



## REVIEW ARTICLE

# Overview of meta-analysis on prevention and treatment of childhood obesity<sup>☆</sup>



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## KEYWORDS

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## Abstract

**Objectives:** This study aimed to assess the quality of systematic reviews on prevention and non-pharmacological treatment of overweight and obesity in children and adolescents.

**Data source:** A search was done in electronic databases (Medline via PubMed, Web of Science, Scopus, LILACS, the Cochrane Library, and Clinical Trials), including only systematic reviews with meta-analysis. Reviews were selected by two researchers, and a third one solved the divergences. PRISMA statement and checklist were followed.

**Summary of data:** A total of 4574 records were retrieved, including 24 after selection. Six reviews were on obesity prevention, 17 on obesity treatment, and one on mixed interventions for prevention and treatment of obesity. The interventions were very heterogeneous and showed little or no effects on weight or body mass index. Mixed interventions that included dieting, exercise, actions to reduce sedentary behavior, and programs involving the school or families showed some short-term positive effects. Reviews that analyzed cardiovascular risk factors demonstrated significant improvements in the short-term.

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**PALAVRAS-CHAVE**

Criança;  
Adolescente;  
Obesidade

**Conclusion:** The systematic reviews of interventions to prevent or reduce obesity in children and adolescents generally showed little or no effects on weight or body mass index, although cardiovascular profile can be improved. Mixed interventions demonstrated better effects, but the long-term impact of obesity treatments of children and adolescents remains unclear.

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**Visão geral das meta-análises sobre prevenção e tratamento da obesidade infantil****Resumo**

**Objetivos:** Este estudo teve como objetivo avaliar a qualidade das revisões sistemáticas sobre prevenção e tratamento não farmacológico do sobrepeso e da obesidade em crianças e adolescentes.

**Fontes de dados:** Foi realizada uma busca em bases de dados eletrônicas (Medline via Pubmed, Web of Science, Scopus, LILACS, The Cochrane Library e Ensaios Clínicos), incluindo apenas revisões sistemáticas com meta-análise. As revisões foram selecionadas por dois pesquisadores e um terceiro resolveu as divergências. A lista de recomendações do PRISMA foi seguida.

**Síntese dos dados:** Foram identificados 4.574 publicações, e 24 foram incluídas após a seleção. Seis publicações eram sobre prevenção da obesidade, 17 sobre tratamento da obesidade e 1 sobre intervenções mistas para prevenção e tratamento da obesidade. As intervenções eram muito heterogêneas e mostraram pouco ou nenhum efeito sobre o peso ou índice de massa corporal. Intervenções mistas que incluíam dieta, exercícios, ações para reduzir o comportamento sedentário e programas que envolviam a escola ou as famílias mostraram alguns efeitos positivos de curto prazo. Revisões que analisaram fatores de risco cardiovascular demonstraram melhoras significativas em curto prazo.

**Conclusão:** As revisões sistemáticas de intervenções para prevenir ou reduzir a obesidade em crianças e adolescentes geralmente mostraram pouco ou nenhum efeito sobre o peso ou índice de massa corporal, embora o perfil cardiovascular possa ter melhorado. Intervenções mistas demonstraram melhores efeitos, mas o impacto em longo prazo dos tratamentos da obesidade de crianças e adolescentes ainda não está claro.

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**Introduction**

Obesity is now responsible for about 5% of all deaths worldwide.<sup>1</sup> If its prevalence continues on its current trajectory, almost half of the world's adult population will be overweight or obese by 2030.<sup>1</sup> Obesity is one of the top three global social burdens generated by human beings, along with smoking and armed violence,<sup>2</sup> and has huge personal, social, and economic costs for society and all healthcare systems.<sup>3</sup> The prevalence of childhood overweight and obesity has increased substantially worldwide in less than one generation. Some low- and middle-income countries have reported similar or more rapid rises in childhood obesity than high-income countries, despite continuing high levels of undernutrition.<sup>4-6</sup>

The global age-standardized prevalence of obesity increased from 0.7% in 1975 to 5.6% in 2016 in girls, and from 0.9% in 1975 to 7.8% in 2016 in boys.<sup>7</sup> This increasing prevalence of childhood obesity is associated with an increased incidence of cardiovascular risk factors, adult obesity, and obesity-related comorbidities.<sup>8,9</sup> There is an urgent need to identify effective preventive and therapeutic interventions that can be targeted at children,

families, the entire population, and in the obesogenic environment.<sup>10</sup>

In order to clarify the available scientific evidence regarding prevention and treatment of obesity in children and adolescents, the authors conducted a quality assessment of all systematic reviews with meta-analysis published so far and summarized the results.

**Methods****Search strategy**

The search was performed in the following electronic databases: Medline via PubMed, Web of Science, Scopus, LILACS, The Cochrane Library, and Clinical Trials.

The selection of the descriptors used was made through MeSH consultation (PubMed's Medical Subject Headings). The search was performed in English, until October 26th 2017, and three blocks of concepts were used: the first, with terms related to obesity and to non-pharmacological treatments for obesity; the second, with terms related to the type of the study design (trial, random\*); and the third, terms related to the age group of interest (adolescent\*, child\*,

preschool\*, school\*; [Supplementary Table S1](#)). The search was not restricted by date or sample size.

The standardized PICO statement is showed below:

- P – Obesity or overweight, children and adolescents
- I – Any intervention, except pharmacological treatment
- C – No intervention
- O – Body mass index (BMI), weight, waist circumference, and cardiovascular risk factors

### Eligibility criteria and data extraction

The criteria for the inclusion of articles were as follows: (a) studies evaluating non-pharmacological interventions for weight loss or prevention of obesity in children or adolescents with overweight or overweight/obesity (b) systematic review with meta-analysis. The exclusion criteria were studies that did not perform a meta-analysis of the results. The articles were selected by two reviewers (GAA and LAB), initially based on reading of the title, then on reading of the abstracts, and subsequently the full articles. In case of disagreement between the two reviewers, a third reviewer had the final decision on inclusion (LB). The bibliographic references of the studies found in these databases were also reviewed.

The authors followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement and checklist for reporting this systematic review.<sup>11</sup>

### Quality and risk-of-bias assessment

The Measurement Tool to Assess Systematic Reviews (AMSTAR 2) was used in order to evaluate quality of the evidence, as it has been widely accepted and utilized by professional health care institutions, and is well known for its reliability and reproducibility ([Supplementary Table S2](#)).<sup>12</sup> AMSTAR 2 consists of 16 items in a total and assess the degree of confidence in the results of systematic reviews. The tool

does not generate a quality score, but a recommendation of a higher or lower confidence level in the results.

