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

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 ≤18 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 (−0.24 kg/m², 95% confidence interval [CI] −0.32 to −0.18) 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 (−1.03 kg/m², 95% CI −1.58 to −0.54) and posttreatment effects (−0.54 kg/m², 95% CI −1.31 to −0.07) 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. 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. 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. The first specific review of dietary interventions, published in 2006, included studies published up to 2003, and found positive effects of interventions that included a dietary component. 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. 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 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 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 ≤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.

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 ($n = 18$), $22,24,28,33,41,46–49,50,56,63,66,68$ 5 in Australia, $25,30,35–37$ and the others in Israel ($n = 3$), $38,43,44$ Germany ($n = 2$), $32,45$ the United Kingdom ($n = 2$), $34,40$ Belgium, $45$ China, $28$ Finland, $42$ Iran, $45$ Korea, $31$ Mexico, $38$ Taiwan, $46$ and Tunisia. $23$ Eighteen studies targeted obese children inclusively, $22,23,26,28,29,31,34,38,40–42,44,46,51,64–66,71$ whereas the others targeted both overweight and obese children. Most studies ($n = 14$) were conducted in a hospital environment, $22,25,29,32,36,38,40–41,43–44,46,63,68,68$ followed by the community ($n = 6$), $26,27,33–35,51$ school ($n = 6$), $26,42,48–50,64$ and primary care setting ($n = 6$), $30,37,39,47,67,68$ Thirteen studies were conducted in children, $25,30,33–35,37,40–42,44,47,50,68$ 7 in adolescents, $22–24,28,29,31,36$ and others enrolled both children and adolescents, $26,27,32,33,39,43,45,46,48,49,51$ 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 $22–24,26,28,29,31,32,56,63,64,68$ 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, $41–43,45,60–69$ 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 studies 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. Twenty-four studies did not specify the method of randomization. $22–24,26,28,29,31,33,34,41,43–45,50,65,69$ Details of allocation concealment $22,24,26,29,31,33–34,41,43–45,50,63–66,67,71$ and study blindness $22,24,26,28,29,31,33–34,41,43–45,50,63–66,67,71$ 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. $25,30,35,45,48,63$
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.22,23 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.22–26,31,32,34–41,48,49,50,51,63,64,68 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 1: Study Characteristics and Weight-Related Outcomes (Structured by Year of Publication)

