The effectiveness of pediatric obesity prevention policies: a comprehensive systematic review and dose–response meta-analysis of controlled clinical trials

Shahnaz Taghizadeh¹ and Mahdieh Abbascalizad Farhangi²*

Abstract

Background: Childhood obesity persists as a serious public health problem. In the current meta-analysis, we summarized the results of controlled trials that evaluated the effect of obesity prevention policies in children and adolescents.

Methods: Three databases (SCOPUS, PubMed and Embase) were searched for studies published before the 6th April 2020, by reported outcome measures of body mass index (BMI) and BMI-Zscore. Forty-seven studies reported BMI, while 45 studies reported BMI-Zscore as final outcome.

Results: The results showed that the obesity-prevention policies had significant effect in reducing BMI (WMD: −0.127; CI: −0.198, −0.056; P < 0.001). These changes were not significant for BMI-Zscore (WMD: −0.020; CI: −0.061, 0.021; P = 0.340). In dose–response meta-analysis, a non-linear association was reported between the duration of intervention and BMI (P_nonlinearity < 0.001) as well as BMI-Zscore (P_nonlinearity = 0.023). In subgroup analysis, the more favorite results were observed for 5–10 years old, with combination of physical activity and diet as intervention materials.

Conclusion: In conclusion, the obesity prevention policies in short-term periods of less than 2 years, in rather early age of school with approaches of change in both of diet and physical activity, could be more effective in prevention of childhood obesity.

Trial registration: PROSPERO registration number: CRD42019138359

Keywords: Childhood obesity, Policy, Prevention, Children, Adolescents

Background

Overweight and obese children persist as a serious health problem and a public challenge of the twenty-first century. Obesity among children and adolescents is a leading cause of health and contributes to cardiovascular disease, cerebrovascular disease, and metabolic diseases [1]. Nearly one in five children and adolescents are overweight or obese [2], and the growing prevalence of obesity in youth has led to an alarming increase of 18.5% in children and adolescents between the ages of 2–19 years [3]. Obese children are at greater risk of obesity in adulthood; a recent study of 200,777 participants showed that 80% of teens with obesity remained obese in adulthood and this continued with a prevalence of 70% past the age of 30 [4]. According to a recent study in the United States comparing the cost–benefit of prevention versus treatment interventions in youth, preventive interventions in...
the early stages of life were found to be more beneficial than in adulthood, and addressing childhood obesity as early as possible is an effective strategy against obesity in later ages [5]. Although the underlying reasons of genetics and individual behavior for being overweight in adults and young people are almost the same [6], obesity prevention policies in the younger age group are different from those adopted in adulthood. Developing and implementing effective strategies to prevent childhood obesity is difficult at the population level. The National Academy of Sciences recommended that more attention should be paid to providing opportunities to choose healthy foods in society [7]. Obesity prevention is a public health priority around the world. The effectiveness of childhood obesity prevention programs has been shown by previous Cochrane reviews [8]. Some previous systematic reviews have focused on childhood obesity prevention programs that were not at national, governmental or macro-population level policies or that focused on some specific interventional approaches, including changes in physical activity (PA), diet and education [9–13]. Although there is evidence to support the beneficial effects of increased PA and diet as a basic and early strategy at any time and for any age against obesity [14, 15], no summarized study is available to critically evaluate the effectiveness of different policies with different interventional approaches in prevention of childhood obesity considering the role of setting, age, geographical distribution, and intervention type or strategy. Therefore, the aim of the current study was to systematically search controlled trials that evaluated the effectiveness of pediatric obesity prevention policies among children and adolescents and to analyze the effectiveness of these policies on the study outcomes of body mass index (BMI) and BMI-Z score (BMI-Z) measurements while considering a possible dose–response association with preventive tools.

Methods and materials
The current systematic review and meta-analysis was prepared according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement for reporting systematic reviews and meta-analyses [16] (checklist is provided in Additional file 1: Table S1). The study protocol was registered in PROSPERO (identifier: CRD42019138359) and was approved by the Research Undersecretary of the Tabriz University of Medical Sciences as the Ph.D. thesis of SHT (Registration number: IR.TBZMED.REC.1398.840).

Data sources and search strategy
Searches were conducted using SCOPUS, PubMed and Embase. All articles were considered eligible, if published before April 6, 2020. Additional file 1: Table S2 shows the full search strategy in PubMed. Four concept groups were organized according to the search terms: (a) Population (pediatric, children, or adolescents); (b) Health problem under consideration (obesity, pediatric obesity); (c) Intervention (policy, program, strategy); and (d) Relevant outcomes of interest (BMI, BMI-Zscores). The reference lists of all related and available articles were reviewed to reduce the possibility of missing articles. The selection criteria for this review were independently verified by two researchers (SHT, MAF).

Study selection
Relevant studies conducting a community approach that evaluated policies to prevent obesity in children and adolescents aged 0–18 years were included in the current review. Studies were excluded if they were aimed to treat childhood overweight/obesity, were performed in children with other diseases, or if their full text was not available. Detailed exclusion and inclusion criteria are shown in Table 1.

Quality assessment and data extraction
Study quality was assessed using the Effective Public Health Practice Project Quality Assessment Tool for Quantitative Studies, a useful tool for quality assessment of randomized and non-randomized intervention trials [17, 18]. This tool is comprised of six components that include selection bias, study design, confounders, blinding, data collection methods (validity/reliability), and withdrawals and dropouts. The overall quality rating and the components are scored as strong, moderate and weak according to the tool’s instructions. Individual component quality rankings are shown in Additional file 1: Table S3. General study characteristics (author, year of publication, country, sample size, number of intervention and control, type of study (randomized or non-randomized), duration of intervention, follow-up from baseline, follow-up from end of intervention, participant characteristics, outcomes (BMI, BMI-Zscores), and policy characteristics were extracted for included studies. Effect size was defined as changes in BMI and BMI-Zscore compared with control group. Two researchers (SHT, MAF) independently extracted the data from all studies.

Statistical analysis
The data were analyzed using STATA version 15 (STATA Corp, College Station, TX, USA), and p-values of less than 0.05 were considered statistically significant.

Two-class meta-analysis of continuous variable
The studies that reported BMI and BMI-Zscore as primary or secondary outcomes in intervention and control groups were included for two-class meta-analysis synthesis. The means and standard deviations (SD) of variables
were used to compute standardized mean differences as effect size computed by pooled estimate of weighted mean difference (WMD) at a 95% confidence interval (CI). Subgroup analyses were conducted to explore sources of heterogeneity. Due to high heterogeneity values (i.e., above 50%), the random effects model was used. Between-study heterogeneity was identified using Cochran’s Q and I-squared tests as follows: I^2 < 25%, no heterogeneity; I^2 25% to 50%, moderate heterogeneity; I^2 > 50%, large heterogeneity [19]. Studies that reported separate results for both sexes, in different age categories, or at different time periods of follow-up were included as individual studies. Publication bias was examined using Begg’s funnel plots, followed by Egger’s regression asymmetry test and Begg’s rank correlation for formal statistical assessment of funnel plot asymmetry. For missing SDs, the method described by Walter and Yao was used to calculate SD [20]. Studies were excluded from the analysis if they (a) were not controlled trials or (b) did not report sufficient data of outcome variables.

### Dose–response meta-analysis of continuous variables

For dose–response meta-analysis of variables, variables of duration of intervention and PA time and training sessions (as education time) were included. The mean difference of variables in each study was also identified. Dose–response meta-analysis of BMI and BMI-Z-score was performed using fractional polynomial modeling [21] to explore nonlinear potential effects of duration of intervention (year), PA and education time and study-specific parameters.

| Table 1 Inclusion and exclusion criteria for study selection |
|-------------------------------------------------------------|
| **Inclusion criteria**                                      | **Exclusion criteria**                          |
| Population                                                 | Target group was not children or adolescents (aged > 18 years) |
| Quantitative studies (e.g., randomized controlled trial, quasi-randomized trials, and cluster randomized trials) | Include overweight and obese children |
| Studies evaluating the effect of policies have been done at the macro-population level interventions to prevention childhood obesity | Pregnant adolescents |
| Children and adolescent aged 0–18 years                    | Children with disabilities, health conditions (e.g. cystic fibrosis) or behavioural/learning difficulties |
| Population includes children 0–18 years and outcomes reported separately children 0–18 years | Studies aimed at treatment childhood obesity |
| Intervention                                               | Children with eating disorders/disordered eating (e.g. binge eating, bulimia) or other mental health disorders |
| Community-based intervention/program                       | Clinical studies (including drugs, single nutrients) |
| Reports outcomes for children and adolescent               | Include programs which are secondary prevention |
| Include programs delivered in school (delivered as part of the curriculum or within school hours or after school programmes, changes to school environments/policies (e.g. foods available in the canteen, water fountain installation) | Programs which involve clinical treatments (e.g. bariatric surgery) |
| Include programs which are primary prevention only         | Targets eating disorders/disordered eating (e.g. binge eating, bulimia) or other mental health disorders |
| Policy changes (e.g. strategies, plans)                    | Environmental changes or interventions—e.g. new parks, water fountain installations |
| Community health service; other community setting (church, sports club, NGO, councils) | Community health service; other community setting (church, sports club, NGO, councils) |
| Outcomes                                                   | Outcomes not reported |
| Primary or secondary outcomes include BMI or BMI Z         | Primary outcomes diet/healthy eating behaviours or activity-related behaviours such as physical activity |
| Time                                                       | Does not report outcomes as BMI or BMI Z of interest |
| Any duration of intervention                                | Does not report outcomes as BMI or BMI Z for children and adolescents age 0–18 years |
| Setting                                                    | Family outcomes only |
| Any country                                                | Parent outcomes only |
| Study type                                                 | Intervention pre-post studies without control group, small scale |
| Intervention studies (e.g. RCT, non-randomised experimental); full scale and pilot implementation studies | Intervention not in the macro-population level |
| Publication year                                            | Any |
| Any                                                        | Abstract only |
| Other                                                      | Review article |
| Article/abstract in any language                            | Editorials |
| Conference abstracts                                       | Conference abstracts |
| Letters                                                    | Letters |
| Commentaries                                               | Commentaries |
| Study protocols                                            | Study protocols |
Results

Literature search and study characteristics

A search of electronic data bases retrieved 30,719 records. After removing duplicates, 20,686 items were screened by title/abstract (Fig. 1) and selected according to the criteria identified above. The remaining 224 full text articles were screened and 49 publications were selected in a qualitative synthesis; finally, 38 publications were included in a quantitative synthesis, which contained outcomes for 64 individual studies as described above.