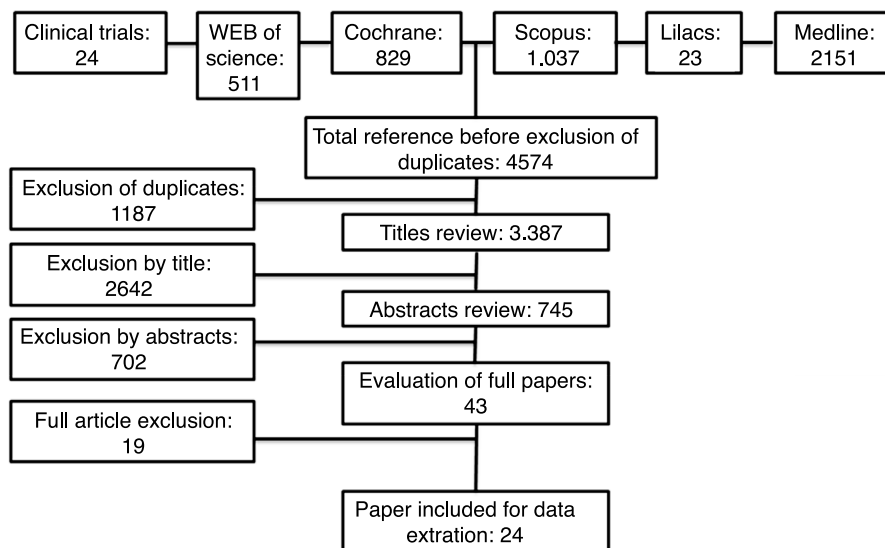
The articles were evaluated by two reviewers (CWS and KS); in case of disagreement between the two reviewers, a third reviewer had the final decision (LB).

### Results

Overall, 4574 records were retrieved; after exclusion of duplicates and non-eligible titles, 24 systematic reviews were included. Six reviews did not meta-analyze their results and were therefore excluded.<sup>13-18</sup> A detailed flowchart of study selection process is presented in [Fig. 1](#). The reviews were classified based on the preventive or treatment approach and the results were presented considering this classification.

The main characteristics of the 24 included studies are described in [Tables 1–5](#). Only four (16.7%) studies were classified as high quality review, almost 80% ( $n = 19$ ) of studies included were considered as critically low quality review ( $n = 7$ ) or low quality review ( $n = 12$ ). The AMSTAR 2 answers for each study are available as a supplement ([Supplementary Table S2](#)).

From the 24 reviews, six of them were on obesity prevention, 17 were on obesity treatment, and one review included mixed interventions for prevention and treatment of obesity ([Table 1](#)). Eleven (46%) of the included studies had been published in the last five years. The majority of reviews included children and adolescents until the age of 18; five (21%) considered only children. Intervention type and settings were highly diverse among reviews, and length of intervention varied from 2.5 to 72 months. The outcomes described were weight, BMI, BMI Z-score, fat content, fat distribution, anthropometric measures (waist circumference, waist-to-hip ratio, triceps skin-fold thickness, and subscapular skin-fold thickness), dietary behavior, sedentary behavior, physical activity behavior, and cardiovascular risk factors (blood pressure, lipids, and glucose).



**Figure 1** Flowchart of study selection.

**Table 1** Characteristics of all included reviews.

Author/data	Date assessed as up to	Population	Interventions	Comparison interventions	Outcomes
O-Meara et al., 1998 <sup>18</sup>	Jan 1997	Children and adults <sup>a</sup>	Dietary, behavioral and exercises interventions.	No intervention	Weight, fat content, and fat distribution
Snethen et al., 2006 <sup>42</sup>	1980 to 2002	Overweight/obesity (6–16 y)	Any intervention with activity, instruction, training or program implemented for the purpose of assisting the overweight child to lose weight	No intervention or waiting list control	Weight
Atlantis et al., 2006 <sup>14</sup>	2004	Overweight/obese (<18 y)	At least one exercise or physical activity treatment arm was investigated either in isolation or as an adjunct to an alternative treatment simultaneously prescribed to the control/comparison group (e.g., exercise plus caloric intake of 1000 kcal/days vs, caloric intake of 1000 kcal/days).	No exercise	Percent body fat, body weight, central obesity, waist girths
Collins et al., 2006 <sup>26</sup>	1975 to 2003	Overweight/obese (<18 y)	Dietary intervention alone or in combination with lifestyle modifications and/or psychological therapies	No intervention	Weight
Young et al., 2007 <sup>34</sup>	NA	Obese (5–12 y)	Behavioral or cognitive-behavioral techniques with family involvement	No intervention	Percent overweight, weight, and BMI or BMI Z-score
McGovern et al., 2008 <sup>40</sup>	Feb 2006	Overweight/obese (2–18 y)	Pharmacological (sibutramine, orlistat, metformin), dietary intervention only, physical activity intervention only, dietary intervention and physical activity intervention.	No intervention	BMI, percent overweight, percent fat-free mass, and visceral adiposity
Kamath et al., 2008 <sup>20</sup>	Feb 2006	Children and adolescents (2–18 y)	Increase physical activity or decrease sedentary activity or increase healthy dietary behavior or reduce unhealthy dietary behavior	No intervention	Dietary behavior and BMI
Katz et al., 2008 <sup>21</sup>	1966 to Oct 2004	Overweight/obese (3–18 y)	Nutrition and physical activity intervention	No intervention	BMI
Harris et al., 2009 <sup>36</sup>	Jan 1966 to Sept 2008	Eutrophic, overweight and obese (5–18 y)	School-based physical activity	No intervention	BMI and anthropometric measures (percent body fat, waist circumference, waist-to-hip ratio, triceps skin-fold thickness, and subscapular skin-fold thickness)
Kanekar et al., 2008 <sup>41</sup>	2000 to 2007	Overweight/obese (<18 y)	School-based childhood obesity interventions	No intervention or usual school activity or writing materials	BMI
Kesten et al., 2011 <sup>22</sup>	1990 to Feb 2010	Overweight/obese girls (7–11 y)	Physical activity, diet or lifestyle modification within the school, family or community setting	No intervention	BMI, physical activity, and nutrition behavior
Luckner et al., 2012 <sup>23</sup>	Nov 2008	Overweight (≤18 y)	Physical activity, education, nutrition or reduction of TV viewing	No intervention	BMI
Lavelle et al., 2012 <sup>31</sup>	Feb 2011	Overweight/obese (≤18 y)	Physical activity and/or nutrition and/or sedentary behavior in school setting	No intervention	BMI

Table 1 (Continued)