<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>
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</thead>
<tbody>
<tr>
<td>Botvin 1979, School, USA</td>
<td>119 F+M</td>
<td>10 wk, 10 wk</td>
<td>(1) Control</td>
<td>(2) DA + PA + BM</td>
<td>(1) 74%</td>
<td>% of participants ≥130% and &lt;130% of ideal weight</td>
<td>Yes: Significant decrease in % overweight of the intervention (P &lt; .05)</td>
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<td>No significant change in % overweight of the control group</td>
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<td>(2) Weekly session (1 class period each) conducted by allied health professionals and by school faculty members. DA: Healthy food selection, prudent diet, pre-planning and changing eating patterns. PA: 10-min supervised session each week (jogging, jumping rope, bicycling)</td>
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<td>Epstein 1984, Setting: unclear, USA</td>
<td>53 families F+M</td>
<td>6 mo, 1, 5, and 10 y</td>
<td>(1) Wait-list control</td>
<td>(2) DA</td>
<td>Overall: 94% at 1 y</td>
<td>Change in % overweight</td>
<td>% overweight: Yes (G &gt; 1 at 6 mo)</td>
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<td>(2) 15 treatment sessions, parent and child in separate groups (session 1–8: weekly, session 9–11: biweekly, session 12–15: monthly). Parents encouraged to lose weight too. Traffic Light Diet (1200–1500 kcal/d, limit to 4 red foods/wk). (3) DA: as group 2 PA: lifestyle change exercise program - increase energy expenditure 200–400 kcal/d</td>
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<td>Kirshenbaum 1984, Setting: unclear, USA</td>
<td>40 families F+M</td>
<td>9 wk, 3 and 12 mo</td>
<td>(1) Wait-list control</td>
<td>(2) DA + PA + CBT (Child only)</td>
<td>(1) 89%</td>
<td>% overweight</td>
<td>% overweight: Yes (at 3 mo (G &gt; 1)</td>
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<td>(2) 9 weekly 90-min treatment sessions. Focus on cognitive-behavioral treatment. DA and PA: no details given. Only children attended the group (6–9 children per group)</td>
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<td>Mellin 1987, &quot;Shapedown Program,&quot; Primary care, USA</td>
<td>66 F+M</td>
<td>3 mo, 6 and 15 mo</td>
<td>(1) Control</td>
<td>(2) DA + PA + CBT (Parent &amp; child)</td>
<td>(3) as group 2, both parents and children attended all sessions together (4–5 dyads per group)</td>
<td>Overall: 84%</td>
<td>Change in relative weight</td>
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<tr>
<td>Becque 1988, Hospital environment, USA</td>
<td>36 F+M</td>
<td>20 wk, 20 wk</td>
<td>(1) Control</td>
<td>(2) DA + BM⁷</td>
<td>NR</td>
<td>% body fat (hydrostatic weighing)</td>
<td>% body fat: Yes (G &gt; 1)</td>
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**TABLE 1** Study Characteristics and Weight-Related Outcomes (Structured by Year of Publication).
<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>
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<th>Retention Rate (%)</th>
<th>Weight-Related Outcome Reported</th>
<th>Significance Difference Between Groups</th>
</tr>
</thead>
</table>
| Rocchini 1988,68,74 Hospital environment, USA          | 72 F+M       | 10 to 17 Overweight and obese (Weight for height >75th percentile, triceps and subscapular skin folds >80th percentile) | 20 wk, 20 wk                    | (1) Control  
(2) DA + BM  
(3) DA + PA + BM | (2) Weekly 1-h class  
DA modified kcal exchange program to produce a weight loss of approximately 1 lb/wk  
(3) DA as group 2  
PA supervised exercise 3 times/wk (1 h each, 10 min stretching and muscle strengthening exercise plus 40 min aerobic exercise) | (1) 82%  
(2) 85%  
(3) 92% | % body fat (hydrostatic weighting)  
(3 >1) |
| Balagopal 2003,22,52,53 "Shapedown Program," Hospital environment, USA | 16 F+M | 14 to 18 Obese (BMI ≥30) | 3 mo, 3 mo | (1) No-treatment control  
(2) DA+PA+SB+BM | (2) DA caloric restriction (snacks and beverages); met with a nutritionist once/wk PA: 45 min 3 times/wk; 1 monitored PA session/wk in the presence of parent SB: limiting TV viewing | Overall: 95%  
BMI, % body fat (DXA) | BMI and % body fat: Yes (2 >1) |
| Jiang 2005,28 Family, China | 75 families F+M | 7th to 9th grade Obese (Chinese references weight for height >120%) | 2 y, 2 y | (1) No-treatment control  
(2) DA+PA+SB+BM | (2) Home visit by pediatrician once per month PA: 20–30 min/d, 4 d/wk SB: general advice | (1) 90%  
(2) 92% | BMI  
BMI: Yes (2 >1) |
| Rooney 2005,33,34 "Growing Healthy Family study," Community, USA | 98 families, 353 people F+M | 5 to 12 Overweight and obese (CDC Growth Chart BMI >84th percentile) | 12 wk, 1 y | (1) No-treatment control  
(2) PA  
(3) DA+PA | (2) family members received a pedometer and instructed to walk 10 000 steps daily and received a biweekly newsletter  
(3) as group 2 plus attended 6, 1-h biweekly sessions concerning nutrition, physical activity, and other parenting issues | Overall: 89% BMI percentile | No |
| Golley 2007,35,36 Hospital environment, Australia | 111 F+M | 6 to 9 Overweight and obese (IOTF cut-off and BMI z score ≥ 3.5) | 6 mo, 12 mo | (1) Wait-list control  
(2) PS (parents only)  
(3) PS + DA + PA | (2) Parent attended 4 weekly 2-h group sessions on parenting skills training (family lifestyle change) followed by 4 weekly then 3 monthly 15- to 20-min individual telephone sessions.  
(3) Parents completed the same parenting skills training as group 2 plus an additional 7 intensive lifestyle support group sessions. Children attended 7 supervised activity sessions (focused on aerobic activity and motor skills development).  
DA: general eating guidelines and core food serve recommendations | (1) 86%  
(2) 78%  
(3) 82% | BMI z score, WC z score  
BMI z score: No  
WC z score: Yes (2 >1, 3 >1) |
<table>
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<tr>
<th>Study, Program Name (When Applicable), Setting, Country</th>
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<tbody>
<tr>
<td>Huang 2007,26 School, Taiwan</td>
<td>120 F+M</td>
<td>Obese (Taiwanese reference BMI ≥95th percentile)</td>
<td>12 wk, 12 wk</td>
<td>(1) No-treatment control (2) DA: children received 30-min nutrition instruction twice/wk at school PA: 40-min classroom-based noncompetitive aerobic activities 3 times/wk</td>
<td>NR</td>
<td>BMI, % body fat (BIA)</td>
<td>BMI and % body fat: Yes (2&gt;1)</td>
</tr>
<tr>
<td>McCallum 2007,26,58 “LEAP trial,” Primary care, Australia</td>
<td>163 F+M</td>
<td>Overweight and obese (IOTF cut-off and BMI z score &lt;3.0)</td>
<td>12 wk, 9 mo, 13 mo</td>
<td>(1) No-treatment control (2) DA + PA + SB</td>
<td>(1) 85%</td>
<td>BMI, BMI z score</td>
<td>No</td>
</tr>
<tr>
<td>Park 2007,51 Setting: unclear, Korea</td>
<td>44 F</td>
<td>Obese (Korean reference BMI ≥95th percentile)</td>
<td>12 wk, 12 wk</td>
<td>(1) No-treatment control (2) DA + PA + BM</td>
<td>(1) 95%</td>
<td>BMI, % fat (BIA), WC and waist/hip ratio</td>
<td>BMI, % body fat and waist/hip ratio: Yes (2&gt;1)</td>
</tr>
<tr>
<td>Shelton 2007,55 Community, Australia</td>
<td>43 F+M</td>
<td>Overweight and obese (CDC growth chart BMI ≥85th percentile)</td>
<td>4 wk, 3 mo</td>
<td>(1) Wait-list control (2) DA + PA + BM (parent only)</td>
<td>NR</td>
<td>BMI</td>
<td>BMI: Yes (2&gt;1)</td>
</tr>
<tr>
<td>Janicke 2008,52,53,54 “Project STORY”, Community (rural setting), USA</td>
<td>93 F+M</td>
<td>Overweight and obese (CDC growth chart BMI ≥85th percentile)</td>
<td>4 mo, 10 mo</td>
<td>(1) Wait-list control (2) DA + PA (3) DA + PA (parents only)</td>
<td>(1) 81%</td>
<td>BMI, z score</td>
<td>BMI z score: Yes (2&gt;1, 3&gt;1)</td>
</tr>
<tr>
<td>Tsiros 2008,56 “Choose Health program,” Hospital environment, Australia</td>
<td>47 F+M</td>
<td>Overweight and obese (IOTF cut-off)</td>
<td>20 wk, 20 wk</td>
<td>(1) No-treatment control (2) DA + PA + BM + CBT</td>
<td>Overall: 38%</td>
<td>BMI, WC, body fat (DXA)</td>
<td>BMI body fat and abdominal fat: Yes (2&gt;1)</td>
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</table>