Fig. 1 Flow chart of study selection
Grey literature searches identified no published results for policies in scope. Study, participant, and program characteristics of the quantitative synthesis (meta-analysis) are presented in Table 2 with additional information including the full name of the studies shown in Additional file 1: Table S4. Studies were performed in various settings of school (n = 16) [22–37], community and school (n = 10) [38–47], school and home (n = 1) [48], community, school, and home (n = 2) [49, 50], community, school, home, and primary care clinic (n = 5) [51–55], community and home (n = 2) [56, 57], primary care clinic (n = 1) [58], and cyberspace/online (n = 1) [59]. In all, 64 individual studies were obtained from 38 publications included in the quantitative synthesis. Twelve studies were performed as combinations of different follow-up times, age groups, genders, or different durations or populations; therefore each was included as two [23–25, 31, 35, 36, 42, 44, 48, 50, 54–56, 59], three [41, 49, 52], or four individual studies [30, 51]. The rationale for extracting several studies from these publications and additional information about the policies are shown in Table 2 and Additional file 1: Table S5. Characteristics of studies that were not included in the meta-analysis with the exclusion reasons are shown in Additional file 1: Table S6.

Approximately 35% of programs were carried out in the United States (n = 13) [29, 31–34, 37, 40, 42, 49–52, 57], and 31% (n = 12) studies in Australia [24–28, 38, 43, 44, 47, 53, 54, 59]. Other studies took place in China (n = 1) [22], Brazil (n = 1) [23], New Zealand (n = 3) [30, 35, 55], Spain (n = 2) [36, 39], the United Kingdom (n = 1) [41], Fiji (n = 1) [45], Tonga (n = 1) [46], France (n = 1) [48], Sweden (n = 1) [58], and one study which was conducted in eight European countries (Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain and Sweden) [56].

Thirty studies reported BMI [22–31, 33–36, 38, 39, 43–48, 49, 50, 52–55, 57–59] and 27 studies reported BMI-Z score [22–25, 27, 28, 32, 33, 35, 37, 39–47, 49, 51–57]. The total number of participants in the systematic reviews was 200,255; 178,017 participants were included in the meta-analysis, ranging from 86 [59] to 35,157 [54], with an average sample size of 2849. Nine studies were carried out among girls, [23, 27, 30, 31, 36, 42, 48, 51, 56], eight studies among boys [24, 26, 30, 36, 42, 48, 51, 56] and 21 studies were performed with both genders. The majority of policies (n = 33) examined combined diet and PA interventions, with five studies that consisted of only PA [22, 26, 30, 34, 36] and no study focused only on diet. The majority of studies (n = 31) were conducted as randomized controlled trials (81.5%), and seven [35, 47, 48, 51, 55, 56, 58] were non-randomized controlled trials (18.4%). BMI or BMI-Z score as outcomes were reported at the end of the intervention in 31 studies [22–27, 29–40, 43–53, 55, 57], and 14 programs had follow-up periods after the end of the intervention [23, 24, 26, 28, 31, 35, 41, 42, 49, 52, 54, 56, 58, 59]. The length of follow-up ranged from 6 weeks [52] to 3 years [54].

Dose–response meta-analysis of the association between education time, PA, duration of intervention and BMI or BMI-Z score

The non-linear dose–response association between the study outcomes of BMI or BMI-Z score and education time, PA, and duration of intervention was performed using fractional polynomial (FP) modelling. Thirteen studies were assessed for a dose–response association between BMI and education time [23–27, 29–31, 33, 37, 39, 52, 57], and 12 studies for BMI-Z score and education time [23–25, 27, 33, 37, 39, 41, 49, 51, 52, 57] (Figs. 2a, 3a). There was no evidence for nonlinear association between BMI (P for nonlinearity = 0.163) or BMI-Z score (P for nonlinearity = 0.270) with education time. Ten studies were assessed for a dose–response association between BMI and PA [24–27, 30, 31, 33, 34, 36, 52] and 8 studies for BMI-Z score [24, 25, 27, 33, 41, 42, 51, 52] (Figs. 2b, 3b). No evidence of nonlinearity association was observed between BMI (P for nonlinearity = 0.254) or BMI-Z score (P for nonlinearity = 0.452) and PA. All 30 studies of BMI and 27 studies of BMI-Z score were included for calculating the dose–response association between changes in BMI or BMI-Z score with duration of intervention, respectively (Figs. 2c, 3c). There was evidence of a nonlinear association between the duration of intervention and BMI (P for nonlinearity < 0.001) as well as BMI-Z score (P for nonlinearity = 0.023).

Details of the dose–response association between duration of intervention, PA, education time and BMI and BMI-Z score are shown in Table 3.

Two-class meta-analysis of the comparison of effectiveness of childhood obesity prevention policies on BMI and BMI-Z score

A total of 38 publications [22–59] were included in the two-class meta-analysis of the effects of obesity prevention policies on BMI (Fig. 4) and BMI-Z score (Fig. 5).

