Interventions aimed at preventing and reducing overweight/obesity among children and adolescents: a meta-synthesis

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Abstract

The prevalence of childhood and adolescent obesity has been a major worldwide problem for decades. To stop the number of children and adolescents with overweight or obesity from increasing, numerous interventions focusing on improving children's weight status have been designed and implemented. This vastly growing body of research on weight-related interventions for children and adolescents has been summarized by several meta-analyses that aim to provide an overview of the effectiveness of these interventions. Yet, the number of meta-analyses is expanding so quickly and overall results differ, making a comprehensive synopsis of the literature difficult. To tackle this problem, a meta-synthesis was conducted to draw informed conclusions about the state of the effectiveness of interventions targeting child and adolescent overweight. The results of the quantitative synthesis of 26 meta-analyses resulted in a standardized mean difference of -0.12 (95%CI: -0.16;-0.08). Several moderator analyses (e.g., gender, age, duration of the intervention, parental involvement) showed that participant and intervention characteristics had little impact on the overall effect size. Overall, the results of this meta-synthesis suggest that interventions result in statistically significant effects albeit of relatively little clinical relevance.

Abbreviations in manuscript

BMI: body mass index

BMIz: standardized BMI score for specific populations

PICOC: Participants, Intervention, Comparison, Outcome, Context

AMSTAR: a measurement tool for the 'assessment of multiple systematic reviews'

UB: upper bound for confidence interval

LB: lower bound for confidence interval

SMD: standardized mean difference

SD: standard deviation

CI: confidence interval

MCID: minimum clinical important differences

Interventions aimed at preventing and reducing overweight/obesity among children and adolescents: a meta-synthesis

The prevalence of childhood and adolescent obesity has been an increasing problem for decades with an estimated increase of 47,1% between 1980 and 2013 (1) and has taken pandemic forms, occurring in developed and developing countries and for boys and girls alike. Childhood overweight and obesity have been repeatedly associated with negative outcomes for youth's physical, social, and mental health (2-5). Studies have furthermore shown that adult overweight and obesity result in an increased risk for early death from a variety of causes: heart diseases, vascular diseases, cancer, medical problems among which gallbladder disease, hypertension, and diabetes mellitus (6,7). Future prospects are worrying with an estimated 57.3% of today's US children predicted to be obese at the age of 35 and the chances of an obese 19-year old to no longer be obese at the age of 35 being 6.1% (8). Thus, the urgency to prevent and decrease the number of overweight and obese children and adolescents is evident.

Theoretically, the problem of childhood overweight and obesity should be solvable by encouraging children and adolescents to eat less sugar- and fat-containing foods and exercise more. However, a long line of research has shown that this is easier said than done. Over the past decades, numerous interventions have been introduced to motivate children and adolescents to eat more healthily and exercise more often, designed for different contexts, such as the school (9-11), family (12,13), sports club (14,15), and online (16,17). Interventions are of short (e.g., 4 weeks (18), 5 weeks (19), 8 weeks (20)) or long (e.g., 12 months (21), 20 months (22)) duration, focus on specific populations (e.g., South Asian population (23,24)), or age groups (25-27). The interventions implemented varied widely in their activities and involved, for example, efforts to improve the offering of foods and drinks in sports canteens, provide afterschool sports activities for children, stimulate children to be physically active during school breaks, make fruits and vegetables available to children at schools, motivate parents to choose healthier food, and stimulate parents to restrict screen time. Some of these interventions suggest positive effects, often in the form of some decrease in weight or BMI of intervention participants.

Trying to systematically summarize the results of individual programs and aiming to provide an overview on "what works" in the vastly growing field of child obesity pre- and intervention, several meta-analyses on weight-related interventions for children and adolescents have been published in recent years. This number is expanding so quickly that a comprehensive overview of the literature is difficult to retrieve, hindering an educated conclusion as to whether or not interventions can really help young people in tackling overweight and obesity and if so, which types of interventions are most suited.

Moreover, the results of these meta-analyses do not always point in the same direction, in that some meta-analyses suggest significant weight loss in children and adolescents following intervention implementation whereas others fail to find improvements. Moderator analyses might explain why some interventions are more effective than others and could increase the effectiveness of future interventions. In this respect, a broad framework for moderator analyses (28) that has been adopted by many authors of meta-analyses (29-39) includes participant features (i.e., participant age, gender, ethnicity, and risk (i.e., how likely one is to become overweight/obese) and intervention features (e.g., intervention duration, parental involvement, psychoeducational content, dietary improvement, increased physical activity, reduced sedentary behavior). Still, the different studies need to be synthesized to understand heterogeneity in results.