TABLE 1 Continued

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REVIEW ARTICLE

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<th>Study, Program Name (When Applicable), Setting, Country</th>
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<th>Selection Criteriaa</th>
<th>Intervention Length, Follow-up From Baseline</th>
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<th>Retention Ratec</th>
<th>Weight-Related Outcome Reported</th>
<th>Significance Difference Between Groupsd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis 2009,24 Setting: unclear, USA</td>
<td>50 F</td>
<td>Age, y: 14 to 18</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>
</tr>
<tr>
<td>Kitzman-Ulrich 2009, 29 Hospital environment, USA</td>
<td>42 F</td>
<td>Age, y: 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</td>
<td>Overall: 83%</td>
<td>BMI z score</td>
</tr>
<tr>
<td>Wake 2009,37 “LEAP 2 trial,” Primary care, Australia</td>
<td>258 F+M</td>
<td>Age, y: 5 to 9.99</td>
<td>Overweight and obese (CDC growth chart BMI &gt; 97th percentile)</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-y-old reading level, targeting change in nutrition, physical activity, and sedentary behavior.</td>
<td>(1) 98%</td>
<td>BMI</td>
</tr>
<tr>
<td>Ben Ounis 2010,23 Community, Tunisia</td>
<td>28 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</td>
<td>NR</td>
<td>BMI, % body fat (skin fold)</td>
</tr>
<tr>
<td>Reinehr 2010,32 “Obeldicks Light” Program, Hospital environment, Germany</td>
<td>71 F+M</td>
<td>Age, y: 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: supervised exercise training 4 times/wk (30 min each)</td>
<td>(1) 84%</td>
<td>BMI, BMI z score, WC, % body fat (BIA)</td>
</tr>
<tr>
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<td>Participants</td>
<td>Intervention Length, Follow-up From Baseline</td>
<td>Study Arms and Study Components</td>
<td>Interventions</td>
<td>Retention Rate&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Weight-Related Outcome Reported</td>
<td>Significance Difference Between Groups&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>Sacher 2010&lt;sup&gt;c,d&lt;/sup&gt;, MEND program, Community, United Kingdom</td>
<td>116 F+M</td>
<td>8 to 12 Obese (UK 1990 reference data BMI &gt;98th percentile)</td>
<td>6 mo, 12 mo</td>
<td>(1) Wait-list control</td>
<td>(1) 68%</td>
<td>BMI and BMI z score</td>
<td>(2) 70%</td>
<td></td>
</tr>
<tr>
<td>Braet 1997&lt;sup&gt;e,f&lt;/sup&gt;,&lt;sup&gt;g&lt;/sup&gt;, Hospital environment, Belgium</td>
<td>259 children (1 y follow-up study) 136 children (4.6 y follow-up study) F+M</td>
<td>7 to 17 Obese (≥20% overweight) Varied, 1.0 and 4.6 y</td>
<td>(1) Minimal therapeutic contact: DA, PA</td>
<td>No: Significant decrease in % overweight in all groups at 3, 6 mo, 1.0 and 4.6 y</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Saelens 2002&lt;sup&gt;f&lt;/sup&gt;,&lt;sup&gt;g&lt;/sup&gt;, Primary care, USA</td>
<td>44 F+M</td>
<td>12 to 16 Overweight and obese (20% to 100% above the median for BMI)</td>
<td>4 mo, 7 mo</td>
<td>(1) Single appointment with a pediatrician at baseline (nontailored counseling session)</td>
<td>(1) 90%</td>
<td>BMI, % overweight</td>
<td>BMI, Yes (2&gt;1)</td>
<td>(2) 78%</td>
</tr>
</tbody>
</table>