The results showed that obesity-prevention policies had a significant effect in reducing BMI (WMD: −0.127; CI −0.198, −0.056; P < 0.001; I² = 99.7%; P-heterogeneity < 0.001) and a non-significant reduction in BMI-Z score (WMD, −0.020; CI −0.061, −0.021; P = 0.340; I² = 99.8). A subgrouping meta-analysis (shown in Tables 4 and 5) and a meta-regression (Table 6) were also performed to assess the source of heterogeneity for the included studies. According to the subgroup meta-analysis, school-based policies in children aged 5–10 years, in relatively short period of time (less or equal to 2 years),
| Setting (N of studies) | First Author/Year of publish/ (reference) | Main focus | Intervention type | Country/ name of program | Increase of PA<sup>a</sup> | Session<sup>b</sup> | Total sample (IN, CN) | Duration (year) | Range of age (year)<sup>c</sup> | Frequency of intervention | Target group | Quality score<sup>f</sup> | %↓ in BMI | %↓ in BMI-Z<sup>g</sup> |
|-----------------------|------------------------------------------|------------|------------------|-------------------------|----------------------|----------------|---------------------|----------------|--------------------------|--------------------------|-------------|-----------------|---------|---------------|
| School (n = 25)       | Wang/2018 [22] PA 2                      |            | China/YOG-Obesity study | NR NR 9658 (5275, 4883) | 1                     | 9–12 0<sup>39</sup> | W Children | ✔ ✔                      |                          |              |                 | ✔       | ✔             |
|                       | Leme/2018 [23] Diet + PA 0              |            | Brazil/H3G-Brazil | NR 60 253 (412, 111) | 0.5                    | 14–18 0.5 M | M Children and parents | 3 – – |                          |                          |              |                 | ✔       |               |
|                       | Lubans/2016 [24] Diet + PA 2            |            | Australia/ATLAS | 26 3 361 (181, 180) | 0.66                   | 12–14 0.84 W | W Children | 1 – – |                          |                          |              |                 | ✔       |               |
|                       | Hollis/2016 [25] Diet + PA 2            |            | Australia/PA4E | 70,156 288 1150 (645, 505) | 1, 2                   | 10–11 0 W | W Children | 2 ✔ ✔ |                          |                          |              |                 | ✔       |               |
|                       | Smith/2014 [26] PA 2                    |            | Australia/ATLAS | 18 1.5 361 (181, 180) | 0.41                   | 12–14 0.25 W | W Children | 2 – – |                          |                          |              |                 | ✔       |               |
|                       | Lubans/2012 [27] Diet + PA 2            |            | Australia/NEAT Girl | 91.5 46 357 (178, 179) | 1                     | 12–14 0 W | W Children | 1 – – |                          |                          |              |                 | ✔       |               |
|                       | Millar/2011 [28] Diet + PA 2            |            | Australia/IYM | NR NR 2054 (1276, 778) | 1                     | 12–18 1.3 D | D Children | 1 ✔ ✔ |                          |                          |              |                 | ✔       |               |
|                       | Llargues/2011 [29] Diet + PA 2          |            | US/Aval | NR 288 509 (272, 237) | 2                     | 5–6 0 W | W Children | 1 – – |                          |                          |              |                 | ✔       |               |
|                       | Salcedo-Aguilar/2010 [30] (four individual study due to sex and duration) PA 2 |            | New Zealand/MOV | 234468 126 921 (375, 546) | 1, 1.66               | 9–10 0 W | W Children | 1 – – |                          |                          |              |                 | ✔       |               |
|                       | Neumark-Sztainer/2010 [31] (two individual study due to follow up) Diet + PA 2 |            | US/New Moves | 32 27.33 356 (182, 147) | 0.33                   | 14–189 0.41 W | W Children | 1 – – |                          |                          |              |                 | ✔       |               |
|                       | Group/2010 [32] Diet + PA 2            |            | US/school-based program on risk factors for DM | NR NR 4603 (2307, 2290) | 2                     | 11–12 0 NR | NR Children | 3 – – |                          |                          |              |                 | ✔       |               |
| Setting (N of studies) | First Author/Year of publish/reference | Main focus | Intervention\(^a\) | Study type\(^b\) | Country/Name of program | Increase of PA\(^c\) | Session\(^d\) | Total sample (IN, CN) | Duration (year) | Follow-up (year)\(^e\) | Frequency of intervention | Target group | Quality score\(^f\) | ↓ in BMI | ↓ in BMI-Z |
|-----------------------|----------------------------------------|------------|-------------------|-----------------|-------------------------|-------------------|-------------|----------------------|----------------|-------------------|-------------------------|-------------|----------------|----------|----------|
| Dzewaltowski/2010[33]  | Diet + PA 2 1 US/HOP IN               | 215        | 240               | 273 (148, 125)  | 2                      | 9–10               | 0           | D                    |                |                   |                          | Children 3 | –               | –        | –        |
| Donnelly/2009[34]     | PA 2 1 US/PAAC                        | 234        | NR                | 1527 (814, 713) | 3                      | 6–9                | 0           | W                    |                |                   |                          | Children 1 | –               | 1        | –        |
| Taylor/2008[35]       | Diet + PA 2 2 New Zealand/APPLE       | NR NR 727  | (381, 346)       | 727 (381, 346)  | 1                      | 6–11               | 0, 1.8      | D                    |                |                   |                          | Children 3 | NR            | ✔        | –        |
| Martínez Vicalino/2008[36] | PA 2 1 Spain/Movi                  | 108        | NR                | 1119 (513, 579) | 0.5                    | 9–10               | 0           | W                    |                |                   |                          | Children 2 | –               | 1        | –        |
| Foster/2008[37]       | Diet + PA 2 1 US/SNPI                | NR 180     | 1349 (749, 600)  | 2                      | 9–12               | 0           | W                    |                |                   |                          | Children 2 | 1              | –        | –        |
| Bell/2019[38]         | Diet + PA 3 1 Australia/OPAL         | NR NR 2353 | (1208, 1145)     | 2353 (1208, 1145) | 5                      | 0–18               | 0           | D                    |                |                   |                          | Children 3 | –              | 1        | –        |
| Santiago Felipe/2018[39] | Diet + PA 3 1 Spain/TCHP          | NR 30      | 2086 (974, 112)  | 2086 (974, 112)    | 1.25                  | 8–10               | 0           | W                    |                |                   |                          | Children 3 | –              | –        | –        |
| Novotny/2018[40]      | Diet + PA 3 1 US/Children's Healthy Living Program | NR NR 1882 | (952, 930)       | 1882 (952, 930)    | 2                      | 2–8                | 0           | NR                   |                |                   |                          | Children 2 | 1              | –        | –        |
| Adab/2018[41]         | Diet + PA 1 1 UK/WAIVES             | 45         | 21                | 1392 (660, 732)   | 1                      | 6–7                | 0.25, 1.5, 2.25 | D                    |                |                   |                          | Children 3 | 1              | –        | –        |
| Sadeghi/2017[42]      | Diet + PA 0 1 US/NSFS               | 10.4       | NR                | 422 (271, 151)    | 3                      | 3–8                | 1           | W                    |                |                   |                          | Children 1 | 1              | –        | –        |
| Swinburn/2014[43]     | Diet + PA 3 1 Australia/BAEW        | NR NR 1674 | (877, 797)       | 1674 (877, 797)    | 3                      | 10–12              | 0           | D                    |                |                   |                          | Children 1 | –              | –        | –        |
| Setting (N of studies) | First Author/Year of publish/ (reference) | Main focus | Intervention type | Study type | Country/ name of program | Increase of PA | Total sample (IN, CN) | Duration (year) | Range of age (year) | Follow-up (year) | Frequency of intervention | Target group | Quality score | ↓ in BMI | ↓ in BMI - Z |
|------------------------|-------------------------------------------|------------|------------------|-----------|--------------------------|---------------|-----------------------|----------------|---------------------|----------------|------------------------|--------------|--------------|---------|-------------|
| Pettman/2014 [44] (two individual study due to age groups) | Diet + PA | 3 | 1 | Australia/ ewiba | NR | NR | 2631 (1300, 1351) | 3 | 4–5, 10–12 | 0 | NR | Children | 2 | – | – | |
| Kremer/2011 [45] | Diet + PA | 3 | 1 | Fiji/HVHC | NR | NR | 2968 (879, 2009) | 1.75 | 13–18 | 0 | NR | Children | 2 | – | – | |
| Fotu/2011 [46] | Diet + PA | 3 | 1 | Tonga/MYP | NR | NR | 1712 (815, 897) | 2.4 | 11–19 | 0 | NR | Children | 3 | – | – | |
| Sanigorski/2008 [47] | Diet + PA | 3 | 2 | Australia/ BAEW | NR | NR | 3688 (1001, 2687) | 3 | 4–12 | 0 | D | Children | 2 | – | ✔ | |
| School, home (n = 2) | Diet + PA | 2 | 2 | France/FLVS | NR | NR | 1502 (804, 698) | 12 | 5–12 | 0 | NR | Children | 2 | ✔ | – | |
| Crespo/2012 [49] (three individual study due to follow up) | Diet + PA | 3 | 1 | US/APN | NR | 22 | 392 (165, 227) | 1 | 5–7 | 0, 1, 2 | NR | Children | 3 | – | – | |
| Gentile/2009 [50] (two individual study due to duration) | Diet + PA | 3 | 1 | US/ Switch & what you Do, View, and Chew | NR | NR | 1323 (670, 653) | 6.12 | 6–11 | 0 | NR | Children | 2 | – | ✔ | |
| Economos CD /2007 [51] (four individual due to community and sex) | Diet + PA | 3 | 2 | US/SUS | 40 | 16 | 1178 (385, 793) | 0.66 | 6–8 | 0 | W | Children | 2 | – | ✔ | |
| Wong/2016 [52] (three individual study due to follow up) | Diet + PA | 2 | 1 | US/Healthy Kids Houston | NR | NR | 877 (524, 353) | 0.125, 0.25, 0.375 | 9–12 | 0, 0.125, 0.25 | W | Children | 1 | – | – | |
Table 2 (continued)

| Setting (N of studies) | First Author/Year of publish (reference) | Main focus | Intervention type | Study type | Country/ name of program | Increase of PA | Session | Total sample (IN, CN) | Duration (year) | Range of age (year) | Follow-up (year) | Frequency of intervention | Target group | Quality score | ↓ in BMI | ↓ in BMI-Z |
|------------------------|------------------------------------------|------------|------------------|------------|--------------------------|----------------|---------|------------------------|----------------|---------------------|---------------|---------------------------|-------------|---------------|---------|-----------|
| Johnson/2012 [5]       | Diet + PA 3                              | Australia/ BAEW NR NR 2903 (1726, 1183) 3 4–12 0 NR Children 3 |              |            |                          |                |         |                        |                |                     |               |                           |             |               |         |           |
| de Silva-Sanigorski/2010 [54] (two individual study due to age groups) | Diet + PA 3 | Australia/ Romp and Chomp NR NR 35,157 (2778, 32,379) 3 0–5 3 D Children 1 |                |            |                          |                |         |                        |                |                     |               |                           |             |               |         |           |
| Taylor/2007 [55] (two individual study due to duration) | Diet + PA 3 | New Zealand/ APPLE NR NR 470 (251, 219) 1.2 5–12 0 NR Children 1 |              |            |                          |                |         |                        |                |                     |               |                           |             |               |         |           |
| de Henauw/2015 [56] (two individual study due to sex) | Diet + PA 3 | 8 European countries/ IDEFICS NR NR 16,228 (4882, 7746) 0.58 2–9.9 1.42 NR Children and parents 1 |              |            |                          |                |         |                        |                |                     |               |                           |             |               |         |           |
| Elder/2014 [57] | Diet + PA 3 | USAMOVE NR NR 36.6 541 (271, 270) 2 10–14 0 W Parent 3 |              |            |                          |                |         |                        |                |                     |               |                           |             |               |         |           |
| Primary care clinic (n = 1) | Diet + PA 0 | Sweden/ PRIMROSE NR NR 1030 (431, 599) 3.25 0.75–5 1 NR Parent 3 |              |            |                          |                |         |                        |                |                     |               |                           |             |               |         |           |
| Cyberspace (n = 2) | Diet + PA 0 | Australia/ Time2b-Healthy NR NR 86 (42, 44) 0.5 2–5 0.25, 0.5 M Parent 3 |              |            |                          |                |         |                        |                |                     |               |                           |             |               |         |           |

D daily, W weekly, M monthly, NR not reported

a 0: Only education, 1: education as curricula, 2: education + change in school environment (such as increased PA or changes in school diet), 3: involvement other community sections

b 1: Randomized controlled-trials (RCT), 2: Non-randomized controlled-trials

c Total hours increase of PA in the duration of intervention

d Educational session was held in the duration of intervention

e Follow-up from end of intervention

f 1: weak, 2: moderate, 3: strong, Component scores for quality rating are included in Additional file 1: Table S4

g Tickets (✔) show a significant decrease (P < 0.05) in the body mass index (BMI) or BMI Z

h Follow up 0 means: Immediately After the End of the Intervention

i BMI was not as outcomes

j BMI Z was not as outcomes

k BMI was among the outcomes, but no significant changes were reported
with approaches to practical changes in diet and PA (i.e., not consisting of education only) and the policies that were performed in combination with both genders seemed to be more effective in reducing BMI and BMI-Z-score with more favorable changes. Subgrouping also revealed that the heterogeneity level for BMI was reduced in subgrouping according to target group (e.g., for the parent group it was reduced from 99.7 to 49.8%), type of
intervention (e.g., for only education it was reduced from 99.7 to 30.9%), study focus (e.g., for PA it was reduced from 99.7 to 35.7%), and frequency of intervention (e.g., for monthly it was reduced from 99.7 to 13.4%). In examining setting, the setting of community, school, and home and school, home and cyberspace and continent as US, the frequency of intervention as weekly, baseline BMI as a range of 22–25 and ≥25 kg/m², and gender as male, heterogeneity disappeared. For BMI-Z score, the target group, the continent, the gender, and the setting were the primary sources of heterogeneity.