Author/data	Date assessed as up to	Population	Interventions	Comparison interventions	Outcomes
Friedrich et al., 2012 <sup>28</sup>	1998 to Aug 2010	Children and adolescents (4–19 y) <sup>a</sup>	Physical activity and/or nutrition education	No intervention	BMI
Ho et al., 2012 <sup>30</sup>	1975 to 2010	Overweight/obese ( $\leq 18$ y)	Lifestyle intervention programs incorporating a nutrition or dietary component	No treatment or wait-list control, usual care, or minimal advice or written diet and physical activity education materials	BMI, BMI Z-score, lipids, glucose, insulin, and blood pressure
Sbruzzi et al., 2013 <sup>24</sup>	May 2012	Eutrophic, overweight or obese (6–12 y)	Educational interventions (intervention strategy performed in the school and/or family) during at least 6 months	Usual care or no intervention for prevention or treatment of childhood obesity	BMI, BMI Z-score, weight, waist circumference (cm), blood pressure, total cholesterol, and high-density lipoprotein cholesterol
Ho et al., 2013 <sup>37</sup>	1975 to 2010	Overweight/obese ( $\leq 18$ y)	Dietary intervention programs, diet plus exercise or an exercise-only intervention	Diet-only vs diet plus exercise intervention; diet-only vs exercise-only intervention	BMI, body fat percentage, lean body mass, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, triglycerides, glucose, and insulin
Ajie et al., 2014 <sup>13</sup>	Jan 2002 to Aug 2013	Adolescents (12–18 y) <sup>a</sup>	Internet-based education or behavioral intervention via a stationary or laptop computer	No intervention	Diet composition, nutrition knowledge, BMI, BMI Z-score, weight, and sedentary behavior
Gow et al., 2014 <sup>29</sup>	1975 to 2013	Overweight/obese ( $\leq 18$ y)	Dietary interventions of varying macronutrient content	Low carbohydrate diet vs low fat diet; Increased protein diet vs standard protein diet; increased fat diet vs standard fat diet	BMI, BMI Z-score
van Hoek et al., 2014 <sup>33</sup>	April 15, 2012	Overweight/obese (3–8 y)	Multicomponent treatment program, including dietary and physical activity education and behavioral therapy or treatment programs with combined dietary and physical activity education only	Some studies with control groups (no intervention) and others without control groups	BMI Z-score
Kelishadi et al., 2014 <sup>16</sup>	2000 to 2012	Overweight/obese (2–18 y)	Community, family, school, and clinic interventions or a combination of them	No intervention	Weight, BMI, BMI Z-score
Liao et al., 2014 <sup>38</sup>	July 2012	Eutrophic, overweight or obese ( $\leq 18$ y)	Reduce sedentary behavior (reduce TV/DVD/VCR, playing sedentary video/computer games, and sitting time in genera) and/or increase physical activity and/or improving dietary habits	Control: some non-obesity prevention-related information; usual-programming; assessment-only	BMI

Table 1 (Continued)

Author/data	Date assessed as up to	Population	Interventions	Comparison interventions	Outcomes
Martin et al., 2014 <sup>39</sup>	May 2013	Overweight/obese (3–18 y)	Lifestyle interventions	Standard care, waiting list control, no treatment or attention control	School achievement, BMI, BMI Z-scores, BMI-SDs, and measures of body fatness by DXA and BIA
Ruotsalainen et al., 2015 <sup>32</sup>	Jan 1950 to Aug 2013	Overweight/obesity ( $\leq$ 18 y)	Physical activity or exercise along with counseling or dietary practices	Control with standard care - no treatment related to physical activity	Physical activity level, BMI, or psychological symptoms
Hung et al., 2015 <sup>19</sup>	NA	Children and adolescents (6–18 y) <sup>a</sup>	School-based childhood obesity prevention programs (nutrition component and/or physical activity component and/or parental involvement and/or specialist involvement)	NA	BMI and skinfold thickness
Foster et al., 2015 <sup>15</sup>	July 1948 to July 2014	Overweight/obese (0–6y)	Diet advice, physical activities, behavioral management, and a motivational interview	Educational sessions	BMI, BMI percentile, or some iteration of percentage, overweight, or obese using height, weight, and waist circumference
Ling et al., 2016 <sup>17</sup>	1966 to Feb 2015	Preschool children (2–5 y) <sup>a</sup>	Lifestyle intervention (any intervention that aimed to improve behaviors, including screen time, sedentary activity, physical activity, diet, and/or sleep)	30-min structured physical activity per day; usual care; wait-list	BMI, waist circumference, skinfold, body fat
Colquitt et al., 2016 <sup>27</sup>	Mar 2015	Overweight/obesity (0–6 y)	Diet, physical activity, and behavioral interventions	No intervention or usual care	BMI, BMI Z-score
Murray et al., 2017 <sup>35</sup>	Dec 2014	Overweight/obese (10–19 y)	Multicomponent weight management interventions (behavioral, dietary, and physical activity components)	No treatment control	Self esteem and BMI Z-score
Kim et al., 2017 <sup>25</sup>	April 2015	Children and adolescents (6–18 y)	Sport-based intervention	Control	Weight

BMI, body mass index; DXA, dual-energy X-ray absorptiometry; BIA, bioelectrical impedance analysis.

<sup>a</sup> No information about the nutritional status at baseline.

**Table 2** Results of reviews on prevention of obesity (standardized mean difference).

Prevention studies	Intervention duration (months)	Participants (age/number)	Number of studies included	Results			
				BMI SMD (95% CI)	BMI Z-score SMD (95% CI)	Weight SMD (95% CI)	BMI Percentile
<b>Kamath et al., 2008<sup>20</sup></b>	≥6	2–18 y (NA)	34				
Physical activity				0.01 (–0.06; 0.08)			
Diet				–0.04 (–0.16; 0.08)			
Combined lifestyle				–0.03 (–0.07; 0.01)			
<b>Katz et al., 2008<sup>21</sup></b>	NA	3–18 y (13,029)	8				
Control group						–0.29 (–0.45; –0.14)	
Nutritional education vs. control						–0.39	
TV reduction vs. control						–0.35	
Physical activity vs. control						1.87	
Family involvement + nutritional education + physical activity vs. control						–0.20 (–0.41; 0.00)	
Family involvement + environmental component + nutritional education + physical activity vs. control						–0.16 (–0.32; 0.00)	
Girls only: physical activity vs. control						–0.38 (–0.74; –0.02)	
Girls only: nutritional education + physical activity vs. control						–0.53 (–1.37; 0.30)	
Boys only: nutritional education + physical activity vs. control						–0.22 (–0.32; –0.12)	
Girls only: physical activity vs. nutritional education + physical activity						–0.53 (–1.37; 0.30)	
Boys only: physical activity vs. nutritional education + physical activity						–0.14 (–0.17; 0.44)	
<b>Luckner et al., 2012<sup>23</sup></b>	NA	0–18 y (NA)	68				
Physical activity				–0.15 (–0.33; –0.03)		–0.7 (–1.05; –0.31)	
Education				–0.15 (–0.24; –0.07)		0.13 (–0.04; 0.3)	
Nutrition				–0.14 (–0.55; –0.27)			
Physical activity + education				–0.19 (–0.37; –0.02)		–1.07 (–2.27; 0.13)	
Physical activity + education + nutrition				–0.1 (–0.77; –0.04)		0.78 (–0.29; 1.86)	
Reduced sedentary behavior				–0.27 (–0.4; –0.13)		0.08 (–0.68; 0.84)	
<b>Sbruzzi et al., 2013<sup>24</sup></b>	≥6	6–12 y (23,617)	8				
Educational intervention vs. usual care or no intervention				–0.86 (–1.59; –0.14)	–0.06 (–0.16; 0.03)		