<sup>a</sup>Retention rate

<sup>b</sup>Significance difference between groups

<sup>c</sup>Sacher 2010, 2010

<sup>d</sup>MEND program, Community, United Kingdom

<sup>e</sup>Braet 1997, 1997

<sup>f</sup>Hospital environment, Belgium

<sup>g</sup>Saelens 2002, 2002

<sup>h</sup>Primary care, USA
<table>
<thead>
<tr>
<th>Study, Program Name (When Applicable), Setting, Country</th>
<th>Participants</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>Nemet 2005,&lt;sup&gt;43,60&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</td>
<td>(1) At least 1 ambulatory nutritional consultation plus general exercise advice. (2) DA hypocaloric diet (30% deficit 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>
</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</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>
</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 (30 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>
</tr>
<tr>
<td>Savoye 2007,&lt;sup&gt;46,61&lt;/sup&gt; “Yale Bright Bodies Weight Management Program”, Hospital environment, USA</td>
<td>208 F+M</td>
<td>8 to 16 Obese (CDC growth chart BMI ≥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 non-dieting 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>
</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 Ratec</td>
<td>Weight-Related Outcome Reported</td>
</tr>
<tr>
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</tr>
<tr>
<td>Hughes 2008,40,57 “SCOTT,” Hospital environment, United Kingdom</td>
<td>134 F+M</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>(1) 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>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% deficit 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>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 (60 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>(1) 85.3% (2) 85.3%</td>
<td>BMI, WC, and % body fat (DXA)</td>
</tr>
<tr>
<td>Sarvestani 2009,45,e Setting, unclear, Iran</td>
<td>60 F</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>
</tr>
<tr>
<td>--------------------------------------------------------</td>
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</tr>
<tr>
<td>Diaz 2010,38 Shapedown Program, Hospital Environment, Mexico</td>
<td>76 F+M 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) Monthly 10- to 15-min consultations with primary care physician DA: Food Guide Pyramid PA: 30 min most days of the wk SB: ≤2 h/d (2) 12 weekly 2-h behavior group program and weekly dietitian counseling sessions for the first 3 mo, then monthly until 12 mo. Plus 12 monthly physician consultations. Parents received 6 education sessions and were encouraged to lose weight if they were overweight DA: Traffic diet approach plus education on glycemic index and provided with an individualized diet plan of 1200 to 1800 kcal/d PA: not specified SB: not specified</td>
<td>(1) 58% (2) 55%</td>
<td>BW, BMI, BMI z score, BMI z score: Yes (2&gt;1)</td>
</tr>
<tr>
<td>Face-to-face education compared with written education materials</td>
<td>Fullerton 2007,48 School, USA</td>
<td>80 6th and 7th graders Overweight and 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>(1) To follow a 12-wk parent guided manual of Trim Kids. (2) Children received an instructor-led daily intervention during school days (1 nutrition class and 4 physical activity classes weekly) for 12 wk, then monthly booster sessions. Parents offered monthly evening training sessions.</td>
<td>NR</td>
</tr>
<tr>
<td>Johnston 2007,49,62 School, USA</td>
<td>71 F+M 10 to 14 Overweight and 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>(1) To follow a 12-wk parent guided manual of Trim Kids. (2) Children received an instructor-led daily intervention (1 nutrition class and 4 physical activity classes weekly, 35 to 40 min each) for 12 wk, then biweekly during the last period of school. Plus received snack bars for a daily afternoon school snack and a cereal for breakfast. Parent attended monthly meetings.</td>
<td>(1) 88% (2) 95%</td>
<td>BMI and % body fat (BIA) BMI: Yes (2&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>
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</tr>
<tr>
<td>Weigel 2008, Community, Germany</td>
<td>N = 73</td>
<td>Age, y = 7 to 15</td>
<td>Selection Criteria</td>
<td>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</td>
<td>(1) Written dietary advice: DA (2) Group sessions: DA, PA, BM</td>
<td>DA: Yes (2.176)</td>
</tr>
</tbody>
</table>