Quality assessment of included studies
The Effective Public Health Practice Project Quality Assessment Tool for Quantitative Studies was used for quality assessment of the studies. Study quality [17, 18] was evaluated as “weak” for 15 studies [22, 24, 27–31, 34, 42, 43, 48, 52, 54–56], “moderate” for 10 studies [25, 26, 36, 37, 40, 44, 45, 47, 50, 51], and “strong” for 13 studies [23, 32, 33, 35, 38, 39, 41, 46, 49, 53, 57–59]. Quality assessment results also showed that the average change in BMI or BMI-Z score in the follow-up compared to baseline was 0.5401 and −0.0054 in the intervention groups and 0.7291 and 0.5401 in the control groups (Additional file 1: Table S3).

Publication bias
Publication bias was determined using the funnel plot of BMI and BMI-Z score (Additional file 1: Figure S1). Begg’s and Egger’s regression tests were used to further illustrate publication bias (Additional file 1: Table S7). No evidence of publication bias was seen for BMI in Begg’s (P = 0.08) or Egger’s regression tests (P = 0.54) or for BMI-Z score in Begg’s (P = 0.89) or Egger’s regression test (P = 0.65).

Sensitivity analysis
A sensitivity analysis was performed to obtain the effects of individual studies on the BMI-Z score results and the results of the sensitivity analysis is presented as a plot in Additional file 1: Figure S2. By removing

Table 3  Details of non-linear association between BMI and BMI-Z score with study specific parameters

| Parameter | Education time | Physical activity hour | Duration of intervention | BMI-Z score |
|-----------|----------------|------------------------|--------------------------|-------------|
| Dose_1    | 0.3085         | 0.0855                 | -1.0312                  | -0.1331     |
| Dose_2    | 0.1785         | 0.0588                 | 0.2833                   | 0.1319      |
| _cons     | 0.6306         | 0.1707                 | 0.096                    | -0.8181     |
| Dose_1    | 0.2787         | 0.9264                 | 0.096                    | 0.8181      |
| Dose_2    | 0.0730         | 0.0973                 | 0.95                     | 0.0103      |
| _cons     | 0.6516         | 0.1710                 | 3.64                     | 1.0312      |
| Dose_1    | -2.7333        | 0.0787                 | 3.64                     | 0.0291      |
| Dose_2    | -1.0968        | 0.2633                 | 3.64                     | 0.0975      |
| _cons     | 0.6516         | 0.1710                 | 3.64                     | 0.0291      |
| Dose_1    | 0.0855         | 0.0588                 | -1.18                    | -0.0103     |
| Dose_2    | 0.1785         | 0.0588                 | 0.95                     | 0.0973      |
| _cons     | 0.6306         | 0.1707                 | 3.69                     | 0.8181      |

The significant P-values of Dose_2 are presented as italic numbers

a Body mass index
b This refers to the hours of physical activity other than the normal physical activity that takes place in the school’s physical activity course
the studies of Kremer et al. [45] and de Silva-Sanigorsk et al. [54] a significant change in the results occurred (WMD: \(-0.036\); CI \(-0.068, 0.005\); \(P = 0.025\); \(I^2 = 72.4\); \(P < 0.005\)). When Sadeghi et al. [42] among boys was also removed, the changes were even more pronounced (WMD: \(-0.042\); CI \(-0.073, 0.010\); \(P = 0.009\); \(I^2 = 71.5\); \(P < 0.001\)).

### Discussion

This systematic review and meta-analysis is the first, to our knowledge, to evaluate the quantitative effects of various childhood obesity prevention policies on children's BMI and BMI-Zscore in an interventional design. There are many systematic reviews or meta-analysis studies that have been performed in specific settings.
such as schools only [12, 13, 60] or were performed for single-axis interventions such as physical activity only [10, 61], diet only [13] or with limited duration of intervention [62] or follow-up [63, 64] and different age ranges [9, 10, 60, 64]. The current comprehensive meta-analysis evaluated the isolated effects of settings, intervention materials, duration and length of follow up, with a focus on the adiposity-related outcome of BMI or BMI-Zscore. The key findings of the current study were as follows. First, obesity prevention policies were associated with a 0.127 kg/m² reduction in BMI but with no significant change in BMI-Zscore. Second, there was a nonlinear dose–response association between duration...
Table 4  Results of subgroup analysis for the effects of childhood obesity policies on childhood BMI

| Group                                      | No. of trial | WMD (95% CI)     | P     | P heterogeneity | I², % |
|--------------------------------------------|--------------|------------------|-------|----------------|-------|
| Total                                      | 47           | −0.127 −0.198    | <0.001| <0.001         | 99.7  |
| Setting                                    |              |                  |       |                |       |
| School                                     | 23           | −0.225 −0.398    | 0.01  | <0.001         | 60.7  |
| Community, school, home                    | 2            | −0.006 −0.075    | 0.864 | 0              |       |
| Community, school                          | 8            | −0.027 −0.285    | 0.839 | <0.001         | 85.1  |
| School–home                                | 2            | −1.098 −1.383    | 0.155 | 0.878          | 0     |
| Community, home                            | 1            | −0.46 −1.094     | 0.174 | <0.001         |       |
| Community                                  | 8            | 0.007 −0.151     | 0.93  | <0.001         | 100   |
| Primary care clinic                        | 1            | −0.1 −0.165      | 0.035 | 0.002          |       |
| Cyberspace                                 | 2            | −0.443 −0.751    | 0.05  | 0.589          | 0     |
| Target group                               |              |                  |       |                |       |
| Children                                   | 38           | −0.109 −0.19     | 0.029 | 0.008          | 99.8  |
| Parent                                     | 4            | −0.276 −0.522    | 0.031 | 0.028          | 49.8  |
| Children and parents                       | 5            | −0.112 −0.435    | 0.211 | 0.019          |       |
| Continent                                  |              |                  |       |                |       |
| USA                                        | 13           | −0.016 −0.083    | 0.632 | 0.976          | 0     |
| Europe                                     | 6            | −0.208 −0.656    | 0.364 | <0.001         | 90.5  |
| Oceania                                    | 27           | −0.109 −0.198    | 0.02  | 0.017          | <0.001| 99.8  |
| Asia                                       | 1            | −0.2 −0.353      | 0.047 | 0.01           |       |
| Intervention contenta                     |              |                  |       |                |       |
| Education                                  | 5            | −0.185 −0.391    | 0.22  | 0.216          | 30.9  |
| Education as curricula                     |              | −              | −     | −              | −     |
| Education + change in school environment (such as increased PA or changes in school diet) | 26 | −0.302 −0.501 | −0.102 | 0.003 | <0.001 | 74.6 |
| Other community sections                   | 16           | −0.009 −0.105    | 0.088 | 0.862          | <0.001| 99.9  |
| Study focus                                |              |                  |       |                |       |
| Diet + PA                                  | 38           | −0.14 −0.219     | 0.061 | 0.001          | <0.001| 99.8  |
| PA                                         | 9            | −0.065 −0.216    | 0.086 | 0.397          | 0.132 | 35.7  |
| Age-category                               |              |                  |       |                |       |
| < 5 years old                              | 6            | −0.022 −0.158    | 0.114 | 0.751          | <0.001| 100   |
| 5–10 years old                             | 22           | −0.3 −0.52       | 0.08  | 0.008          | <0.001| 87.5  |
| ≥ 10 years old                             | 19           | −0.133 −0.28     | 0.014 | 0.077          | 0.009 | 48.7  |
| By sample size                             |              |                  |       |                |       |
| ≤ 1000                                     | 28           | −0.388 −0.632    | 0.143 | 0.002          | <0.001| 78    |
| 1000–2000                                  | 10           | −0.044 −0.146    | 0.057 | 0.393          | 0.008 | 59.4  |
| > 2000                                     | 9            | 0.037 −0.08      | 0.154 | 0.531          | <0.001| 100   |
| Frequency of intervention                  |              |                  |       |                |       |
| Daily                                      | 9            | −0.023 −0.154    | 0.108 | 0.73           | <0.001| 100   |
| Weekly                                     | 22           | −0.042 −0.121    | 0.038 | 0.303          | 0.541 | 0     |
| Monthly                                    | 4            | −0.302 −0.61     | 0.005 | 0.054          | 0.326 | 13.4  |
| NR²                                        | 12           | −0.127 −0.198    | −0.056| 0.002          | <0.001| 90.7  |
| Duration of intervention (years)           |              |                  |       |                |       |
| ≤ 1                                        | 25           | −0.243 −0.388    | −0.098| 0.001          | <0.001| 67.5  |
| 1–2                                        | 9            | −0.38 −0.725     | −0.036| 0.03           | <0.001| 72.1  |
| > 2                                        | 13           | −0.006 −0.109    | 0.098 | 0.917          | <0.001| 99.9  |
| Follow up from baseline (years)            |              |                  |       |                |       |
| ≤ 1                                        | 21           | −0.114 −0.223    | −0.006| 0.039          | 0.047 | 36.8  |
| 1–2                                        | 10           | −0.366 −0.697    | −0.035| 0.03           | <0.001| 99.9  |
| > 2                                        | 16           | −0.077 −0.176    | 0.021 | 0.122          | 0.001 | 68.7  |
| Sex                                        |              |                  |       |                |       |
of intervention and reduction in BMI and BMI-Z score in studies with duration of intervention of ≤ 2 years.