Meta-synthesis

Meta-analysis is a commonly used tool to assess the strength of evidence for particular interventions, methods, or treatments as objectively as possible. Given the variation between meta-analyses on obesity pre- and intervention in type (e.g., physical activity, dietary intake, health literacy), sample (e.g., preschoolers, children, adolescents), and context (e.g., school-based interventions, community-based interventions, home-based interventions), it is challenging to comprehensively evaluate the literature and its implications for effectively tackling child and youth obesity in its entirety. This difficulty has not only presented itself in health behavior change research (40), but also in a diversity of other fields (41-44). Therefore, an overarching level of reviews was introduced (45), leading to the appearance of meta-review studies under different names: meta-syntheses (40,42,46), meta-analysis of meta-analyses (41,44), or second-order meta-analyses (47).

Discussing how to best integrate evidence from multiple meta-analyses, Ioannidis (48) stressed the *raison d'être* for meta-synthesis: a single meta-analysis addressing one treatment comparison for one outcome may offer a short sighted view of the evidence when there are more treatment options for the condition under review. More often than not, there are many treatments available and many relevant outcomes. This seems especially true for the field of prevention and treatment interventions targeting child and adolescent overweight/obesity: the problem can be targeted through different behavior changes (e.g., reducing weight, increasing physical activity), directed at different groups (e.g., toddlers, young children, teenagers), and be situated in different contexts (e.g., school, sports club, family home). Thus, to obtain an informed, well-substantiated insight of the state of the field of overweight/obesity pre- and interventions and their overall effectiveness, a meta-synthesis[1] is needed.

In balance, the central aim of the meta-synthesis presented here is to contribute to a more complete understanding of the empirical evidence by providing a quantitative summary statistic of the overall effectiveness of weight-related improving interventions. To get a better understanding of the variability of effectiveness of interventions, moderator analyses are carried out to determine whether and which participant and intervention characteristics might influence intervention effectiveness.

Method

Search strategy

A two-phased research strategy was carried out in April 2017 by the first author. First, a survey of the literature was conducted to assemble suitable search terms. Second, a systematic literature search of all relevant databases was employed, using the terms established during the first search. After consulting a librarian, the following databases were included: PubMed, PsycInfo, Eric, SocIndex and Web of Science, presuming that these databases provide a thorough overview of the accessible literature on meta-analyses of obesity prevention/treatment interventions. Different combinations of key terms were used (*Table 1*). Additional eligible meta-analyses were identified from the reference sections of meta-analyses found in the search.

[1] We use the term 'meta-synthesis' instead of 'second-order meta-analysis' or 'meta-analysis of meta-analyses' because it is the most prevalent term in the existing literature.
[2] To calculate a BMIz score, a person's BMI score is compared to the BMI score of a reference population (49).

Inclusion and exclusion criteria

Meta-analyses were included if they: 1) were written in English; 2) categorized participants as children or adolescents (i.e., not adults); 3) included interventions focusing on reducing weight and/or preventing overweight; 4) assessed the effectiveness of interventions by means of physical measures (e.g., BMI, BMIz[2], waist circumference); 5) provided sufficient methodological details to allow for assessment of the quality of the meta-analysis, such as information about the data collection and analysis method.

Criteria for exclusion from this meta-synthesis were as follows: 1) focus on surgical and/or pharmaceutical treatments (e.g., gastric bypasses for overweight patients); 2) focus on weight-related behaviors in relation to certain medical or psychological consequences or causes (e.g., diabetes, kidney disease, ADHD); 3) interventions targeting clinical or other subgroups (e.g., children with Down syndrome, US children from specific states or ethnicity). The latter were excluded because these types of interventions are hardly generalizable but provide information for specific target groups.

In cases of doubt, inclusion or exclusion of meta-analyses was discussed with the second and fourth author. When publications were not available to the researcher (e.g., no accessible file) or when there were ambiguities concerning the meta-analysis (e.g., almost identical titles by the same authors) the corresponding author was contacted by email twice. In cases of no response, the meta-analysis was excluded from further analysis.

Data extraction and quality appraisal

The Participants, Intervention, Comparison, Outcome, and Context (PICOC) method (50) was used to extract all necessary information from meta-analyses in a standardized manner (*Table 2*). This entailed information about the year the meta-analysis was published in, focus of the meta-analysis (i.e., obesity prevention, obesity treatment), types of interventions included in a meta-analysis, other conditions (e.g., European interventions only, interventions targeting specific behaviors), which participants were targeted by the meta-analyses, comparisons that were made (e.g., treatment *vs.* control, or treatment *vs.* treatment), as well as effect sizes and corresponding information about the statistical significance.