Data are expressed as standardized mean difference.

NA, not available.

Kamath et al.<sup>20</sup>: Combined lifestyle interventions = interventions that include dietary changes and physical activity interventions.

Luckner et al.<sup>23</sup>: Physical activity = regular exercise; Education = information or teaching on either general healthy behavior or specifically related to nutrition, physical activity or sedentary behavior; Nutrition = intervention consisted of a change in at least one major daily meal; Reduced sedentary behavior = aimed at reducing TV viewing (TV) regardless of other components involved.

**Table 3** Results of reviews on prevention of obesity (effect size).

Prevention studies	Intervention duration (months)	Participants (age/number)	Number of studies included	Outcomes/results
<b>Kesten et al., 2011<sup>22</sup></b> Physical activity, diet or lifestyle modification within the school, family or community setting with a qualitative, quantitative or mixed methods approach	3	7–11 y (NA) Girls	30	Physical activity, nutrition, knowledge and attitudes, physical measures (BMI, weight)  Effect sizes ranged from 0.01 to 1.45  66 less than 0.2, 56 low (0.2), 16 medium (0.5) and two high (0.8) <sup>a</sup>
<b>Hung et al., 2015<sup>19</sup></b> School-based childhood obesity prevention programs	<12 or ≥12	6–18 y (26,114)	27	BMI Summary effect size: 0.039 (95% CI: –0.013 to 0.092, <i>p</i> =0.145)
<b>Kim et al., 2017<sup>25</sup></b> Sport-based physical activity intervention on body weight in children and adolescents	<3; 3–6; or >6	6–18 y (1777)	18	Body weight Effect sizes: 0.52 (95% CI: 0.08 to 0.95, <i>p</i> =0.021)

Data is expressed as effect size.

NA, not available; CI, confidence interval; BMI, body mass index.

<sup>a</sup> Majority of results failed to produce medium to large effect sizes.

## Obesity prevention

Seven systematic reviews with meta-analysis addressed the interventions for childhood and adolescent obesity prevention.<sup>19–25</sup> The main results are presented in [Tables 2 and 3](#). The number of studies included in each review ranged from eight to 68. Two of these reviews were based on educational programs,<sup>19,24</sup> one in sport-based physical activity intervention,<sup>25</sup> and the other four offered mixed interventions for prevention, including nutrition changes, physical activity stimulation, and sedentary behavior reduction.<sup>20–23</sup>

Three reviews addressing lifestyle behavior changes (nutrition, physical activity, or both),<sup>20</sup> educational interventions,<sup>24</sup> and school-based childhood obesity prevention programs<sup>19</sup> did not show any significant effect on BMI when compared with control. However, three other reviews<sup>21–23</sup> showed that these interventions produced significant but modest short-term weight reduction: two showed these results for nutritional education, TV watching reduction, and physical activity (alone or in combination with a parent or family involvement),<sup>21,23</sup> and one showed positive results for physical activity, diet, or lifestyle modification within the school, family, or community setting.<sup>22</sup>

## Obesity treatment

Eighteen systematic reviews with meta-analysis addressed the interventions for childhood and adolescent obesity treatment. The main results are presented in [Tables 4 and 5](#). The number of studies included in each review ranged between five and 61. Of these reviews, ten<sup>26–35</sup> have shown that interventions such as diet, family behavior, physical activity promotion, supervised exercise, lifestyle or

multicomponent intervention, school-based education, and low-carbohydrate diet<sup>26–34</sup> were associated with reduction in the main outcomes. However, 11 studies<sup>24,28,29,32,33,36–40</sup> did not observe an association between the interventions (dietary intervention, physical activity promotion, resistance training, reduced sedentary behavior, lifestyle or educational intervention, nutritional education, and increased-protein diet) and reduction in the main outcomes.

The interventions were based on nutritional changes, physical activity stimulation, sedentary behavior reduction, and educational interventions, alone or in combination, as follows.

### Reviews that included mixed interventions for obesity treatment

In their study, van Hoek et al.<sup>33</sup> showed significant improvement in BMI Z-score with multi-component intervention associated with decreased cardiovascular risk factors and insulin resistance in children. In turn, Liao et al.<sup>38</sup> failed to demonstrate that multi-component interventions were more effective in BMI reduction than sedentary behavior-only interventions.

Friedrich et al.<sup>28</sup> showed that only the interventions that combined physical activity and nutritional education had positive effects on BMI reduction when compared with interventions applied separately.

Kanekar et al.<sup>41</sup> analyzed only studies performed in the United States and in the United Kingdom, and showed that school-based interventions were not associated with BMI changes.

Snethen et al.<sup>42</sup> examined the effectiveness of 14 different combination of interventions (dietary, physical activity, behavioral change, and parental involvement) and showed that the effect size for weight loss was small. However, longer intervention programs produced better results.