In a meta-analysis by Stice et al. [65], no statistically significant effects on prevention or treatment of obesity were reported in a large percentage of studies (79%). In the current meta-analysis childhood obesity prevention policies were associated with 0.127 kg/m² decrease in BMI. This BMI reduction due to weight control programs in the present study was similar to Peirson et al. [63], who assessed 76 studies for normal, overweight and obese children. In contrast in a study by Harris et al., in a systematic review of 18 interventions studies, no significant effects on BMI were found [61]. Another finding in the current study was a small but non-significant change in BMI-Z score in intervention groups (e.g., 0.0054 units’ reduction of BMI-Z score in the intervention vs 0.5401 units’ increase in the control). On the other hand, Peirson et al. [63] found a significant reduction in BMI-Z score in their study. These inconsistencies might be due to differences in inclusion criteria. A nonlinear dose–response association between the duration of intervention (less than 2 years) and decrease in BMI and BMI-Z score, indicated long-term duration of intervention reduces the efficacy of weight management policies. As shown in Fig. 2c, for interventions longer than 2 years, the increase in intervention time reduced the mean change in BMI between the intervention and control groups. Consistent with our findings, Stice et al. also found that the weight reducing effects of weight management programs disappeared after a 3-year follow-up, suggesting that short-term obesity prevention programs are more effective than long-term ones in obesity management [65]. These findings were not similar for adults; for example, in a study of adults with an intervention duration that ranged from 6 weeks to 2 years, it was reported that obesity prevention programs could be effective for more than 4 months [66]. Some studies have found no association between the duration of the intervention and weight change [63]. These differences could be due to different populations, age groups, or settings. Stone et al. in a study conducted in Italy to evaluate the effectiveness of the recommended activities in schools, with at least 20 min’ physical activity in a day, reported that less than half of children (49%) took part in the physical activity, while after 7 years follow-up none of the children were engaged in physical activity schedules of more than 20 min [67]. Although we did not show the minimum possible time for the interventions to be effective in this study, the theory of Prochaska and DiClemente [68], recommended that 6 months is the minimum time for stabilizing behavior change involving PA practice. We were not able to assess the long-term sustainability of obesity prevention policies, because there was a limited number of studies that included long-term follow-up after the end of the intervention [54, 69, 70]. From the perspective of the frequency of intervention, optimal frequencies seemed to be daily or weekly schedules, with little effectiveness seen at monthly intervals. It has been established that integration of obesity prevention interventions in the classroom is difficult to achieve [65] and
| Group                        | No. of trial | WMD (95% CI) | P     | P_{heterogeneity} | I^2, % |
|-----------------------------|--------------|--------------|-------|-------------------|--------|
| **Total**                   | 45           | −0.02        | −0.061| 0.021             | 0.34   | <0.001 | 99.8          |
| **Setting**                 |              |              |       |                   |        |        |               |
| School                      | 14           | −0.073       | −0.137| 0.01              | 0.024  | <0.001 | 69.4          |
| Community, school, home     | 7            | −0.08        | −0.202| 0.043             | 0.203  | 0.773  | 0             |
| Community, school           | 13           | 0.057        | −0.012| 0.125             | 0.105  | <0.001 | 76.5          |
| School–home                 |              |              |       |                   |        |        |               |
| Community, home             | 3            | −0.127       | −0.263| 0.01              | 0.068  | 0.511  | 0             |
| Community                   | 8            | −0.052       | 0.14  | 0.036             | 0.245  | <0.001 | 100           |
| **Target group**            |              |              |       |                   |        |        |               |
| Children                    | 34           | −0.028       | −0.074| 0.018             | 0.23   | <0.001 | 99.8          |
| Parent                      | 1            | −0.18        | −0.345| 0.015             | 0.032  | <0.001 | 69.4          |
| Children and parents        | 6            | 0.034        | −0.023| 0.091             | 0.242  | 0.891  | 0             |
| Children and parents and teachers | 4 | 0.03 | −0.135 | 0.196 | 0.058 | 59.9 |
| **Continent**               |              |              |       |                   |        |        |               |
| USA                         | 17           | −0.011       | −0.047| 0.025             | 0.539  | 0.449  | 0             |
| Europe                      | 6            | 0.034        | −0.056| 0.123             | 0.46   | 0.102  | 45.6          |
| Oceania                     | 21           | −0.032       | −0.09 | 0.025             | 0.27   | <0.001 | 99.9          |
| Asia                        | 1            | −0.1         | −0.155| −0.045            | <0.001 |        |               |
| **Intervention content**    |              |              |       |                   |        |        |               |
| Education only              | 4            | 0.053        | −0.149| 0.254             | 0.609  | 0.007  | 75.4          |
| Education as curricula      | 3            | 0.026        | −0.138| 0.19              | 0.753  | 0.015  | 76.4          |
| Education + change in school environment (such as increased PA or changes in school diet) | 15 | −0.071 | −0.128 | −0.014 | 0.014 | <0.001 | 67 |
| **Other community sections**| 23           | −0.006       | −0.062| 0.051             | 0.841  | <0.001 | 99.9          |
| **Study focus**             |              |              |       |                   |        |        |               |
| Diet + PA                   | 44           | −0.017       | −0.059| 0.024             | 0.415  | <0.001 | 99.8          |
| PA                          | 1            | −0.1         | −0.155| −0.045            | <0.001 |        |               |
| **Age-category**            |              |              |       |                   |        |        |               |
| < 5 years old               | 3            | 0.072        | −0.063| 0.208             | 0.295  | <0.001 | 100          |
| 5–10 years old              | 24           | −0.069       | −0.137| −0.001            | 0.046  | <0.001 | 78.8          |
| ≥ 10 years old              | 18           | 0.018        | −0.032| 0.067             | 0.483  | <0.001 | 67.2          |
| **By sample size**          |              |              |       |                   |        |        |               |
| ≤ 1000                      | 22           | 0.015        | −0.03 | 0.06              | 0.096  | <0.001 | 76.8          |
| 1000–2000                   | 12           | 0.015        | −0.03 | 0.06              | 0.506  | 0.142  | 31.1          |
| ≥ 2000                      | 11           | 0.028        | −0.047| 0.103             | 0.46   | <0.001 | 99.9          |
| **Frequency of intervention**|            |              |       |                   |        |        |               |
| Daily                       | 11           | −0.029       | −0.105| 0.046             | 0.444  | 0      | 99.9          |
| Weekly                      | 18           | −0.013       | −0.068| 0.042             | 0.643  | 0.002  | 55.7          |
| Monthly                     | 2            | 0.067        | −0.075| 0.209             | 0.357  | 0.687  | 0             |
| NRb                         | 14           | −0.035       | −0.12 | 0.049             | 0.412  | 0      | 82.7          |
| **Duration of intervention (years)** | | | | | | |
| ≤ 1                         | 24           | −0.046       | −0.105| 0.012             | 0.119  | <0.001 | 68.7          |
| 1–2                         | 10           | −0.037       | −0.147| 0.072             | 0.506  | <0.001 | 86.3          |
| > 2                         | 11           | 0.033        | −0.042| 0.109             | 0.386  | <0.001 | 99.9          |
| ≥ 2                         | 1            | −0.14        | −0.277| −0.003            | 0.045  | <0.001 | 82.7          |
| **Follow up from baseline (years)** | | | | | | |
| ≤ 1                         | 15           | −0.03        | −0.089| 0.029             | 0.313  | 0.021  | 47.4          |
| 1–2                         | 14           | −0.016       | −0.108| 0.076             | 0.739  | <0.001 | 81.1          |
| > 2                         | 16           | −0.02        | −0.083| 0.043             | 0.539  | <0.001 | 99.9          |
| **Sex**                     |              |              |       |                   |        |        |               |
The nine studies was included as two individual studies [2–4, 14, 21, 23, 33–35], three studies as three individual studies [20, 28, 31], and one study as four individual studies [30]; the significant P-values are presented as italic numbers.

### Table 5 (continued)

| Group               | No. of trial | WMD (95% CI) | P     | P_{heterogeneity} | I^2 (%) |
|---------------------|--------------|--------------|-------|-------------------|---------|
| Boys and girls      | 32           | −0.034 −0.079 | 0.012 | 0.147             | <0.001  | 99.8   |
| Girls               | 7            | 0.011 −0.084  | 0.105 | 0.826             | 0.272   | 20.7   |
| Boys                | 6            | 0.079 −0.098  | 0.257 | 0.382             | 0.031   | 59.4   |
| Quality rating      |              |              |       |                   |         |
| Strong              | 12           | 0.032 −0.046  | 0.109 | 0.104             | <0.001  | 75.6   |
| Moderate            | 16           | −0.054 −0.118 | 0.011 | 0.423             | <0.001  | 73.9   |
| Weak                | 17           | −0.024 −0.092 | 0.044 | 0.482             | <0.001  | 99.9   |

The nine studies was included as two individual studies [2–4, 14, 21, 23, 33–35], three studies as three individual studies [20, 28, 31], and one study as four individual studies [30]: the significant P-values are presented as italic numbers.

