (P = .07)
Test for subgroup differences: Chi² = 0.24, df = 1 (P = .62), I² = 0%

B  Outcome: Change in BMI z score at the latest point of follow-up

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Lifestyle intervention</th>
<th>Control</th>
<th>Weight</th>
<th>Mean Difference IV, Random, 95% CI</th>
<th>Mean Difference IV, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Total</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>151</td>
<td>128</td>
<td>36.6%</td>
<td>-0.09 [-0.17, -0.02]</td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.00; Chi² = 1.53, df = 3 (P = .87), I² = 0%
Test for overall effect Z = 2.55 (P = .01)

FIGURE 2

Meta-analysis of studies comparing lifestyle intervention with no-treatment or wait-list controls.

* Children defined as the mean age ≤ 12 years; adolescents as the mean age >12 years
months) and the longer-term studies (WMD $-0.24$ mmol/L, 95% CI: $-0.30$ to $-0.17$, $I^2 = 0$%; study period: 1 to 2 years) [28,46]. The pooled intervention effect on triglycerides for the same group of studies (Fig 5A) was $-0.20$ mmol/L in the short-term studies (95% CI: $-0.35$ to $-0.05$, $I^2 = 59$%) and $-0.09$ mmol/L in the longer-term studies (95% CI: $-0.11$ to $-0.07$, $I^2 = 0$%).

Low-Density Lipoprotein and High-Density Lipoprotein Cholesterol

Meta-analysis of 4 studies including 372 participants with study length between 4 and 12 months showed a significant improvement in LDL cholesterol ($-0.30$ mmol/L, 95% CI: $-0.45$ to $-0.15$, $I^2 = 59$%) favoring lifestyle intervention (Fig 5B). No differences were found for HDL cholesterol ($P = 0.22$) (Fig 5C).

Fasting Glucose, Fasting Insulin, and HOMA-IR

Meta-analyses of 4 studies including 372 participants showed a significant improvement in fasting insulin ($-55.1$ pmol/L, 95% CI: $-71.2$ to $-39.1$, $I^2 = 0$%) in favor of lifestyle interventions.
over 1 year (Fig 6A) and no differences was found for fasting glucose (P = .08) (Supplemental Fig 11). The pooled difference for HOMA-IR was 2.32 (95% CI: 2.35 to 2.19) in favor of lifestyle intervention over 1 year; however, the heterogeneity was high (I² = 79%) (Fig 6C).

**Blood Pressure**

Meta-analyses of 7 studies (554 participants) showed that lifestyle interventions led to a significantly greater improvement in diastolic blood pressure in the short-term studies (WMD = 1.69 mm Hg, 95% CI: -3.25 to -1.39) in favor of lifestyle intervention over 1 year; however, there was no difference in the longer-term studies (Fig 7A). On the contrary, a significantly greater improvement in systolic blood pressure was shown only in the studies with a study length of 6 months or less but there was no difference in the longer-term studies (Fig 7B). Studies comparing lifestyle interventions with usual care also resulted in significant immediate and posttreatment effects on BMI up to 1 year from baseline. The meta-analysis shows that weight loss was greater when the duration of treatment was longer than 6 months. Lifestyle interventions also produced significant treatment effects on BMI and BMI z-score, compared with written information only, over a 6- to 12-month intervention period.

**DISCUSSION**

This systematic review reports on lifestyle intervention trials incorporating a dietary component aimed at treating overweight and obesity in children and adolescents published between 1975 and September 2010 (n = 38). It is the first review to summarize the effects of lifestyle interventions on cardio-metabolic outcomes in this age group and provides an improved understanding of the effects of lifestyle interventions on weight loss and cardio-metabolic outcomes. The results support the importance of lifestyle interventions incorporating a dietary component as a critical part of treatment of childhood obesity.

The meta-analyses indicate that lifestyle interventions incorporating a dietary component led to significant weight loss when compared with no treatment. These results support previous reviews and extend the evidence base on the use of lifestyle interventions in the treatment of childhood obesity, as this review includes more trials, uses clearly defined no-treatment, or wait-list controls, and extends ascertainment to September 2010. Studies comparing lifestyle interventions with usual care also resulted in significant immediate and posttreatment effects on BMI up to 1 year from baseline. The meta-analysis shows that weight loss was greater when the duration of treatment was longer than 6 months. Lifestyle interventions also produced significant treatment effects on BMI and BMI z score, compared with written information only, over a 6- to 12-month intervention period.