**Table 4** Results of reviews on treatment of obesity (standardized mean difference).

Treatment studies	Intervention duration (months)	Participants (age/number)	Number of studies included	Results			
				BMI SMD (95% CI)	BMI Z-score SMD (95% CI)	Weight SMD (95% CI)	BMI Percentile
<b>Collins et al., 2006<sup>26</sup></b> Dietary intervention vs. control	NA	≤18 y (2262)	8			-1.82 (-2.40; -1.23)	
Dietary intervention vs. control at follow-up						-0.64 (-0.89; -0.39)	
<b>Young et al., 2007<sup>34</sup></b> Family behavioral Other treatments Control group	≥2.5	5-12 y (666)	16			-0.62 (-0.79; -0.44)	
<b>McGovern et al., 2008<sup>40</sup></b> Dietary intervention vs. control	NA	2-18 y (NA)	61	-0.22 (-0.56; 0.11)			
Physical activity intervention vs. control				-0.02 (-0.21; 0.18)			
Reduced sedentary behavior vs. control				0.02 (-0.35; 0.39)			
Combined lifestyle interventions vs. control				-0.17 (-0.40; 0.05)			
<b>Harris et al., 2009<sup>36</sup></b> Physical activity vs. control	≥6	5-18 y (18,141)	15	-0.05 (-0.19;0.10)			
<b>Friedrich et al., 2012<sup>28</sup></b> Physical activity Nutritional education Physical activity + nutritional education	≥3	≤19 y (9997)	23	-0.02 (-0.08; 0.04)			
				-0.03 (-0.10; 0.04)			
				-0.37 (-0.63; -0.12)			
<b>Ho et al., 2012<sup>30</sup></b> Lifestyle intervention vs. control (A)	1-24	≤18 y (NA)	32	-1.25 (-2.18; -0.32)	-0.10 (-0.18; -0.02)		
Lifestyle interventions vs. usual care (B)				-1.30 (-1.58; -1.03)			
Lifestyle intervention vs. usual care (C)				-0.92 (-1.31; -0.54)			
Lifestyle intervention vs. written education (B)				-2.52 (-5.95;0.91)	-0.06 (-0.10; -0.02)		

Table 4 (Continued)

Treatment studies	Intervention duration (months)	Participants (age/number)	Number of studies included	Results			
				BMI SMD (95% CI)	BMI Z-score SMD (95% CI)	Weight SMD (95% CI)	BMI Percentile
<b>Lavelle et al., 2012<sup>31</sup></b>	≥6–72	≤18 y (36,579)	43				
School based education vs. control				–0.17 (–0.26; –0.08)			
Girls only: school based education vs. control				–0.28 (–0.50; –0.06)			
Boys only: school based education vs. control				–0.17 (–0.26; –0.08)			
Physical activity promotion in school vs. control				–0.13 (–0.22; –0.44)			
Nutritional education + physical activity promotion in school vs. control				–0.17 (–0.29; –0.08)			
<b>Ho et al., 2013<sup>37</sup></b>	6 weeks–6 m	≤18 y (NA)	12				
Dietary interventions + exercise vs. diet only				–0.24 (–0.62; 0.14)			
Resistance training				0.40 (0.08; 0.71)			
Resistance training + aerobic training				–0.10 (–0.45; 0.26)			
<b>Sbruzzi et al., 2013<sup>24</sup></b>	≥6	6–12 y (23,617)	18	–0.86 (–1.59; –0.14)	–0.06 (–0.16; 0.03)		
Educational interventions vs. usual care or no intervention							
<b>Gow et al., 2014<sup>29</sup></b>	≥2	≤18 y	14				
Low-carbohydrate diet vs. standard low-fat diet (A)				1.46 (–2.48; –0.44)	–0.25 (–0.44; –0.06)		
Low-carbohydrate diet vs. standard low-fat diet (B)				0.57 (–1.44; 2.58)			
Increased-protein diet vs. standard-protein diet (A)				–0.18 (–0.78; 0.42)	–0.01 (–0.06; 0.04)		
Increased-protein diet vs. standard-protein diet (B)					–0.06 (–0.15; 0.02)		

Table 4 (Continued)

Treatment studies	Intervention duration (months)	Participants (age/number)	Number of studies included	Results			
				BMI SMD (95% CI)	BMI Z-score SMD (95% CI)	Weight SMD (95% CI)	BMI Percentile
<b>van Hoek et al., 2014<sup>33</sup></b> Multicomponent intervention very low intensity vs. control Multicomponent intervention moderate or high intensity vs. control Nutritional education combined with either behavioral therapy or physical activity education - very low intensity vs. control Nutritional education very low intensity vs. control Physical activity education high intensity vs. control	≥6	3–8 y (1015)	11		–0.08 (–0.15; 0.02)		
					–0.46 (–0.53; –0.39)		
					–0.31 (–0.51; 0.02)		
					–0.46 (–0.94; 0.02)		
					–0.31 (–0.88; 0.27)		
<b>Liao et al., 2014<sup>38</sup></b> Physical activity vs. control Physical activity + Reduced sedentary behavior Physical activity + Reduced sedentary behavior + diet	NA	≤18 y (NA)	25		–0.15 (–0.35; 0.04)		
					–0.08 (–0.20; 0.02)		
					–0.06 (–0.15; 0.03)		
<b>Martin et al., 2014<sup>39</sup></b> Lifestyle interventions vs. standard care	NA	3–18 y (792)	6		0.03 (–0.15; 0.21)		

Table 4 (Continued)

Treatment studies	Intervention duration (months)	Participants (age/number)	Number of studies included	Results			
				BMI SMD (95% CI)	BMI Z-score SMD (95% CI)	Weight SMD (95% CI)	BMI Percentile
Colquitt et al., 2016 <sup>27</sup> Multicomponent intervention vs. control (A)	6–24	0–6 y (923)	5		–0.26 (–0.37; –0.16)	–1.18 (–1.91; –0.45)	–1.54 (–2.82; –0.26)
					–0.38 (–0.58; –0.19)	–2.81 (–4.39; –1.22)	–3.47 (–5.11; –1.82)
Ruotsalainen et al., 2015 <sup>32</sup> Supervised exercise vs. control Physical activity promotion vs. control Supervised exercise + physical activity promotion vs. control	3–6	12–18 y (NA)	14		–0.36 (–0.64; –0.08)		
					–0.10 (–0.24; 0.04)		
					–0.18 (–0.40; 0.03)		

NA, not available.

Collins et al.<sup>26</sup>: control group received usual care or no intervention.

Young et al.<sup>34</sup>: Family behavioral = use of at least one named behavioral or cognitive-behavioral technique to encourage children to pursue and maintain healthy physical and/or eating habits; Other treatments = behavioral treatments analogous to the family-behavioral groups without the direct involvement of the parents, Control group = not defined.

McGovern et al.<sup>40</sup>: Dietary interventions = reduced-glycemic-load diet, protein-sparing modified diet, low-carbohydrate diet, high-protein diet, and hypocaloric diet; combination lifestyle interventions = physical activity and dietary modification.

Harris et al.<sup>36</sup>: Physical activity: intervention took place during regular class time; Control group = continued with the existing physical education curriculum of school.

Ho et al.<sup>30</sup>: A = at latest point of follow-up, B = at the end of active treatment. C = at follow up. Lifestyle intervention = program incorporating a nutrition or dietary component; control = no treatment; usual care = minimal advice; written education = written diet and physical activity education materials.