WMD weighted mean difference, PA physical activity

a Education, is various training that can be different based on policies, but education as curricula is a unit of instruction in schools that is done as course regularly during the school year

b Not reported

### Table 6 Meta regression analysis for in obesity prevention policies on BMI and BMI-Zscore

| Body mass index (BMI)                          | Tau^2     | P       | 95% CI          |
|------------------------------------------------|-----------|---------|-----------------|
| Estimate of between-study variance             | 0.020     |         |                 |
| By setting/community versus others             | 0.1461    | 0.186   | −0.0929, 0.4653 |
| By target group/children versus others         | 0.1594    | 0.528   | −0.3282, 0.6312 |
| By country/USA versus others                    | 0.1604    | 0.728   | −0.3080, 0.4377 |
| By intervention content/education versus others| 0.1614    | 0.923   | −0.4419, 0.4867 |
| By study focus/Diet + PA versus PA only        | 0.1402    | 0.524   | −0.4518, 0.2333 |
| By age/≤ 5 years versus others                 | 0.1586    | 0.476   | −0.2434, 0.5130 |
| By sample size/≤ 1000 versus others            | 0.1191    | 0.005   | 0.0703, 0.3816  |
| By frequency of intervention/ daily versus others| 0.16      | 0.752   | −0.2873, 0.3951 |
| By duration of intervention/≤ 1 year versus others| 0.1595    | 0.322   | −0.1622, 0.4836 |
| By follow-up/≤ 1 year versus others            | 0.1574    | 0.285   | −0.1661, 0.5518 |
| By sex/combination of both genders versus others| 0.1619    | 0.589   | −0.4114, 0.2364 |
| By baseline BMI/≤ 18 versus others             | 0.1604    | 0.199   | −0.4802, 0.1027 |
| By study quality/strong versus others           | 0.1572    | 0.384   | −0.4514, 0.1769 |

BMI-Zscore

| Estimate of between-study variance             | 0.0129    |         |                 |
| By setting/community versus others             | 0.0158    | 0.173   | −0.0309, 0.1667 |
| By target group/children versus others         | 0.0168    | 0.301   | −0.0151, 0.4787 |
| By country/USA versus others                    | 0.0173    | 0.797   | −0.0854, 0.1106 |
| By intervention content/education versus others| 0.0169    | 0.367   | −0.0951, 0.2525 |
| By study focus/diet + PA versus PA only        | 0.0173    | 0.550   | −0.1931, 0.3578 |
| By age/≤ 5 years versus others                 | 0.0164    | 0.222   | −0.0629, 0.2642 |
| By sample size/≤ 1000 versus others            | 0.0148    | 0.045   | 0.0013, 0.1075  |
| By frequency of intervention/daily versus others| 0.0174    | 0.771   | −0.1191, 0.0889 |
| By duration of intervention/≤ 1 year versus others| 0.0163    | 0.253   | −0.1441, 0.0390 |
| By follow-up/≤ 1 year versus others            | 0.0173    | 0.906   | −0.1078, 0.0958 |
| By sex/combination of both genders versus others| 0.0167    | 0.210   | −0.1867, 0.0422 |
| By study quality/strong versus others           | 0.0167    | 0.268   | −0.1490, 0.0423 |

The significant P-values are presented as italic numbers

a Physical activity
their long-term effectiveness is negligible [67]. Another finding of this study was that school-based programs had the most favorable results in prevention of obesity, which was consistent with the results of some previous studies [64] supporting Centers for Disease Control and Prevention (CDC) [71] and World Health Organization (WHO) [72] recommendations that schools are the best place for obesity prevention in children and adolescents. Wang et al. found that multi-setting trials had beneficial and significant effects compared to single-setting interventions against pediatric obesity [9]. Since most studies of the studies in pediatrics are conducted in schools, further investigations in other settings are indicated to elucidate their effectiveness in pediatric obesity prevention. In our finding, the integration of education alongside changes in the school environment had more favorable results compared with education only. Similarly, Sbruzzi et al. [73] reported that education-only interventions are effective the obesity treatment but not prevention. The heterogeneity of educational materials that are provided in different studies make it difficult to achieve a unique finding about their effectiveness [74]. Most studies (65%) were carried out in either Australia or the United States. Wang et al., in a meta-analysis across high-income countries, found similar results [9]. In subgrouping according to age, reductions in BMI and BMI-Zscore were observed in children aged 5–10 years old; similarly, in one study conducted by Peirson et al. in 2013 [63] among 0–18 years old children, beneficial results were observed in the same age range. Richards et al. showed that the strongest effect of PA intervention was found in the youngest children (grade 3 learners compared to the grade 4–6 learners). This was interpreted to be because the intervention promoted PA in the form of playing may have been more attractive and suitable for the younger children [75], or maybe it is because of the ease of interventions in this age groups [76]. On the other hand, high schools and middle schools were more likely to sell competitive foods than were elementary schools [77], which can have a negative impact on the implementation of obesity prevention policies. Finkelstein et al. in their study demonstrated that the consumption of unhealthy foods were high in the high schools children than in elementary school children [78], which is probably due to the fact that the behavior of buying fast food and soft drinks is not fully formed at this age group of children. Finally, most of the childhood obesity prevention studies used diet and physical activity combined as an intervention strategy. The result of the current study showed that diet and physical activity-based policies were more effective regarding BMI and BMI-Zscore reduction while studies with physical activity-only interventions were not effective. The results of studies by Katz et al. [79], Peirson et al. [63] and Wang et al. [9] found that a combination of diet and physical activity compared to diet-only or physical activity-only interventions had the most favorable results in pediatric obesity prevention. Our sensitivity analysis showed that by removing the studies of Kremer et al. [45], de Silva-Sanigorsk et al. [54] and Sadeghi et al. [42], a significant reduction in BMI-Zscore was observed. One of the most important features that these three studies had in common was poor management of selection bias in the quality assessment. As shown by Munafò et al., selection bias can considerably influence observed associations in large-scale cross-sectional studies [80].

Strengths and limitations
The principal strength of the current study is a comprehensive assessment of obesity prevention policies with an emphasis on different settings, age ranges, and intervention materials and content with BMI and BMI-Zscore as target outcomes. We also considered the possible role of the intervention duration, follow-up time and the amount of physical activity by including both randomized and non-randomized controlled clinical trials. Some of the limitations of the current meta-analysis should also be noted; for example, we were not able to obtain the education time and physical activity from all included articles because some of the articles did not specify these. Physical activity and nutrition education interventions are complex and, in each study, different approaches and theories may be used, which in all studies didn’t mention the approach and method of them, therefore, different approaches in educational methods and physical activities made it difficult to classify.

Conclusion
In conclusion, childhood obesity prevention (a) in school-based policies (b) between the ages of 5–10 years old children, (c) in short-term periods (less than 2 years) at more frequent intervals, (d) with a dual approach of diet and physical activity, can be effective in preventing childhood obesity. These findings can be used by health policymakers and policy providers to apply more effective strategies for obesity prevention in this age group.

Supplementary information
Supplementary information accompanies this paper at https://doi.org/10.1186/s12967-020-02640-1.

Additional file 1: Table S1. PRISMA checklist. Table S2. Search strategies and the number of records according to different electronic database. Table S3. Study quality of final studies, assessed by Effective Public Health Practice Project Quality Assessment Tool for quantitative studies. Table S4. Full name of studies. Table S5. Summary of study findings and additional information of some studies. Table S6. The general characteristics of the studies that not include in the meta-analysis. Table S7. Publication bias checked by the Begg’s and Egger test in the BMI and BMI-Zscore.
The authors declare that there is no conflict of interest.

Tabriz University of Medical Sciences (Registration number: IR.TBZMED.REC.1398.840). The study protocol has been approved by the ethics committee of the Tabriz University of Medical Sciences, Tabriz, Iran (Grant Number: IR.TBZMED.REC.1398.840).

The work has been granted by a grant from Tabriz University of Medical Sciences, Attar Nishabouri St., POBOX: 14711, Tabriz, Iran. (Grant Number: IR.TBZMED.REC.1398.840).

Role of Funder/Sponsor: The Tabriz University of Medical Sciences had no role in the design and conduct of the study.

Acknowledgements
Not applicable.

Authors’ contributions
SHT was involved in data extraction, search, review of articles and manuscript writing, MAF designed the idea of the project, performed the statistical analysis and revised the manuscript draft, and LN was also involved in review and extraction of papers. All authors read and approved the final manuscript.

Funding
The data are available with reasonable request from corresponding authors.

Abbreviations
BM: Body mass index; PA: Physical activity; BMI-Z: BMI-Zscore; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; WMD: Weighted mean difference; CI: Confidence interval; FP: Fractional polynomial.

Competing interests
The authors declare that there is no conflict of interest.

Author details
1 Student Research Committee, Department of Community Nutrition, Tabriz University of Medical Sciences, Tabriz, Iran. 2 Drug Applied Research Center, Tabriz University of Medical Sciences, Attar Nishabouri St., POBOX: 14711, 5166614711 Tabriz, Iran.