[2] To calculate a BMIz score, a person's BMI score is compared to the BMI score of a reference population (49). A BMIz score is thus not necessarily similar across age groups or countries.

Additionally, a list of individual intervention studies included in each meta-analysis was maintained to assess overlap between meta-analyses.

The methodological quality of the included meta-analyses was assessed using a 42-item tool (51) based on the AMSTAR tool (52) and the Cochrane Handbook for Systematic Reviews of Interventions (53) that places strong emphasis on the quality of individual meta-analyses' statistical appropriateness and adequacy of interpretation. The 42 items are conceptually summarized into four overarching questions, which are scored 'yes' (scored as 1), 'probably yes' (2), 'probably no' (3), 'no' (4) (*Table 3*), or 'unclear' or 'not applicable' (the latter two are not scored). 10% of the studies were rated by the first and second author and agreement was calculated using Cohen's kappa (54).

Analytical procedure

Two data files were compiled: one containing all information extracted from meta-analyses by means of the PICOC method, and another containing the intervention studies included in each meta-analysis. This second data file (*Table S1*) was used to estimate overlapping samples, similar to Zell, Krizan and Teeter (42). That is, meta-analyses were excluded if they were replaced by more recent meta-analyses addressing the same research question or covering the same topic or if they analyzed only a subset of studies of another meta-analysis. The degree of sample overlap was quantified by comparing the intervention studies included in the meta-analyses in RStudio 1.0.153 (55) and evaluated following Zell and colleagues' approach of applying a margin of 25% overlap, expressing that if 75% of all the studies are unique, the meta-analyses incorporated into the model are mostly independent, in that they largely contain unique data.(42).

The analytical procedure as described by Tang, Caudy and Taxman (46) was used to conduct the meta-synthesis. This approach is based on the assumption that conducting a meta-synthesis of meta-analyses is essentially the same as conducting a meta-analysis of individual interventions and requires only overall effect sizes as reported in meta-analyses and their corresponding variance estimates. Most meta-analyses provided confidence intervals instead of variances, thus variances were thus obtained by using $(UB\text{-}LB)^2/(2 * 1.96)^2$ (46). Data (i.e., effect sizes obtained from meta-analyses) were analyzed (i.e., summarized to provide an overarching effect size) using the "metafor" package (56) in RStudio 1.0.153 (55). Effect sizes were computed as *d* indices – or standardized mean differences (SMD) – and expressed the difference in mean change between intervention and control groups. Negative values expressed a greater decrease for the intervention groups. Each effect size was weighed by the inverse of its variance to ensure that studies with larger samples were given greater weight. If meta-analyses did not express effect sizes in Cohen's *d* or Hedge's *g* (which is a correction for small sample sizes), the reported effect size and its corresponding confidence interval were converted. Specifically, effect sizes expressed as Pearson's *r* were converted by applying the formulae described by Borenstein and colleagues (57). Odds ratio were converted using the formulae as documented by Chinn (58), see *Figure S1*. When meta-analyses applied unstandardized effect sizes, means and standard deviations of the intervention and control groups were used to calculate the SMD (*Figure S1*). If there was not enough information reported in the published meta-analysis to calculate the SMD, authors were emailed. Meta-analyses were excluded from further analysis when no response could be obtained.

Even though meta-analyses reported the same effect measure, they differed substantially in their methodologies and in/exclusion criteria and thus heterogeneity was assumed to be high. Therefore, a random effects model was employed, which accounts for the variability in effect sizes caused by both sampling error and true differences in effect sizes between studies. Effect sizes were interpreted according to Cohen's scale (59), with effect sizes of 0.2 indicating a small effect, effect sizes of 0.5 indicating a moderate effect, and effect sizes of 0.8 indicating a large effect. Effect sizes of 0.1 are sometimes deemed as trivial (57). Between-study heterogeneity was quantified using the I^2 statistic (60).

To statistically test for possible explanations of effect size differences, moderator analyses were conducted following the same procedure. First-level moderators (i.e., on the level of the meta-analysis) were selected based on the contents of the included meta-analyses. That is, frequently employed moderators in original meta-analyses were also examined as moderators in the present meta-synthesis as these would likely be the most influential moderators. Second-level moderators (i.e., on the level of the meta-synthesis) were the type of obesity intervention (i.e., treatment or prevention), the focus of the intervention (i.e., school-based or family-based), and the methodological quality of the meta-analysis. Their moderating effect was explored to elucidate reasons for varying effect sizes reported by different meta-analyses.