Meta-analyses showed that lifestyle interventions resulted in significant
TABLE 3  Effects of Lifestyle Interventions on Anthropometric and Metabolic Outcomes (Structured by Year of Publication)

<table>
<thead>
<tr>
<th>Study</th>
<th>Time of Measurementa</th>
<th>Anthropometric/Body Composition</th>
<th>Metabolic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BMI BMI z Body Fat % Waist</td>
<td>Total Cholesterol LDL HDL Triglyceride Fasting Glucose Fasting Insulin Insulin Resistancei SBP DBP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Circumference</td>
<td></td>
</tr>
<tr>
<td>Lifestyle intervention compared with no-treatment or wait-list control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Becque 198863</td>
<td>20 wk</td>
<td>✓b,d</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Rocchini 198868</td>
<td>20 wk</td>
<td>✓b,d</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Balagopal 200322</td>
<td>3 mo</td>
<td>✓b,a</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Jiang 200528</td>
<td>24 mo</td>
<td>✓b</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Huang 200736</td>
<td>12 wk</td>
<td>✓b, f</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Park 200731</td>
<td>12 wk</td>
<td>✓b, f</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Davis 200924</td>
<td>16 wk</td>
<td>✓b</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Reinehr 201013</td>
<td>6 mo</td>
<td>✓b, n</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Sacher 201014</td>
<td>6 mo</td>
<td>✓b, n</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Lifestyle intervention compared with usual care</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nemet 200543</td>
<td>3 mo</td>
<td>✓b, h</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Nemet 200543</td>
<td>12 mo</td>
<td>✓b, h</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Gillis 200730</td>
<td>6 mo</td>
<td>✓ b</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Savoye 200746</td>
<td>6 mo</td>
<td>✓b, f</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Savoye 200746</td>
<td>12 mo</td>
<td>✓b, f</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Kalarchian 200841</td>
<td>6 mo</td>
<td>✓b, n</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Kalarchian 200841</td>
<td>12 mo</td>
<td>✓ b</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Lifestyle intervention compared with written education materials only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Johnston 200743</td>
<td>6 mo</td>
<td>✓ b</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>Weigel 200843</td>
<td>12 mo</td>
<td>✓ b</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
</tbody>
</table>

DBP, diastolic blood pressure; SBP, systolic blood pressure; ✓, the outcomes were reported.

a Counted from baseline.

b Indicates a statistically significant improvement in that outcome when compared with no-treatment control/usual care/written education materials.

c Findings reported in graph.

d Body fat % measured by hydrostatic weighting.
e Body fat % measured by dual-energy x-ray absorptiometry.
f Body fat % measured by bio-impedance analyzer.
g Body fat % determined by deuterium dilution.
h Body fat % determined by skin folds.
i Insulin resistance determined by the homeostasis model assessment of insulin resistance (HOMA-IR).
improvements in total cholesterol and triglycerides up to 2 years from baseline, as well as improvements in fasting insulin and HOMA-IR up to 1 year from baseline; however, the improvements were not uniformly associated with the extent of weight loss or body fat reduction. It is uncertain whether the positive effects were attributable to weight loss per se or attributable to aspects of the lifestyle intervention that were independent of weight loss, such as reduction in saturated fat intake or increased physical activity. Some studies have reported that lifestyle intervention resulted in improvement in plasma lipid concentrations, insulin sensitivity, and blood pressure in obese children, even in the absence of weight loss or body composition change.75,76 The absence of individual participants’ data on weight and cardio-metabolic outcome changes makes it impossible to characterize the relationship between the extent of weight loss and changes in various cardio-metabolic outcomes. Although most studies showed a significant improvement in total cholesterol (6/7)26,28,31,43,46 or LDL cholesterol,26,63 fewer than half demonstrated significant improvements in triglycerides26,28,31 or HDL cholesterol.26,63 High triglycerides and low HDL cholesterol levels are the important risk factors of cardiovascular disease. Future studies should explore effective strategies to improve triglycerides and HDL cholesterol concentrations.