Received: 16 September 2020 Accepted: 27 November 2020
Published online: 14 December 2020

References
1. Lindberg L, Danielsson P, Persson M, Marcus C, Hagman E. Association of childhood obesity with risk of early all-cause and cause-specific mortality: a Swedish prospective cohort study. PLoS Med. 2020;17(3):e1003078.
2. World Health Organization, Commission on Ending Childhood Obesity. 2019. https://www.who.int/end-childhood-obesity/en/. Accessed 23 Apr 2020.
3. Centers for Disease Control, Childhood Obesity Facts. 2020. https://www.cdc.gov/obesity/data/childhood.html. Accessed 26 June 2020.
4. Simmonds M, Llewellyn A, Owen C, Woolacott N. Predicting adult obesity from childhood obesity: a systematic review and meta-analysis. Obes Rev. 2016;17(2):95–107.
5. Cawley J. The economics of childhood obesity. Health Aff. 2010;29(3):364–71.
6. Centers for Disease Control and Prevention, Childhood Obesity Causes &Consequences. 2020. https://www.cdc.gov/obesity/childhood/cause.html. Accessed 1 Nov 2020.
7. McGuire S, Institute of Medicine. Accelerating progress in obesity prevention: solving the weight of the nation. Washington, DC: The National Academies Press, Oxford University Press; 2012. p. 708–9.
8. Waters E, de Silva-Sanigorski A, Burford B, Brown T, Campbell K, Gao Y, Armstrong R, Prosser L, Summerbell CD. Interventions for preventing obesity in children. Cochrane Database Syst Rev. 2011(12).
9. Wang Y, Cai L, Wu Y, Wilson R, Weston C, Fawole O, Bleich SN, Cheskin LJ, Showell NN, Lau B. What childhood obesity prevention programmes work? A systematic review and meta-analysis. Obes Rev. 2015;16(7):547–65.
10. Finch MJ, Jones Y, Yoong S, Wiggers J, Wolfenden L. Effectiveness of centre-based childhood interventions in increasing child physical activity: a systematic review and meta-analysis for policymakers and practitioners. Obes Rev. 2016;17(5):412–28.
11. Moores C, Bell L, Miller J, Darnall R, Matwijieczyk L, Miller M. A systematic review of community-based interventions for the treatment of adolescents with overweight and obesity. Obes Rev. 2019;20(5):698–715.
12. Levinson J, Kohl K, Balfag V, Ross DA. Investigating the effectiveness of school health services delivered by a health provider: a systematic review of systematic reviews. PLoS ONE. 2019;14(6):e0212603.
13. Micha R, Karageorgou D, Bakogianni I, Trichia E, Whitesell LP, Story M, Penalvo JL, Mozaffarian D. Effectiveness of school food environment policies on children’s dietary behaviors: a systematic review and meta-analysis. PLoS ONE. 2018;13(3):e0194555.
14. Hale I. Obesity prevention: are we missing the (conception to infancy) window?, Royal College of General Practitioners. 2018. pp. 262–3.
15. Aziz Z, Absetz P, Oldroyd J, Prink NP, Oldenburg B. A systematic review of real-world diabetes prevention programs: learnings from the last 15 years. Implement Sci. 2015;10(1):172.
16. Moher D, Liberati A, Tetzlaff J, Altman DG, Group, P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6(7):e1000097.
17. Deeks JJ, Dinnes J, D’Amico R, Sowden AJ, Sakarovitch C, Song F, Petticrew M, Altman D. Evaluating non-randomised intervention studies. Health Technol Assess. 2003;7(27):iii–173.
18. Thomas B, Ciliska D, Dobkins M, Miccucci S. A process for systematically reviewing the literature: providing the research evidence for public health nursing interventions. Worldviews Evid Based Nurs. 2004;1(3):176–84.
19. Higgins J, Thompson S. Quantifying heterogeneity in a meta-analysis. Stat Med. 2002;21(11):1539–58.
20. Walter S, Yao X. Effect sizes can be calculated for studies reporting ranges for outcome variables in systematic reviews. J Clin Epidemiol. 2007;60(8):849–52.
21. Fan J, Gijbels I. Local polynomial modelling and its applications: monotone graphs on statistics and applied probability 66. Boca raton: CRC Press; 1996.
22. Wang Z, Xu F, Ye Q, Tse LA, Xue H, Tan Z, Leslie E, Owen N, Wang Y. Childhood obesity prevention through a community-based cluster randomized controlled physical activity intervention among schools in china: the health legacy project of the 2nd world summer youth olympic Games (YOG-Obesity study). Int J Obes. 2014;134(3):e723–31.
23. Leme ACB, Baranowski T, Thompson D, Nicklas T, Philippi SP. Sustained impact on adiposity in adolescents from economically disadvantaged communities: solving the weight of the nation. Washington, DC: The National Academies Press, Oxford University Press; 2012. p. 708–9.
24. Lubans DR, Smith JH, Plotnikoff RC, Daily KA, Okely AD, Salmon J, Morgan PJ. Assessing the sustained impact of a school-based obesity prevention program for adolescent boys: the ATLAS cluster randomized controlled trial. Int J Behav Nutr Phys Act. 2016;13(1):92.
25. Hollis JL, Sutherland R, Campbell L, Morgan PJ, Lubans DR, Nathan N, Wolfenden L, Okely AD, Davies L, Williams A, Cohen KE, Oldmeadow C, Gillham K, Wiggers J. Effects of a ‘school-based’ physical activity intervention on adiposity in adolescents from economically disadvantaged communities: secondary outcomes of the ‘Physical Activity 4 Everyone’RCT. Int J Obes. 2016;40(10):1486–93.
26. Smith JH, Morgan PJ, Plotnikoff RC, Daily KA, Salmon J, Okely AD, Finn TL, Lubans DR. Smart-phone obesity prevention trial for adolescents in low-income communities: The ATLAS RCT. Pediatrics. 2014;134(3):e723–31.
27. Lubans DR, Morgan PJ, Okely AD, Dewar D, Collins CE, Batterham M, Callister R, Plotnikoff RC. Preventing obesity among adolescent girls: one-year outcomes of the nutrition and enjoyable activity for teen girls (NEAT Girls) cluster randomized controlled trial. Arch Pediatr Adolesc Med. 2012;166(9):821–7.

28. Millar L, Kremer P, de Silva-Sanigorski A, McCabe MP, Mavoa H, Moodie M, Utter J, Bell C, Malakellis M, Mathews L, Roberts G, Robertson N, Swinburn BA. Reduction in overweight and obesity from a 3-year community-based intervention in Australia: the 'It's Your Move!' project. Obes Rev. 2011;12(SUPPL. 2):20–8.

29. Llargues E, Franco R, Recasens A, Nadal A, Vila M, Pérez MJ, Manresa JM, Recasens I, Salvador G, Serra J, Roure E, Castells C. Assessment of a school-based intervention in eating habits and physical activity in school children: The AVAll study. J Epidemiol Community Health. 2011;65(10):896–901.

30. Salcedo Aguilar F, Martinez-Vizcaino V, Sanchez Lopez M, Solera Martinez M, Franquelo Gutierrez R, Serrano Martinez S, Lopez-Garcia E, Rodriguez Artafelio F. Impact of an after-school physical activity program on obesity in children. J Pediatr. 2010;157(1):36–42.e3.

31. Neumark-Sztainer DR, Friend SE, Flattum CF, Hannan PJ, Story MT, Bauer H.S. A school-based intervention for diabetes risk reduction. N Engl J Med. 2010;363(5):443–53.

32. Dzewaltowski DA, Rosenkranz RR, Geller KS, Coleman KJ, Welk GJ, Hast-Group, H.S. A school-based intervention for diabetes risk reduction. N Engl J Med. 2010;363(5):443–53.

33. Donnelly JE, Greene JL, Gibson CA, Smith BK, Washburn RA, Sullivan DK, DuBoise K, Mayo MS, Schmetzle KH, Ryan JJ. Physical Activity Across the Curriculum (PAAC): a randomized controlled trial to promote physical activity and diminish overweight and obesity in elementary school children. Prev Med Int J Devoted Pract Theory. 2009;49(4):336–41.

34. Taylor R, McAuley K, Barbezat W, Farmer V, Williams S, Mann J. Two-year follow-up of an obesity prevention initiative in children: the APPLE project 1-3. Am J Clin Nutr. 2008;88(5):1371–7.

35. Martinez Viacalvo V, Salcedo Aguilar F, Franquelo Gutierrez R, Solera Martinez M, Sanchez Lopez M, Serrano Martinez S, Lopez Garcia E, Rodriguez Artafelio F. Assessment of an after-school physical activity program to prevent obesity among 9- to 10-year-old children: A randomized trial. Int J Obes. 2008;32(12):1–22.

36. Foster GD, Sherman S, Borradalle KE, Grundy KM, Vander Veur SS, Nachmann LJ, Karpyn A, Kumanyika S, Shulits A. A policy-based school intervention to prevent overweight and obesity. Pediatrics. 2008;121(4):e794–802.

37. Bell L, Ullah S, Leslie E, Magarey A, Olds T, Ratcliffe J, Chen G, Miller M, Jones C, Cobiac L. Changes in weight status, quality of life and behaviours of South Australian primary school children: results from the Obesity Prevention and Lifestyle (OPAL) community intervention program. BMC Public Health. 2019;19(1):1338.

38. Santiago Felipe G, Rafael Casas E, Subiran S, Serra-Najel M, Torrent MF, Homs C, Rowhead Ahmed B, Estrada L, Fito M, Schroder H. Effect of a community-based childhood obesity intervention program on changes in anthropometric variables, incidence of obesity, and lifestyle choices in Spanish children aged 8 to 10 years. Eur J Pediatr. 2018;177(10):1531–9.

39. Novotny R, Davis J, Butel J, Boutheyre CJ, Falkowski MK, Nigg CR, Braun KL, Leon Guerrero RT, Coleman P, Bersamin A, Areta AAR, Barber LR Jr, Belyeu-Camacho T, Greenberg J, Fleming T, Dela Cruz-Talbert E, Yamana K, Willems LR. Effect of the children's healthy living program on young child overweight, obesity, and acanthosis nigricans in the US-affiliated pacific region: a randomized clinical trial. JAMA Netw Open. 2018;1(6):e183896.

40. Adab P, Pallan MJ, Lancashire ER, Hemmings K, Frew E, Barrett T, Bhopal R, Cade JE, Canaway A, Clarke JL, Daley A, Deeks JJ, Duda JL, Ekelund U, Gill P, Griffin T, McGee E, Hurley K, Martin J, Parry J, Passmore S, Cheng KK. Effectiveness of a childhood obesity prevention program delivered through schools, targeting 6 and 7 year olds: cluster randomised controlled trial (Wave5 study). BMJ (Online). 2018;360(4):1–15.