Publication bias

The selective publication of studies resulting in significant outcomes at the cost of non-significant outcomes is commonly referred to as publication bias. As a result, interventions might be unjustly assumed as effective and theory-building corrupted simply because significant findings are easier to publish than intervention or program trials that did not yield significant outcomes for experimental groups compared to control groups. For strategies to assess the publication bias at the level of the meta-analysis, other meta-syntheses were reviewed, and the strategy of Castellanos and Verdú (44) was adopted where the correlation between the effect sizes and sample sizes was calculated. Because larger studies have greater probability of finding significant results, a small correlation coefficient would imply the absence of evidence for publication bias. To strengthen conclusions regarding publication bias drawn in the present meta-synthesis, a file was maintained containing information about whether publication bias was assessed in every included meta-analysis and what the outcome.

Results

The systematic literature search yielded 457 articles across all databases. After removing duplicates and publications written in languages other than English, 209 articles remained, of which 26 were not available online. Authors of these articles were emailed and several of those publications (n = 15) were in fact conference papers or presentations and thus not included in subsequent analyses. In five cases, the author or library sent a copy of the publication. For six studies, authors did not respond to emails; these meta-analyses could thus not be included in subsequent analysis (*Figure 1*). After reading titles and abstracts of the 183+5 retrieved articles, 71 meta-analyses were excluded from further analysis because they did not concern obesity prevention/treatment. 117 meta-analyses about obesity prevention/treatment interventions were included for full text reading.

Based on full text reading of the 117 meta-analyses, another 72 meta-analyses were excluded mostly because of non-fitting samples (e.g., clinical sample, specific subsample of population), outcome measures (e.g., physical activity, fruit/vegetable intake, blood pressure, health literacy), and because mental and physical health outcomes were combined, which made it impossible to extract the intervention effect on weight. The reference lists of the remaining 45 meta-analyses were scanned and another six meta-analyses were added to the data set. This resulted in a collection of 51 meta-analyses (28-34,36,37,39,61-101), of which relevant information was extracted using the PICOC method.

Although in line with in/exclusion criteria, all meta-analyses assessed physical changes as outcome, these assessments varied along dimensions of BMI, BMIz, percentage of overweight/obesity in control and intervention groups, as well as waist circumference, or body fat percentage. A meaningful quantification of an overall effect, however, needs to be based on comparable outcomes. For this reason, the 26 meta-analyses that reported intervention effectiveness in terms of change in BMI were included in the quantitative meta-synthesis. The remainder (n = 25) is included in the subsequent descriptive overview.

The majority of meta-analyses (n = 28) did not implement restrictions to the kind of interventions they included. Twelve meta-analyses included only single-component interventions, and eleven meta-analyses included multi-component interventions (*Table 4*). Some meta-analyses placed in/exclusion restrictions on the intervention setting, for example, to the school environment (n = 22), sports club (n = 1), or family home (n = 5). The majority of meta-analyses included general populations, allowing both healthy-weight and overweight/obese participants to participate in the interventions reviewed, however, a minority of meta-analyses (n = 11) included only interventions based on overweight/obese samples. Some meta-analyses (n = 10) restricted intervention duration, varying from four to 24 weeks. The majority of the meta-analyses were based on interventions carried out with school-aged children and adolescents (5-18 years old), however, six meta-analyses included any children aged 18 or younger, and one meta-analysis included only adolescents between the ages of 13 and 18.

Quality Appraisal

An overview of the methodological quality of the included meta-analyses can be found in *Table S2*. The inter-rater reliability was $k = 0.75$ or 75%. Most of the disagreements between the raters were small; where rater 1 answered a question with ‘yes’, rater 2 answered that question with ‘probably yes’ and vice versa. Major differences (one rater answering ‘yes’ where the other would answer 'no') did occur only once. On a scale of 1 to 4, meta-analyses scored on average 3.25, implying that the methodological quality of the meta-analyses was relatively high. Meta-analyses scored on average 2.86 on the question whether "review methods were adequate such that biases in location and assessment of studies were minimized or able to be identified"; this being the lowest average across the four quality questions. It is likely that this low score results from a lack of assessment of methodological quality of included intervention studies in some meta-analyses, thus the possibility of biased meta-analytic effect size cannot be excluded.