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. We 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.
<table>
<thead>
<tr>
<th>Study Program Name (When Applicable), Setting, Country</th>
<th>Participants</th>
<th>Intervention</th>
<th>Retention Ratec</th>
<th>Weight-Related Outcome Reported</th>
<th>Significance Difference Between Groupsd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estabrooks 2009,47 Primary care, USA</td>
<td>220 F+M</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: Yes (3 &gt; 2)</td>
<td>BMI z-score Yes (3 &gt; 1, &gt; 2)</td>
</tr>
<tr>
<td>Resnick 2009,50,e CHEER Program, School, USA</td>
<td>46 families F+M</td>
<td>(1) Written materials; (2) Written materials + home visit or phone call by the community health workers</td>
<td>(1) 100%; (2) 86%</td>
<td>BMI percentile: No: both groups lost weight</td>
<td>BMI percentile: No: both groups lost weight</td>
</tr>
</tbody>
</table>

- F, female; M, male; BW, body weight; DA, dietary advice; PA, physical activity; BM, behavioral modification; kcal, kilocalorie; CBT, cognitive behavior therapy; NR, not reported; SI, sedentary behavior; DXA, dual-energy x-ray absorptiometry; CDC, Centers for Disease Control and Prevention; IOTF, International Obesity Taskforce; WC, waist circumference; PS, parenting skill; BIA, bioelectrical impedance analysis; Project STORY, Project sensible treatment of obesity in rural youth; SCOTT, Scottish Childhood Overweight Treatment Trial; WHO, World Health Organization; CHEER Program, Communicating about Health, Exercising, and Eating Right Program.

- Number of participants at randomization.
- 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.
- Retention rates reported post intervention if no follow-up, or at latest point of follow-up.
- 2 indicates group 2 had a greater reduction than group 1 (P < .05).
- e Not included in the meta-analyses.
mean difference $-0.97$, 95% confidence interval (CI) $-1.39$ to $-0.55$ for lifestyle interventions compared with control over 2 years (Supplemental Fig 8). However, the studies were significantly heterogeneous ($I^2 = 90\%$) and the effect size varied by age and length of study. There was no evidence of publication bias or small-study effects with visual inspection of the funnel plot.

We also conducted meta-analyses of 12 studies (899 participants) that reported BMI (Fig 2A) and 7 studies (493 participants) that reported BMI z score (Fig 2B). There was a pooled BMI reduction of 1.25 kg/m$^2$ (95% CI: 0.32–2.18, $I^2 = 98\%$) and a 0.10 BMI z score reduction (95% CI: 0.02–0.18, $I^2 = 0\%$–50%) greater for the lifestyle intervention compared with the control condition.

The short-term study of children with the greatest postintervention effect was a 6-month community-based program (mean BMI difference $= 2.10$ kg/m$^2$) in which parents and children attended eight 2-hour group education and exercise sessions held twice weekly in sports centers and schools, followed by a 12-week free family swimming pass (Table 1). However, the greatest BMI reduction in the studies of adolescents (mean BMI difference $= 4.30$ kg/m$^2$) was in a 2-month community-based intensive exercise training program (4 times per week, 90 minutes each) combined with dietary restriction (500 kcal/d less than the reported baseline energy intake).

### 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/m$^2$ at the end of active intervention (95% CI: 1.03–1.58, $I^2 = 0\%$ to 48%) (Fig 3A). Studies with longer intervention periods (>6 months) showed greater weight loss than 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 (95% CI: $-0.51$ to $-0.30$, $I^2 = 0\%$; study length: 4 to 6 months) showed greater weight loss than shorter term interventions.