Lavelle et al.<sup>31</sup>: School based education = physical activity promotion and/or sedentary behavior reduction and/or nutritional education.

Ho et al.<sup>37</sup>: Dietary interventions = calorie restriction approach, with energy levels ranging from 900 to 1800 kcal/d and with varied macronutrient combinations. Others either used the Traffic Light Diet, aimed at limiting added sugar consumption and increasing dietary fiber intake or provided general dietary advice.

Sbruzzi et al.<sup>24</sup>: Educational intervention = school-based program defined as an intervention strategy performed in the school and/or family based program.

Gow et al.<sup>29</sup>: A = end of intervention; B = 2-year follow up.

Van Hoek et al.<sup>33</sup>: multicomponent intervention = dietary, physical education and behavioral therapy; Intensity of treatment (duration over the course of the intervention period) was categorized as very low (<10 hours), low (10–25 hours), moderate (26–75 hours), or high (>75 hours).

Liao et al.<sup>38</sup>: Sedentary behaviors = watching TV/DVD/VCR, playing sedentary video/computer games and sitting time in general.

Martin et al.<sup>39</sup>: lifestyle intervention (physical activity promotion, sedentary behavior reduction, nutritional education, psychological interventions).

Colquitt et al.<sup>27</sup>: multicomponent intervention (nutritional, physical activity, and behavioral interventions); A = end of intervention (6–12 months); B = 12–18 months follow-up (6–8 months post intervention);

Ruotsalainen et al.<sup>32</sup>: control = standard care.

**Table 5** Results of reviews on treatment of obesity (effect size).

Treatment studies	Intervention duration (months)	Participants (age/number)	Number of studies included	Outcomes/results
Snethen et al., 2006 <sup>42</sup> Some form of the weight-loss intervention: dietary, physical activity, behavioral changes, and parental involvement	NA	6–16 y Overweight/ obese children and adolescents	7	Weight loss In seven studies, there were 14 interventions <sup>a</sup> with effect size $d = 0.95$ (95% CI: 0.79 to 1.11) In four studies, there were seven interventions <sup>a</sup> with effect size $d = 1.70$ (0.74 to 3.33)
Kanekar et al., 2008 <sup>41</sup> School-based childhood obesity interventions <sup>b</sup>	NA	Students	5	BMI reduction Pooled estimate - Effect size: 0.0649 (95% CI: -0.29 to 0.16) Random effects model - Effect size: 0.179 (95% CI: -0.38 to 0.72)
Murray et al., 2017 <sup>35</sup> Multicomponent <sup>c</sup> weight management interventions on self-esteem	2.2 to 6	10–19 y (217) Overweight/ obese adolescents	5	BMI Z-score Effect size: -0.17 (95% CI: -0.22 to -0.11)

NA, not available; BMI, body mass index; CI, confidence interval.

<sup>a</sup> Exercise, nutrition, dietary, and/or a combination of them.

<sup>b</sup> Promoting physical activity, and/or dietary modifications.

<sup>c</sup> Lifestyle, health education, nutrition, physical activity, and/or a combination of them.

### Reviews that included dietary interventions for obesity treatment

Two meta-analyses<sup>26,40</sup> assessed only the effectiveness of dietary interventions on the treatment of obese children and adolescents and demonstrated some effect on weight loss, although details on dietary intervention or participants' food intake were rarely described in studies; therefore, it was not possible to evaluate which particular dietary intervention was the most effective.

One study<sup>29</sup> examined the effectiveness of diets varying in macronutrient distribution as part of a weight management intervention in overweight or obese children and adolescents. An improvement on weight status was achieved regardless of the macronutrient distribution of a reduced-energy diet.

In studies measuring cardio-metabolic outcomes, improvements in blood lipids, blood glucose, insulin resistance, and blood pressure were reported.<sup>29,30</sup>

### Reviews that included physical activity interventions for obesity treatment

Only one meta-analysis assessed the impact of physical activity alone on obesity treatment<sup>36</sup> and failed to demonstrate any effect of exercise alone on body weight, BMI or central obesity. Only a moderate decrease on fat percentage was observed with physical activity intervention.

### Reviews that included educational interventions for obesity treatment

Sbruzzi et al.<sup>24</sup> showed that educational interventions for at least six months were associated with a significant reduction in waist circumference, BMI, and diastolic blood pressure.

## Discussion

The purpose of this review was to help readers of systematic reviews to critically appraise the available scientific information on prevention and non-pharmacological treatment of overweight and obesity in childhood and adolescence. This analysis showed that 19 studies (80%) were of low or very low quality according to the AMSTAR 2 criteria, *i.e.*, the studies have a low degree of confidence in the results. Nevertheless, almost all authors have drawn attention to the heterogeneity of the included studies in their systematic reviews and to the low quality of many primary studies, which compromise their translation into definitive recommendations in any context.

The prevention studies demonstrated small and short-term effects or no effect on body weight.<sup>19–23</sup> Parental involvement and reducing television time were the interventions associated with the greatest benefits.<sup>16,19,22–24,34,38</sup>

Considering the studies focused in treating obesity in childhood and adolescence, the vast majority of them showed no significant effects on weight reduction and maintenance with numerous well-known interventions. Some positive results were reported in short-term and multi-component interventions, but no definitive recommendation can be drawn on the intervention type or duration needed to achieve long-term success. These results are in line with what is already known from the nonpharmacological treatment of obesity in adults.

Despite the small improvement on body weight and adiposity in children observed from increase in physical activity in the reviewed studies,<sup>20,21,28,32,33,36–38,40</sup> structured physical activity programs may lead to other benefits, such as improved coordination skills, skeletal health, flexibility, and

aerobic capacity; greater self-confidence; team participation; and social inclusion. So far, no definitive conclusion can be made on the efficacy of physical activity to prevent or reduce obesity in children and adolescents, but the importance of developing actions and programs to promote active lifestyles should be targeted. Moreover, the practice of regular physical activity, starting early in childhood or adolescence, may prevent sedentary lifestyles in adult life.<sup>43</sup>

Studies evaluating different dietary approaches failed to recognize benefits of a particular type of diet or macronutrients composition,<sup>20,26,27,29,30,37,38,40</sup> perhaps because details on dietary intervention or participant's food intake were rarely described in studies and there was a high heterogeneity of designs and outcome measures.

The current analysis showed many limitations in published reviews so far, such as the heterogeneity of primary studies including the intervention length, parental involvement or not, nutrition targets, physical activity programs, and educational targets, which also makes it hard for a single meta-analysis study to conclude the best intervention.