Publication bias

To assess the probability of publication bias, the correlation between the effect size and sample size *k* was measured. The Pearson's *r* was 0.16, providing no evidence for the presence of publication bias. Of the 51 included meta-analyses, 28 assessed publication bias mostly through funnel plots, Egger's test, or by calculating the fail-safe N (*Table S3*). Of these 28 meta-analyses, 4 reported evidence of publication bias, 22 found no evidence for publication bias, and 2 studies did find evidence but deemed the influence of the bias trivial.

Overlap

Each of the 51 meta-analysis was compared to each other meta-analysis to identify overlap in inclusion of intervention studies, however, the average overlap between the studies included in the meta-analyses was modest at 5% (*SD* = 0.11, *median* = 0). A separate overlap analysis was conducted for the 26 meta-analyses included in the meta-synthesis (n = 26). A few studies overlapped considerably (70% (33,34), 71% (39,62), 71% (37,39), 80% (37,62), 80% (76,88)), however, the average overlap here was also modest at 8% (*SD* = 0.13, *median* = 0). We conducted analyses in- and excluding these studies and evaluate differences wherever substantial.

Meta-synthesis of meta-analyses expressing weight-change in BMI

As described above, the 26, meta-analyses expressing the difference between intervention and control groups in change in BMI[3] were eligible for inclusion in the meta-synthesis (*Figure 2, Table 5*). Combining the 26 effect sizes resulted in an overall statistically significant but very small SMD of -

[3] Because BMI and BMIz are highly correlated (102), meta-analyses combining BMI and BMIz in one effect size were included as well.

0.12 (95%CI: -0.16, -0.08, *Figure 3*). Considering the substantial overlap between some of the included studies, another meta-synthesis was conducted, leaving out the meta-analyses which contributed most to the high degree of overlap (33,34,62,71,87,89,94). Excluding these seven studies resulted in a SMD of -0.17 (95%CI: -0.25, -0.09). High heterogeneity among effect sizes was evident in both analyses (*Table 6*).

First-level moderators

First-level moderators were selected based on moderators frequently included in the 51 meta-analyses that form the basis of the present study and effects for respective subgroups summarized across the meta-analyses (*Table 6*). Five meta-analyses examined gender as moderator. The SMD for girls was small but statistically significant, while the SMD for boys was statistically non-significant. Regarding age (included as moderator in seven meta-analyses), participants older than 12 years seemed to show a slightly greater decrease in BMI than younger participants The duration of the intervention was included as a moderator in 11 meta-analyses. Interventions lasting 12 months or less resulted in a slightly smaller effect size than interventions lasting longer than 12 months. Three meta-analyses assessed the influence of parental involvement on interventions effectiveness, suggesting that minimal parental involvement yielded similar effect sizes to no parental involvement whereas substantial parental involvement increased the intervention effect somewhat. Comparing single- and multicomponent interventions yielded similar effect sizes for both types.

Finally, three meta-analyses included the risk of bias (as assessed by the authors of the meta-analyses) in intervention studies as a moderator. Meta-synthesizing those suggests that interventions with a low risk of bias resulted in a statistically non-significant SMD, as did interventions with an unclear risk of bias. In contrast, meta-synthesis of interventions with a high risk of bias were more likely to report statistically significant effects..

Second level-moderators

Included as second-level moderators, i.e., on the level of the meta-analyses, were intervention type (i.e., obesity prevention or obesity treatment), methodological quality as assessed by the authors of the present study, and the intervention context (*Table 6*). Regarding the type of intervention, meta-synthesis of meta-analyses assessing the effectiveness of obesity *preventing* interventions resulted in a

SMD of -0.08. Meta-synthesis of meta-analyses assessing the effectiveness of obesity *treatment* interventions resulted in a SMD of -0.48.

Twelve meta-analyses focused on school-based interventions, while two meta-analyses focused on family-based interventions, demanding the involvement of parents in interventions. Meta-synthesis of school-based meta-analyses resulted in a SMD of -0.08. Meta-synthesis of family-based meta-analyses resulted in a SMD of -0.12.

Finally, the methodological quality was included as a second-level moderator. Two groups of meta-analyses were constructed based on their overall methodological quality score, which was calculated as the average of the four summary questions, thus had a possible range of 1 to 4. The overall methodological quality was considerably high (*Table S2*). Meta-synthesis of meta-analyses scoring lower than 3 resulted in a SMD of -0.13. Meta-synthesis of meta-analyses scoring 3 or higher resulted in a SMD of -0.12 (Table 6). Thus, neither quality nor context appeared to have influenced the effect sizes reported, whereas there seems to be a considerable difference in effect sizes reported by meta-analyses that focus on treatment compared to prevention programs.