### 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/m$^2$ greater reduction in pooled BMI (95% CI: 0.91–5.95, $I^2 = 97\%$) and 0.06 greater reduction in pooled BMI z score (95% CI: 0.02–0.10, $I^2 = 99\%$) 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. Eight of the 11 studies reported blood lipids results; 6 studies reported results of fasting glucose, fasting insulin, or HOMA-IR. Eight studies reported blood lipids results; 6 studies reported results of fasting glucose, fasting insulin, or HOMA-IR. Eight studies reported blood lipids results; 6 studies reported results of fasting glucose, fasting insulin, or HOMA-IR.
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 Mean</th>
<th>SD</th>
<th>Total</th>
<th>Control Mean</th>
<th>SD</th>
<th>Total</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><strong>1.2.1 Children</strong>&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sacher 2010, 6 mo</td>
<td>-1.5</td>
<td>1.18</td>
<td>37</td>
<td>0.6</td>
<td>1.62</td>
<td>45</td>
<td>7.7%</td>
<td>-2.10 [-2.71, -1.49]</td>
<td></td>
</tr>
<tr>
<td>Shelton 2007, 3 mo</td>
<td>-1.6</td>
<td>1.37</td>
<td>28</td>
<td>0.1</td>
<td>1.95</td>
<td>15</td>
<td>7.2%</td>
<td>-1.70 [-2.81, -0.59]</td>
<td></td>
</tr>
<tr>
<td>Reinherz 2010, 6 mo</td>
<td>-0.85</td>
<td>1.02</td>
<td>34</td>
<td>0.75</td>
<td>0.99</td>
<td>32</td>
<td>7.8%</td>
<td>-1.81 [-2.08, -1.13]</td>
<td></td>
</tr>
<tr>
<td>Huang 2007, 4 mo</td>
<td>-1.1</td>
<td>1.3</td>
<td>60</td>
<td>0.4</td>
<td>1.5</td>
<td>60</td>
<td>7.8%</td>
<td>-1.50 [-2.00, -1.00]</td>
<td></td>
</tr>
<tr>
<td>Wake 2009, 12 mo</td>
<td>0.6</td>
<td>1.03</td>
<td>127</td>
<td>0.7</td>
<td>0.84</td>
<td>115</td>
<td>8.9%</td>
<td>-0.10 [-0.24, 0.04]</td>
<td></td>
</tr>
<tr>
<td>McCallum 2007, 15 mo</td>
<td>1.2</td>
<td>1.22</td>
<td>70</td>
<td>0.4</td>
<td>0.89</td>
<td>76</td>
<td>7.9%</td>
<td>0.80 [0.45, 1.15]</td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>356</td>
<td>343</td>
<td>46.5%</td>
<td>-1.00 [-1.91, -0.08]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 1.22; Chi² = 129.39, df = 5 (P < .0001); I² = 98%
Test for overall effect Z = 2.13 (P = 0.03)

**1.2.2 Adolescents**<sup>*</sup>

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Lifestyle intervention Mean</th>
<th>SD</th>
<th>Total</th>
<th>Control Mean</th>
<th>SD</th>
<th>Total</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>Ben Ounis 2010, 2 mo</td>
<td>-3.9</td>
<td>0.46</td>
<td>14</td>
<td>0.4</td>
<td>0.62</td>
<td>14</td>
<td>7.9%</td>
<td>-4.30 [-4.70, -3.90]</td>
<td></td>
</tr>
<tr>
<td>Jiang 2005, 2 y</td>
<td>-2.6</td>
<td>1.6</td>
<td>33</td>
<td>-0.1</td>
<td>1.1</td>
<td>35</td>
<td>7.7%</td>
<td>-2.50 [-3.16, -1.84]</td>
<td></td>
</tr>
<tr>
<td>Tsiros 2008, 5 mo</td>
<td>-1.6</td>
<td>0.28</td>
<td>10</td>
<td>0.3</td>
<td>1.17</td>
<td>8</td>
<td>7.5%</td>
<td>-1.90 [-2.73, -1.01]</td>
<td></td>
</tr>
<tr>
<td>Park 2007, 4 mo</td>
<td>-1.9</td>
<td>0.9</td>
<td>19</td>
<td>-0.1</td>
<td>0.6</td>
<td>21</td>
<td>7.8%</td>
<td>-1.80 [-2.28, -1.32]</td>
<td></td>
</tr>
<tr>
<td>Balagopal 2003, 3 mo</td>
<td>-0.6</td>
<td>0.66</td>
<td>7</td>
<td>0.6</td>
<td>1.37</td>
<td>6</td>
<td>7.2%</td>
<td>-1.20 [-2.27, -0.10]</td>
<td></td>
</tr>
<tr>
<td>Davis 2009, 4 mo, 1 vs 4#</td>
<td>-0.5</td>
<td>0.9</td>
<td>15</td>
<td>-0.5</td>
<td>0.5</td>
<td>4</td>
<td>7.7%</td>
<td>0.00 [-0.67, 0.67]</td>
<td></td>
</tr>
<tr>
<td>Davis 2009, 4 mo, 1 vs 3#</td>
<td>1.1</td>
<td>0.6</td>
<td>9</td>
<td>-0.5</td>
<td>0.5</td>
<td>3</td>
<td>7.7%</td>
<td>1.60 [0.91, 2.29]</td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>107</td>
<td>93</td>
<td>53.5%</td>
<td>-1.45 [-3.02, 0.12]</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Heterogeneity: Tau² = 4.36; Chi² = 266.38, df = 6 (P < .00001); I² = 98%
Test for overall effect Z = 1.81 (P = 0.07)