One challenging aspect for healthy weight promotion strategies is adherence outside schools. Healthy eating is negatively impacted by the food industry through advertisements and other marketing strategies to stimulate consumption of calorie-dense foods and beverages.<sup>44</sup> Technological devices such as videogames and computers attract children to a lifestyle of little physical activity and increased calorie consumption.<sup>45</sup> Interventions have better results when the strategy includes a family component, because children are strongly influenced by their parents' habits.<sup>46</sup> Therefore, recommendations introduced in schools should be followed at home through the positive example of parents for their children, through healthy nutrition and the regular practice of physical activity.<sup>47</sup>

Several factors contribute to obesity, including genetic, environmental, metabolic, biochemical, psychological, and physiological.<sup>23</sup> These complex causal links make it unlikely that any single intervention will be successful for obesity prevention or treatment. Despite the considerable ongoing academic research evaluating preventive and therapeutic approaches to childhood obesity, there is a lack of strong evidence at comprehensive strategies to reverse the alarming obesity trends.

Healthcare professionals, politicians, and several stakeholders will likely need to combine different approaches targeting schools, communities, clinics, worksites, households, urban design, food marketing regulation, and taxation to effectively control the obesity epidemic. There is a growing consensus that large changes in population levels of physical activity and eating behaviors would be needed to control the obesity epidemics, requiring major modifications in built and food environments and policies.<sup>48</sup>

Environmental changes or community-wide multilevel interventions (built environment attributes such as, recreation and transportation purpose) had recently been shown to provide positive effects on physical activity and obesity in children.<sup>49,50</sup> Moreover, racial/ethnic minorities and low-income communities are disadvantaged in access to recreation facilities, positive esthetics, and protection from traffic.<sup>48</sup> Engaging policy makers in the process of modifying the food environment and in evaluating the

costs and benefits of programs and policies designed for these modifications prior to implementation is also very important.<sup>51</sup> Furthermore, regulatory actions in markets should be considered in this context. The authors believe that only when an array of strategies has been aligned with global cooperation, can we reasonably hope to see significant improvements in the obesity scenario.

## Conclusion

The available scientific evidence on the effects of clinical and behavioral interventions to reduce obesity is of low quality, very heterogeneous, and not conclusive. Based on existing evidence, any single component intervention for obesity prevention or treatment of children and adolescents is likely to produce minor and non-durable effects on body weight, adiposity, and cardio-metabolic outcomes. The involvement of all society and government, not just health-care professionals, is necessary to achieve better results in the prevention and treatment of this dangerous epidemic of childhood obesity.

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## Conflicts of interest

The authors declare no conflicts of interest.

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at [doi:10.1016/j.jped.2018.07.009](https://doi.org/10.1016/j.jped.2018.07.009).

## References

1. Kelly T, Yang W, Chen CS, Reynolds K, He J. Global burden of obesity in 2005 and projections to 2030. *Int J Obes (Lond)*. 2008;32:1431–7.
2. World Health Organization (WHO), Department of Health Statistics and Information Systems. WHO methods and data sources for Global Burden of Disease estimates 2000–2011. Geneva: WHO; 2013.
3. Finkelstein EA, Trogon JG, Cohen JW, Dietz W. Annual medical spending attributable to obesity: payer- and service-specific estimates. *Health Aff (Millwood)*. 2009;28, w822–31.
4. Conde WL, Monteiro CA. Nutrition transition and double burden of undernutrition and excess of weight in Brazil. *Am J Clin Nutr*. 2014;100:1617S–22S.
5. Lobstein T, Jackson-Leach R, Moodie ML, Hall KD, Gortmaker SL, Swinburn BA, et al. Child and adolescent obesity: part of a bigger picture. *Lancet*. 2015;385:2510–20.
6. Bloch KV, Klein CH, Szklo M, Kuschnir MC, Abreu GA, Barufaldi LA, et al. ERICA: prevalences of hypertension and obesity in Brazilian adolescents. *Rev Saude Publica*. 2016;50:9s.
7. Ezzati M, Brantham J, Di Cesare M, Bilano V, Bixby H, Zhou B, et al. Worldwide trends in body-mass index, underweight,

- overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. *Lancet*. 2017;390:2627–42.
8. Juonala M, Magnussen CG, Berenson GS, Venn A, Burns TL, Sabin MA, et al. Childhood adiposity, adult adiposity, and cardiovascular risk factors. *N Engl J Med*. 2011;365:1876–85.
  9. Kuschir MC, Bloch KV, Szklo M, Klein CH, Barufaldi LA, Abreu GA, et al. ERICA: prevalence of metabolic syndrome in Brazilian adolescents. *Rev Saude Publica*. 2016;50:11s.
  10. Brownell KD, Kelman JH, Stunkard AJ. Treatment of obese children with and without their mothers: changes in weight and blood pressure. *Pediatrics*. 1983;71:515–23.
  11. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int J Surg*. 2010;8:336–41.
  12. Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, et al. AMSTAR 2 a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ*. 2017;358, j4008.
  13. Ajie WN, Chapman-Novakofski KM. Impact of computer-mediated, obesity-related nutrition education interventions for adolescents: a systematic review. *J Adolesc Health*. 2014;54:631–45.
  14. Atlantis E, Barnes EH, Singh MA. Efficacy of exercise for treating overweight in children and adolescents: a systematic review. *Int J Obes (Lond)*. 2006;30:1027–40.
  15. Foster BA, Farragher J, Parker P, Sosa ET. Treatment interventions for early childhood obesity: a systematic review. *Acad Pediatr*. 2015;15:353–61.
  16. Kelishadi R, Azizi-Soleiman F. Controlling childhood obesity: a systematic review on strategies and challenges. *J Res Med Sci*. 2014;19:993–1008.
  17. Ling J, Robbins LB, Wen F. Interventions to prevent and manage overweight or obesity in preschool children: a systematic review. *Int J Nurs Stud*. 2016;53:270–89.
  18. O'Meara S, Glenny AM, Sheldon T, Melville A, Wilson C. Systematic review of the effectiveness of interventions used in the management of obesity. *J Hum Nutr Diet*. 1998;11:203–6.
  19. Hung LS, Tidwell DK, Hall ME, Lee ML, Briley CA, Hunt BP. A meta-analysis of school-based obesity prevention programs demonstrates limited efficacy of decreasing childhood obesity. *Nutr Res*. 2015;35:229–40.
  20. Kamath CC, Vickers KS, Ehrlich A, McGovern L, Johnson J, Singhal V, et al. Clinical review: behavioral interventions to prevent childhood obesity: a systematic review and meta-analyses of randomized trials. *J Clin Endocrinol Metab*. 2008;93:4606–15.
  21. Katz DL, O'Connell M, Njike VY, Yeh MC, Nawaz H. Strategies for the prevention and control of obesity in the school setting: systematic review and meta-analysis. *Int J Obes (Lond)*. 2008;32:1780–9.
  22. Kesten JM, Griffiths PL, Cameron N. A systematic review to determine the effectiveness of interventions designed to prevent overweight and obesity in pre-adolescent girls. *Obes Rev*. 2011;12:997–1021.
  23. Luckner H, Moss JR, Gericke CA. Effectiveness of interventions to promote healthy weight in general populations of children and adults: a meta-analysis. *Eur J Public Health*. 2012;22:491–7.
  24. Sbruzzi G, Eibel B, Barbiero SM, Petkowicz RO, Ribeiro RA, Cesa CC, et al. Educational interventions in childhood obesity: a systematic review with meta-analysis of randomized clinical trials. *Prev Med*. 2013;56:254–64.
  25. Kim K, Ok G, Jeon S, Kang M, Lee S. Sport-based physical activity intervention on body weight in children and adolescents: a meta-analysis. *J Sports Sci*. 2017;35:369–76.
  26. Collins CE, Warren J, Neve M, McCoy P, Stokes BJ. Measuring effectiveness of dietetic interventions in child obesity: a systematic review of randomized trials. *Arch Pediatr Adolesc Med*. 2006;160:906–22.
  27. Colquitt JL, Loveman E, O'Malley C, Azevedo LB, Mead E, Al-Khudairy L, et al. Diet, physical activity, and behavioural interventions for the treatment of overweight or obesity in preschool children up to the age of 6 years. *Cochrane Database Syst Rev*. 2016:CD012105.
  28. Friedrich RR, Schuch I, Wagner MB. Effect of interventions on the body mass index of school-age students. *Rev Saude Publica*. 2012;46:551–60.
  29. Gow ML, Ho M, Burrows TL, Baur LA, Stewart L, Hutchesson MJ, et al. Impact of dietary macronutrient distribution on BMI and cardiometabolic outcomes in overweight and obese children and adolescents: a systematic review. *Nutr Rev*. 2014;72:453–70.
  30. Ho M, Garnett SP, Baur L, Burrows T, Stewart L, Neve M, et al. Effectiveness of lifestyle interventions in child obesity: systematic review with meta-analysis. *Pediatrics*. 2012;130:e1647–71.
  31. Lavelle HV, Mackay DF, Pell JP. Systematic review and meta-analysis of school-based interventions to reduce body mass index. *J Public Health*. 2012;34:360–9.
  32. Ruotsalainen H, Kyngas H, Tammelin T, Kaariainen M. Systematic review of physical activity and exercise interventions on body mass indices, subsequent physical activity and psychological symptoms in overweight and obese adolescents. *J Adv Nurs*. 2015;71:2461–77.
  33. van Hoek E, Feskens EJ, Bouwman LI, Janse AJ. Effective interventions in overweight or obese young children: systematic review and meta-analysis. *Child Obes*. 2014;10:448–60.
  34. Young KM, Northern JJ, Lister KM, Drummond JA, O'Brien WH. A meta-analysis of family-behavioral weight-loss treatments for children. *Clin Psychol Rev*. 2007;27:240–9.
  35. Murray M, Dordevic AL, Bonham MP. Systematic review and meta-analysis: the impact of multicomponent weight management interventions on self-esteem in overweight and obese adolescents. *J Pediatr Psychol*. 2017;42:379–94.
  36. Harris KC, Kuramoto LK, Schulzer M, Retallack JE. Effect of school-based physical activity interventions on body mass index in children: a meta-analysis. *CMAJ*. 2009;180:719–26.
  37. Ho M, Garnett SP, Baur LA, Burrows T, Stewart L, Neve M, et al. Impact of dietary and exercise interventions on weight change and metabolic outcomes in obese children and adolescents: a systematic review and meta-analysis of randomized trials. *JAMA Pediatr*. 2013;167:759–68.
  38. Liao Y, Liao J, Durand CP, Dunton GF. Which type of sedentary behaviour intervention is more effective at reducing body mass index in children? A meta-analytic review. *Obes Rev*. 2014;15:159–68.
  39. Martin A, Saunders DH, Shenkin SD, Sproule J. Lifestyle intervention for improving school achievement in overweight or obese children and adolescents. *Cochrane Database Syst Rev*. 2014:CD009728.
  40. McGovern L, Johnson JN, Paulo R, Hettinger A, Singhal V, Kamath C, et al. Clinical review Treatment of pediatric obesity: a systematic review and meta-analysis of randomized trials. *J Clin Endocrinol Metab*. 2008;93:4600–5.
  41. Kanekar A, Sharma M. Meta-analysis of school-based childhood obesity interventions in the U.K. and U.S. *Int Q Community Health Educ*. 2008;29:241–56.
  42. Snethen JA, Broome ME, Cashin SE. Effective weight loss for overweight children: a meta-analysis of intervention studies. *J Pediatr Nurs*. 2006;21:45–56.
  43. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (*EarlyBird 54*). *BMJ*. 2012;345:e5888.
  44. Gertner D, Gertner AK, Araujo DV, Bahia L, Bouzas I. Calories and cents: customer value and the fight against obesity. *Soc Mar Q*. 2016;22:325–39.

45. Oliveira JS, Barufaldi LA, Abreu Gde A, Leal VS, Brunken GS, Vasconcelos SM, et al. ERICA: use of screens and consumption of meals and snacks by Brazilian adolescents. *Rev Saude Publica*. 2016;50:7s.
46. Salvy SJ, Elmo A, Nitecki LA, Kluczynski MA, Roemmich JN. Influence of parents and friends on children's and adolescents' food intake and food selection. *Am J Clin Nutr*. 2011;93:87–92.
47. Savage JS, Fisher JO, Birch LL. Parental influence on eating behavior: conception to adolescence. *J Law Med Ethics*. 2007;35:22–34.
48. Sallis JF, Floyd MF, Rodriguez DA, Saelens BE. Role of built environments in physical activity, obesity, and cardiovascular disease. *Circulation*. 2012;125:729–37.
49. Gordon-Larsen P, Nelson MC, Page P, Popkin BM. Inequality in the built environment underlies key health disparities in physical activity and obesity. *Pediatrics*. 2006;117:417–24.
50. Pont K, Ziviani J, Wadley D, Bennett S, Abbott R. Environmental correlates of children's active transportation: a systematic literature review. *Health Place*. 2009;15:827–40.
51. Anderson Steeves E, Martins PA, Gittelsohn J. Changing the food environment for obesity prevention: key gaps and future directions. *Curr Obes Rep*. 2014;3:451–8.