Discussion

The central aim of this meta-synthesis was to provide comprehensive insight into the effectiveness of obesity prevention/treatment interventions. In addition to summarizing individual effect sizes into an overarching measure, moderator analyses were conducted to inform about participant and intervention characteristics that might affect effectiveness. The overall meta-synthesis suggests that intervention programs elicit a small but significant difference (SMD = -0.12) in weight loss between intervention and control groups. According to Cohen's (59) interpretation of effect sizes, an effect size of 0.20 should be interpreted as a small effect. Borenstein and colleagues (57) deem an effect size smaller than 0.20 trivial. However, the interpretation is dependent on the field of research. Previous studies have tried to estimate minimum clinical important differences (MCID) on BMIz scores to ensure health benefits in overweight children (103-108), showing that a change in BMIz score of 0.1 might already have beneficial health consequences. The effect size yielded here does not come close to this value. Although it is reasoned that clinically irrelevant interventions might still achieve public health significance at the population level, little is known about when population-level public health significance is reached (37).

First-level moderators were analyzed to gain clarity about the impact of gender, age, parental involvement, intervention duration, intervention type and the intervention's risk of bias. Meta-analyses examining those factors have yielded ambiguous results which makes a meta-synthesis of effect sizes for subgroups or specific conditions particularly valuable. Overall, BMI change in intervention and control groups was significantly different among girls, but not boys. This is in line with the assumption that girls are more motivated to adhere to the intervention than boys, because sociocultural pressure to be thin(ner) is greater for girls (28,109,110). Moreover, adolescents seemed to benefit slightly more from the intervention than children under the age of 12. It is possible that that teenagers are less active than children, which may leave more room for change among them (111). Similarly, the level of parental involvement is of some influence on the intervention's effectiveness, though only when substantial. This is also the case for intervention duration, in that longer interventions appear to yield slightly better results. Extended interventions might be more effective because they allow for repeated practice and provide more opportunity for behavior change (33). Additionally, significant BMI change is not likely to happen at a short time span (85). Notably, interventions with a high risk of bias were more likely to report statistically significant weight loss, in contrast to interventions with a low or unclear risk of bias. This pattern is worrying as it suggests that what are presumed to be effective interventions might in fact be studies that are carried out without the necessary scientific rigor.

It is important to keep in mind that several moderators mentioned in Stice and colleagues' framework (28) (e.g. ethnicity, delivery features, psychoeducational content) were not measured frequently enough in the included meta-analyses to warrant meta-synthesis. The risk status of participants is perhaps the most surprising moderator which has not been included by many authors. Participants identified as 'high risk' are more likely to gain weight in the future and are therefore important target groups for interventions. Groups with high risk status include participants from certain ethnic groups (112,113) , with intellectual disabilities (114), or from low socio economic status

(115,116). It is theoretically feasible that these factors impact intervention success, thus should be considered in future work.

Second-level moderator analyses provided little support for effect size moderation by type of intervention or quality appraisal but did show that the change in BMI in obesity treatment interventions was considerably larger than for prevention programs. This large effect size is in line with earlier research contrasting obesity prevention and treatment interventions (88,89) . A ceiling effect might exist for obesity prevention programs consisting of mixed weight populations, reasoning that if there were to be an intervention sample consisting of 20% obese participants, 20% overweight participants and 60% healthy weight participants who would all gain or maintain a healthy BMI, the effect size of such an intervention would still only be SMD = -0.41 (32), which is greater than the SMD found by this meta-synthesis, but still not high enough to be deemed clinically relevant (62).

Limitations and strengths

Despite providing the opportunity to efficiently summarize an existing body of literature, conducting a meta-synthesis carries difficulties: Firstly, meta-analyses often express the magnitude of effect by different effect sizes (e.g. Pearson's *r,* Hedge's *g,* Cohen's *d*, Odds ratio, unstandardized mean differences), and not all meta-analyses contained enough information to convert (unstandardized) effect sizes to a SMD. As a result, only about half of the initially obtained 51 meta-analyses measuring BMI (n = 26) were included in the overall meta-synthesis. Another two meta-analyses were eligible for moderation analyses, because these meta-analyses did express the effect size in a SMD, but did not provide an overall effect size and could therefore not be added to the overall effect size (*Figure 2*).