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 Mean</th>
<th>SD</th>
<th>Total</th>
<th>Control Mean</th>
<th>SD</th>
<th>Total</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><strong>1.3.1 Children</strong>&lt;sup&gt;*&lt;/sup&gt; (study length: 6 months or less)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reinherz 2010, 6 mo</td>
<td>-0.26</td>
<td>0.22</td>
<td>34</td>
<td>0.05</td>
<td>0.19</td>
<td>32</td>
<td>11.2%</td>
<td>0.31 [-0.41, -0.20]</td>
<td></td>
</tr>
<tr>
<td>Sacher 2010, 6 mo</td>
<td>-0.3</td>
<td>0.37</td>
<td>37</td>
<td>-0.01</td>
<td>0.47</td>
<td>45</td>
<td>8.0%</td>
<td>-0.29 [-0.47, -0.11]</td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>71</td>
<td>77</td>
<td>19.3%</td>
<td>0.31 [-0.39, -0.22]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.00; Chi² = 0.04, df = 1 (P = 0.95); I² = 0%
Test for overall effect Z = 6.88 (P < .00001)

**1.3.2 Children**<sup>*</sup> (study length: longer than 6 months)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Lifestyle intervention Mean</th>
<th>SD</th>
<th>Total</th>
<th>Control Mean</th>
<th>SD</th>
<th>Total</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>Jancke 2008, 10 mo, 1 vs 2#</td>
<td>-0.115</td>
<td>0.22</td>
<td>24</td>
<td>0.022</td>
<td>0.17</td>
<td>10</td>
<td>9.7%</td>
<td>-0.21 [-0.27, 0.00]</td>
<td></td>
</tr>
<tr>
<td>Jancke 2008, 10 mo, 1 vs 3#</td>
<td>-0.091</td>
<td>0.2</td>
<td>26</td>
<td>0.022</td>
<td>0.17</td>
<td>11</td>
<td>10.2%</td>
<td>-0.11 [-0.24, 0.01]</td>
<td></td>
</tr>
<tr>
<td>Golley 2007, 12 mo, 1 vs 3#</td>
<td>-0.24</td>
<td>0.43</td>
<td>31</td>
<td>-0.13</td>
<td>0.4</td>
<td>31</td>
<td>7.2%</td>
<td>-0.11 [-0.32, 0.00]</td>
<td></td>
</tr>
<tr>
<td>McCallum 2007, 15 mo</td>
<td>0</td>
<td>0.46</td>
<td>70</td>
<td>0.02</td>
<td>0.41</td>
<td>76</td>
<td>9.6%</td>
<td>0.02 [-0.18, -0.02]</td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>151</td>
<td>128</td>
<td>36.6%</td>
<td>-0.09 [-0.17, -0.02]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.00; Chi² = 1.53, df = 3 (P = 0.87); I² = 0%
Test for overall effect Z = 2.55 (P = 0.01)

**1.3.3 Adolescents**<sup>*</sup> (study length: 6 months or less)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Lifestyle intervention Mean</th>
<th>SD</th>
<th>Total</th>
<th>Control Mean</th>
<th>SD</th>
<th>Total</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>Kitzman-Ulrich 2009, 1 vs 2#</td>
<td>-0.05</td>
<td>0.09</td>
<td>15</td>
<td>0</td>
<td>0.08</td>
<td>4</td>
<td>11.6%</td>
<td>-0.05 [-0.14, 0.04]</td>
<td></td>
</tr>
<tr>
<td>Davis 2009, 4 mo, 1 vs 4#</td>
<td>-0.05</td>
<td>0.09</td>
<td>14</td>
<td>0</td>
<td>0.1</td>
<td>4</td>
<td>10.6%</td>
<td>0.00 [-0.11, 0.01]</td>
<td></td>
</tr>
<tr>
<td>Davis 2009, 4 mo, 1 vs 3#</td>
<td>0.00</td>
<td>0.09</td>
<td>9</td>
<td>0</td>
<td>0.09</td>
<td>3</td>
<td>11.0%</td>
<td>0.00 [-0.02, 0.10]</td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>51</td>
<td>44.1%</td>
<td>-0.02 [-0.09, 0.06]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Tau² = 0.00; Chi² = 6.01, df = 3 (P = 0.11); I² = 50%
Test for overall effect Z = 0.46 (P = 0.64)

**Total (95% CI)** | 273 | 220 | 100.0% | -0.10 [-0.18, -0.02] | | | |

Heterogeneity: Tau² = 0.01; Chi² = 38.98, df = 9 (P < .0001); I² = 77%
Test for overall effect Z = 2.44 (P = 0.01)
Test for subgroup differences: Chi² = 25.36, df = 2 (P < .00001); I² = 92.1%

* Children defined as the mean age ≤ 12 years; adolescents as the mean age >12 years

**FIGURE 2**
Meta-analysis of studies comparing lifestyle intervention with no-treatment or wait-list controls.
months) \(^{26,31,49}\) 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 (95% CI: \(-0.35\) to \(-0.05\), \(I^2 = 59\%\)) favoring lifestyle intervention (Fig 5A).

**Low-Density Lipoprotein and High-Density Lipoprotein Cholesterol**

Meta-analysis of 4 studies including 372 participants 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).