41. Sadeghi B, Kasler L, Schafer S, Tseregounis I, Martinez L, Gomez-Camacho R, de la Torre A. Multifaceted community-based intervention reduces rate of BMI growth in obese Mexican-origin boys. Pediatr Obes. 2017;12(3):247–56.

42. Swinburn B, Malakellis M, Moodie M, Waters E, Gibbs L, Millar L, Herbert J, Virgo-Milton M, Mavoa H, Kremer P, de Silva-Sanigorski A. Large reductions in childhood overweight and obesity in intervention and comparison communities 3 years after a community project. Pediatr Obes. 2017;12(4):485–62.

43. Pettman T, Magarey A, Mastersson N, Wilson A, Dollman J. Improving weight status in childhood: results from the eat well be active community programs. Int J Public Health. 2014;59(1):43–50.

44. Kremer P, Waqa G, Vanualailai N, Schultz JT, Roberts G, Moodie M, Mavoa H, Malakellis M, McCabe MP, Swinburn BA. Reducing unhealthy weight gain in Fijian adolescents: results of the Healthy Youth Healthy Communities study. Obes Rev. 2011;12(SUPPL. 2):29–40.

45. Fotu K, Millar L, Mavoa H, Kremer P, Moodie M, Snowden W, Utter J, Vivili P, Schultz J, Malakellis M. Outcome results for the Mā'ālāhi Youth Project, a Tongan community-based obesity prevention programme for adolescents. Obes Rev. 2011;12:41–50.

46. Sanigorski AM, Bell K, Kremer PJ, Cuttler R, Swinburn BA. Reducing unhealthy weight gain in children through community capacity-building: results of a quasi-experimental intervention program, Be Active Eat Well. Int J Obes. 2008;32(7):1060–7.

47. Romon M, Lommez A, Taffett M, Basdevant A, Oppert JM, Bresson JL, Ducimetiere P, Charles MA, Boyes J.M. Downward trends in the prevalence of childhood overweight in the setting of 12-year-school- and community-based obesity prevention programs. Public Health Nutr. 2009;12(10):1735–42.

48. Crespo NC, Elder JP, Ayala GX, Slymen DJ, Campbell NR, Sallis JF, McKenzie TL, Baquero B, Aredondo EM. Results of a multi-level intervention to prevent and control childhood obesity among Latino children: the Aventuras Para Niños Study. Ann Behav Med. 2012;43(1):84–100.

49. Gentile DA, Wolk G, Eisenmann JC, Reimer RA, Walsh DA, Russell DW, Cal-Jahan R, Walsh M, Strickland S, Frizk K. Evaluation of a multiple ecological level child obesity prevention program: switch what you do, View, and Chew. BMC Med. 2009;7(1):49.

50. Economos CD, Hyatt RR, Goldberg JP, Must A, Naumova EN, Collins JI, Nelson ME. A community intervention reduces BMI z-score in children: Shape up somewmell first year results. Obesity. 2007;15(S):1325–36.

51. Wong VW, Ortiz CL, Staff JE, Mikhail C, Lathan D, Moore LA, Alejandro ME, Butte NF, Smith E.O. A community-based healthy living promotion program improved self-esteem among minority children. J Pediatr Gas-troenterol Nutr. 2016;63(1):106–12.

52. Johnson BA, Kremer PJ, Swinburn BA, De Silva-Sanigorski AM. Multi-level analysis of the Be Active Eat Well intervention: environmental and behavioural influences on reductions in child obesity risk. Int J Obes. 2017;41:901–7.

53. de Silva-Sanigorski AM, Bell AC, Kremer P, Nichols M, Cirellin M, Smith M, Sharp S, de Groot F, Carpenter L, Boak R. Reducing obesity in early childhood: results from Romp & Chomp, an Australian community-wide intervention program. Am J Clin Nutr. 2010;91(4):831–40.

54. Taylor RW, McAuley KA, Barbezat W, Strong A, Williams SW, Mann JI. APPLE Project: 2-y findings of a community-based obesity prevention program in primary school-age children. Am J Clin Nutr. 2012;95(3):735–42.

55. de Henauw S, Huybrechts I, de Bourdeaudhiu J, Bammens K, Barbé G, Lissner L, Mårild S, Molnár D, Moreno LA, Pigeot I, Tornaritis M, Veidebaum T, Verbeest V, Ahrens W. Effects of a community-oriented obesity prevention programme on indicators of body fatness in preschool and primary school children. Main results from the IDEFTICS study. Obes Rev. 2015;16:16–29.

56. Elder JP, Crespo NC, Corder K, Ayala GX, Slymen DJ, Lopez NV, Moody JS, McKenzie TL. Childhood obesity prevention and control in city recreation centres and family homes: the MOVE/me Muevo Project. Pediatr Obes. 2014;9(3):218–31.

57. Eno Persson J, Bohman B, Tynelius P, Rasmussen F, Ghaderi A. Prevention of childhood obesity in child health services: follow-up of the PRIMROSE children. Int J Obes. 2018;42(9):99–105.

58. Hammersley ML, Okely AD, Batterham MJ, Jones RA. An internet-based childhood obesity prevention program (TIME2behealthy) for parents of preschool-aged children: randomised controlled trial. J Med Internet Res. 2019;21(2):e16 1964.

59. Vetvas-Janssen SBH, van de Kolk, I, Van Kann DHH, Kremers SPJ, Gerards SMPL. Effectiveness of school-based physical activity and nutrition interventions with direct parental involvement on children's BMI and...
61. 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(7):719–26.
62. Lim S, Hill BJ, Teede HJ, Moran LJ, O'Reilly S. An evaluation of the impact of lifestyle interventions on body weight in postpartum women: a systematic review and meta-analysis. Obes Rev. 2020;21(4):e12990.
63. Perison L, Fitzpatrick-Lewis D, Morrison K, Clitsika D, Kenny M, Usman Ali M, Raina P. Prevention of overweight and obesity in children and youth: a systematic review and meta-analysis. CMAJ Open. 2015;3(1):E23–33.
64. Bleich SN, Segal J, Wu Y, Wilson R, Wang Y. Systematic review of community-based childhood obesity prevention studies. Pediatrics. 2013;132(1):e201–10.
65. Stice E, Shaw H, Marti CN. A Meta-Analytic Review of Obesity Prevention Programs for Children and Adolescents: The Skinny on Interventions That Work. Psychol Bull. 2006;132(5):667–91.
66. Hebdon L, Chey T, Allman-Farinelli M. Lifestyle intervention for preventing weight gain in young adults: a systematic review and meta-analysis of RCTs. Obes Rev. 2012;13(8):692–710.
67. Stone MR, Faulkner GE, Zeglen-Hunt L, Bonne JC. The Daily Physical Activity (DPA) policy in Ontario: is it working? An examination using accelerometer-measured physical activity data. Can J Public Health. 2012;103(3):170–4.
68. Prochaska JO, DiClemente CC. Stages of change in the modification of problem behaviors. Prog Behav Modif. 1992;28:183–218.
69. Lazorick S, Fang X, Crawford Y. The MATCH program: long-term obesity prevention through a middle school based intervention. Child Obes. 2016;12(2):103–12.
70. Rush E, McLennan S, Obolonkin V, Vandal AC, Hamlin M, Simmons D, Graham D. Project Energize: whole-region primary school nutrition and physical activity programme: evaluation of body size and fitness 5 years after the randomised controlled trial. Br J Nutr. 2014;111(2):363–71.
71. CDC. CDC Healthy Schools. 2019. https://www.cdc.gov/healthyschools/health_and_academics/index.htm. Accessed 26 June 2020.
72. World Health Organization, Global Strategy on Diet, Physical Activity and Health. 2020. https://www.who.int/dietphysicalactivity/childhood_schools/en/. Accessed 26 June 2020.
73. Sbruzzi G, Eibel B, Barbiero SM, Petkowicz RO, Ribeiro RA, Cesa CC, Martins CC, Marobin R, Schaan CW, Souza WB. Educational interventions in childhood obesity: a systematic review with meta-analysis of randomized clinical trials. Prev Med. 2013;65(5):254–64.
74. Shrewsbury VA, Nguyen B, O’Connor J, Steinbeck KS, Lee A, Hill AJ, Shah S, Kohn MR, Torvaldsen S, Baur LA. Short-term outcomes of community-based adolescent weight management: the Looiz8 study. BMC Pediatr. 2011;11(1):13.
75. Richards J, Foster C. Sport-for-development interventions: whom do they reach and what is their potential for impact on physical and mental health in low-income countries? J Phys Activity Health. 2013;10(7):929–31.
76. Stock S, Miranda C, Evans S, Plessis S, Ridley J, Yeh S, Chanoine J-P. Healthy Buddies: a novel, peer-led health promotion program for the prevention of obesity and eating disorders in children in elementary school. Pediatrics. 2007;120(4):e1059–68.
77. Story M, Nanner MS, Schwartz MB. Schools and obesity prevention: creating school environments and policies to promote healthy eating and physical activity. Milbank Q. 2009;87(1):71–100.
78. Finkelstein DM, Hill EL, Whitaker RC. School food environments and policies in US public schools. Pediatrics. 2008;122(1):e251–9.
79. Katz DL, O’Connell M, Nijke YY, Yeh M-C, Nawaz H. Strategies for the prevention and control of obesity in the school setting: systematic review and meta-analysis. Int J Obes. 2008;32(12):1780–9.
80. Munafò MR, Tilling K, Taylor AE, Evans DM, Davey Smith G. Collider scope: when selection bias can substantially influence observed associations. Int J Epidemiol. 2018;47(1):226–35.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.