Secondly, the meta-synthesis approach used in this meta-synthesis is relatively novel. One of the disadvantages of combining meta-analyses in this way is that intervention studies might be included in multiple meta-analyses and as a result, some interventions might influence the effect size more (often) than other interventions. To reduce the probability of this happening, the degree of overlap was calculated and found to be minor. Additionally, meta-synthesis with and without meta-analyses with high overlap were conducted, differing only marginally in results. Therefore, overlap does not seem to have influenced the meta-synthesis to a large extent.

Thirdly, meta-analyses included here showed a high degree of heterogeneity, which is similar to other meta-analyses (Stanley, Carter & Doucouliagos – unpublished paper). A high level of heterogeneity implies that the robustness of the findings might be limited and that results should be interpreted with caution. Statistical heterogeneity was addressed by applying a random effects model and conducting moderator analyses, although the latter did not inform about the sources for heterogeneity, leaving open the possibility that other – untested – moderators have a greater impact.

Fourthly, this meta-synthesis included only published literature written in English. This might have increased the chances of publication bias. However, the correlation between effect size and the number of interventions included in the meta-analyses provided no evidence for the presence of publication bias. Additionally, the majority of the meta-analyses (n = 28) assessed publication bias and only four found presence of bias.

Finally, using BMI/BMIz as an outcome measure might be regarded as a limitation of this meta-synthesis. While BMI reflects a change in body weight, and thus provides information about the effectiveness of interventions, this does not necessarily imply that the absence of change in BMI reflects the ineffectiveness of an intervention. Some studies have found that other health-related outcomes improved over the course of an intervention (e.g., blood pressure, physical activity, nutrition) while no change in BMI was detected (117-119). For this meta-synthesis, BMI/BMIz was selected as the outcome measure because it was the most commonly used measure. In addition, meta-analyses using other physical measures (i.e., body weight, skinfold thickness) showed no substantially different results (29,31,63,78).

Conflict of interest statement

The authors declare no conflict of interest

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Table 1: Overview of terms used for literature search

Umbrella term	Search terms
Review	meta-analy*OR meta analy*
Weight-related	*health* OR *weight OR obesity OR nutrition OR eating OR food OR dietary intake OR fruit OR vegetable OR sedentary behavio* OR fitness OR sport* OR physical activity OR lifestyle OR exercise OR energy balance behavio* OR bmi OR tobacco OR smok* OR cigarette OR marijuana OR drug* OR alcohol OR underage drinking OR
Intervention	interven* OR prevent* OR control* OR promot* OR treat* OR improv* OR program*
Target Group	Youth OR young people OR child* OR adolescen* OR teen* OR school*

Table 2: Overview of PICOC extraction terms

Definition	Description
Population	Information about the children and adolescents which were included (e.g., age, gender, nationality, overweight or 'normal')
Intervention	Type of intervention (e.g., dietary intake, physical activity)
Comparison	Control groups with no treatment or waitlist treatment
Outcome	BMI, BMIz, prevalence of overweight/obesity, waist circumference
Context	Information about the specific context in which the interventions took place (e.g., schools, at home, community)

Table 3: Scores assigned to methodological quality of the meta-analyses

Label	Score
No	1
Probably no	2
Probably yes	3
Yes	4
Unclear	U
Not applicable	NA

Table 4: Overview of number of meta-analyses that set restrictions to the type of intervention and the intervention context

Type of intervention included		Intervention context	
	n		n
No restrictions	28	No restrictions	23
DI/SB/PA	5	Pre-school	1
DI/PA	5	School	18
PA	7	Afterschool	2
DI	3	Sports club	1
SB	1	Families	6
SB/PA	1		
HIIT	1		
Total	51	Total	51

Table 5: Characteristics of meta-analyses included in meta-synthesis.