**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 $2.32 \, (95\% \text{ CI: } 2.25 \text{ to } 2.19)$ in favor of lifestyle intervention over 1 year; however, the heterogeneity was high ($I^2 = 79\%$) (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 $= 1.69 \, \text{mm Hg}$, $95\% \text{ CI: } -3.15 \text{ to } -0.24$, $I^2 = 26\%$, study length: 6 months or less) but 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 1 year or more (WMD $= 3.72 \, \text{mm Hg}$, $95\% \text{ CI: } -4.74 \text{ to } -2.69$, $I^2 = 0\%$) (Fig 7B). Five studies were not included in the meta-analyses, as they reported the absolute values only at baseline and follow-up. These studies reported a similar trend as those included in the meta-analyses.

The study that achieved the greatest improvement across all cardio-metabolic outcome measures, including blood lipids, fasting glucose and insulin, HOMA-IR, and blood pressure, was a 12-week intensive school-based lifestyle intervention program targeting 10- to 13-year-old obese students. The participants received 30-minutes of nutrition instruction twice per week at school plus 40-minutes of classroom-based non-competitive aerobic activity 3 times per week. The mean BMI and body fat percentage difference between the intervention group and the no-treatment control at the end of active intervention was $-1.5 \, \text{kg/m}^2$ and $-1.2\%$ respectively.

### 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 Measurement</th>
<th>Anthropometric/Body Composition</th>
<th>Metabolic</th>
<th>SBP</th>
<th>DBP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BMI</td>
<td>BMI z Score</td>
<td>Body Fat %</td>
<td>Waist Circumference</td>
</tr>
<tr>
<td>Lifestyle intervention compared with no-treatment or wait-list control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Becque 1988&lt;sup&gt;63&lt;/sup&gt;</td>
<td>20 wk</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Rocchini 1988&lt;sup&gt;68&lt;/sup&gt;</td>
<td>20 wk</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Balagopal 2003&lt;sup&gt;22&lt;/sup&gt;</td>
<td>3 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Jiang 2005&lt;sup&gt;20&lt;/sup&gt;</td>
<td>24 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Huang 2007&lt;sup&gt;26&lt;/sup&gt;</td>
<td>12 wk</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Park 2007&lt;sup&gt;21&lt;/sup&gt;</td>
<td>12 wk</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Davis 2009&lt;sup&gt;24&lt;/sup&gt;</td>
<td>16 wk</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Reinehr 2010&lt;sup&gt;12&lt;/sup&gt;</td>
<td>6 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Sacher 2010&lt;sup&gt;14&lt;/sup&gt;</td>
<td>6 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Lifestyle intervention compared with usual care</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nemet 2005&lt;sup&gt;43&lt;/sup&gt;</td>
<td>3 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Nemet 2005&lt;sup&gt;43&lt;/sup&gt;</td>
<td>12 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Gillis 2005&lt;sup&gt;20&lt;/sup&gt;</td>
<td>6 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Savoye 2007&lt;sup&gt;46&lt;/sup&gt;</td>
<td>6 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Savoye 2007&lt;sup&gt;46&lt;/sup&gt;</td>
<td>12 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Kalarchian 2008&lt;sup&gt;41&lt;/sup&gt;</td>
<td>6 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Kalarchian 2008&lt;sup&gt;41&lt;/sup&gt;</td>
<td>12 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Lifestyle intervention compared with written education materials only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Johnston 2007&lt;sup&gt;49&lt;/sup&gt;</td>
<td>6 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>Weigel 2008&lt;sup&gt;51&lt;/sup&gt;</td>
<td>12 mo</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
</tbody>
</table>

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

<sup>a</sup> Counted from baseline.

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

<sup>c</sup> Findings reported in graph.

<sup>d</sup> Body fat % measured by hydrostatic weighting.

<sup>e</sup> Body fat % measured by dual-energy x-ray absorptiometry.

<sup>f</sup> Body fat % measured by bio-impedance analyzer.

<sup>g</sup> Body fat % determined by deuterium dilution.

<sup>h</sup> Body fat % determined by skin folds.

<sup>i</sup> 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. 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), LDL cholesterol, fewer than half demonstrated significant improvements in triglycerides or HDL cholesterol. 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
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. 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.

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.

Exercise Intervention

Another frequent feature of effective studies is involvement of a structured exercise training component. 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.

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, in the absence of longer-term cardiovascular morbidity data.
of lifestyle interventions, but also to determine what magnitude of weight reduction in the pediatric population is compatible with clinically significant benefits. Further, cost-effectiveness analyses need to be conducted.

ACKNOWLEDGMENT

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Effectiveness of Lifestyle Interventions in Child Obesity: Systematic Review With Meta-analysis
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Pediatrics 2012;130;e1647
DOI: 10.1542/peds.2012-1176 originally published online November 19, 2012;

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