The impact of lifestyle interventions on blood pressure is less certain from the included studies. Most overweight or obese children are likely to be normotensive. In addition, blood pressure is
strongly related to age and height in children and adolescents, and therefore direct comparison of blood pressure reading possibly underestimates the intervention effects and limits our ability to draw definitive conclusions on the effects of lifestyle interventions on blood pressure.

Features of Effective Interventions

The heterogeneity of the included studies makes it difficult to give definitive recommendations for practice. However, the studies provide evidence to support a variety of dietary and lifestyle components in treating childhood obesity across a wide range of treatment settings, age groups, and severity of obesity.

Family Involvement

Family involvement in treatment of childhood obesity is widely advocated and discussed.8,9,80,81 Our review demonstrated that almost all effective interventions (particularly in studies that enrolled children <12 years of age) reported including a family component, including separate education sessions for parent and child.25,27,32,41,42,44,48,51,66

Dietary Intervention

We found that dietary interventions were rarely evaluated as a sole component of treatment in comparison with a wait-list or no-treatment control group. Dietary interventions were usually part of a broader lifestyle intervention program. Not all studies adequately described the dietary intervention. The most commonly reported dietary interventions were the modified Stop/Traffic Light approach and a hypocaloric diet/calorie restriction approach. Both dietary approaches were demonstrated to achieve effective relative weight loss across different age groups, settings, and countries.22,23,27,32,38,41,44,66 The influences on weight were sustained up to 1 year from baseline.27,41–43

Exercise Intervention

Another frequent feature of effective studies is involvement of a structured exercise training component.22,43,45,48,49,64,68 Again, the varied strategies, intensity, and duration of intervention make it difficult to conduct direct comparisons and to identify the most effective exercise intervention for weight loss in this age group.

Strengths and Limitations

This review comprehensively included lifestyle intervention trials published between 1975 and 2010 during which time childhood obesity became prevalent. Strengths of the study include the reporting of mean differences in BMI and percentage body fat, weight change indicators commonly used by clinicians, as well as cardio-metabolic outcomes. Also, separate meta-analyses were conducted to compare lifestyle interventions with clearly defined no-treatment or wait-list controls, usual care, or minimal advice and written diet and physical activity education materials respectively. This provides clinically meaningful information for future pediatric obesity treatment service planning.

A number of limitations of the present analyses should be acknowledged.
First, this review was confined to published literature written in English; this may have introduced publication bias and an overrepresentation of effective interventions. Second, a high degree of clinical and statistical heterogeneity among the included studies means the results should be interpreted with caution. We addressed statistical heterogeneity by using a random effects meta-analysis and by subgroup analysis. The potential sources of heterogeneity include variations in the participant populations, the intensity and duration of interventions, and the variety of diet and exercise regimens used. The review was also limited by the less than optimal methodological quality of the included studies and the lack of isolation of the effects of the dietary intervention components. In addition, there were inadequate data reported to allow inclusion of some studies in meta-analyses, and almost 40% of included studies (n = 19) reporting only absolute values of weight outcome. For these studies, we calculated weight change from absolute values and used imputation methods to estimate the SD of the change. To facilitate future systematic reviews and meta-analyses, authors should be encouraged to report both weight change and SD data. Finally, the review was also limited by the use of intermediate outcomes, such as lipoprotein and blood pressure, in the absence of longer-term cardiovascular morbidity data.

CONCLUSIONS

The body of research reviewed suggests that lifestyle interventions incorporating a dietary component along with an exercise and/or behavioral therapy component are effective in treating childhood obesity and improving the cardio-metabolic outcomes under a wide range of conditions at least up to 1 year. To draw firm clinical recommendations, future studies should provide details of all intervention components, participant characteristics, and the study design, including the method of randomization.
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Mandy Ho, Sarah P. Garnett, Louise Baur, Tracy Burrows, Laura Stewart, Melinda Neve and Clare Collins

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