Author	Year	Type	Context	Focus	Interventions specified	Other conditions	Range	Age	ES	CI, p-value or standard error	Type	Outcome	k	n
Aceves-Martins et al.	2016	obesity prevention	school-based	Europe		interventions ≥12 weeks	1990 - 2014	5 to 17	-0,11	[-0,20;-0,02]	SMD	BMI	18	8681
Annesi et al.	2010	obesity prevention			Youth fit for Life			4 to 12	0,07	[0,02;0,12]	*r*	BMI	16	3199
Azevedo et al.	2016	obesity prevention			sedentary behavior		1980 - 2015	0 to 17	-0,06	[-0,098;-0,022]	SMD	BMI/BMIz	71	29650
Brown et al.	2015	obesity prevention		South Asian			2006 - 2014		-0,01	[-0,29;0,28]	SMD	BMI/BMIz	5	1980
Cook-Cottone et al.	2009	obesity prevention	school-based				1997 - 2008	5 to 18	0,05	[0,04;0,06]	*r*	BMI/BMIz	66	31059
Costigan et al.	2015	obesity prevention			HIIT	interventions ≥4 weeks	any - 2014	13 to 18	-0,37	[-0,68;-0,05]	SMD	BMI	8	870
Dellert et al.	2014	obesity prevention	family-based			interventions had to involve parents	1990 - 2011		-0,09	[-0,37;0,19]	SMD	BMI	6	647
Gonzalez-Suarez et al.	2009	obesity prevention	school-based				1995 - 2007		0,74	[0,60;0,92]	OR	prevalence of overweight/obesity	7	7459
Guerra et al.	2013	obesity prevention	school-based		physical activity		any - 2012	6 to 18	-0,02	[-0,13;0,17]	SMD	BMI	11	4273
Guerra et al.	2014	obesity prevention	school-based		physical activity and diet		any - 2012	6 to 18	-0,03	[-0,09;0,04]	SMD	BMI	38	28870

Hammersley et al.	2016	obesity prevention	family-based		eHealth	interventions had to involve parents	1995 - 2015	0 to 18	-0,15	[-0,45;0,16]	SMD	BMI/BMIz	9	1452
Ho et al.	2012	obesity treatment				interventions had follow-up period ≥2 months	1975- 2010	0 to 18	-1,25	[-2,18;-0,32]	MD	BMI	13	899
Kanekar et al.	2009	obesity prevention	school-based	US/UK			2000-2007	no restrictions	0,172	[-0,38;0,72]	SMD	BMI	5	1865
Kelley et al.	2014	obesity treatment			physical activity	interventions ≥4 weeks	1990 - 2012	2 to 18	-0,47	[-0,86;-0,08]	ES $\bar{X}$	BMI	8	562
Kong et al.	2016	obesity prevention	school-based		nutrition education		any - 2014	5 to 12	0,73	[0,55;1,05]	OR	prevalence of overweight/obesity	11	17277
Liao et al.	2014	obesity prevention			sedentary behavior		any - 2012	0 to 18	-0,073	[-0,135;-0,011]	SMD	BMI	25	7045
Mei et al.	2016	obesity prevention	school-based		physical activity	intervention ≥12 months	1990 - 2015	6 to 12	-2,23	[-2,92;-1,56]	MD	BMI	18	
Niemeier et al.	2012	obesity prevention				interventions had to involve parents	any - 2011	2 to 19	0,3	SE=0,11	WAD	BMI	42	
Oosterhoff et al.	2016	obesity prevention	school-based		lifestyle		any - 2013	4 to 12	-0,07	[-0,11;-0,04]	SMD	BMI	151	
Peirson et al.	2015	obesity prevention				interventions ≥12 weeks	2010 - 2013	0 to 18	-0,07	[-0,10;-0,03]	SMD	BMI/BMIz	76	56342

Peirson et al.	2015	obesity treatment			interventions had follow-up period ≥ months	2008 - 2013	2 to 18	-0,54	[-0,73;-0,36]	SMD	BMI/BMIz	28	3346
Sbruzzi et al.	2013	obesity prevention	school-based		interventions ≥6 months	any - 2012	6 to 12	-0,07	[-0,19;0,05]	MD	BMI	20	18423
Sobol-Goldberg et al.	2013	obesity prevention	school-based			2006 - 2012	5 to 18	-0,076	[-0,123;-0,028]	SMD	BMI	32	52109
Stoner et al.	2016	obesity treatment		physical activity		any - 2015	10 to 19	0,41	[0,25;0,57]	SMD	BMI	18	647
Van Grieken et al.	2012	obesity prevention		sedentary behavior		1990 - 2010	0 to 18	-0,09	[-0,14;-0,03]	SMD	BMI	14	5197
Vasques et al.	2014	obesity prevention	school-based		interventions ≥6 weeks	2000 - 2011	0 to <19	0,068	[0,058;0,079]	*r*	BMI	52	28236

Table 5 (legend): ES, effect size; CI, confidence interval; k = number of effect sizes included; n = number of participants included; SMD, standardized mean difference; BMI, body mass index; *r,* Pearson's *r*; OR, odds ratio.

Table 6: Results of overall meta-synthesis and moderator analyses

Group or subgroup		Meta-synthesis	Hetero-geneity I^2	*k*
	Overall change	-0.12 (-0.16; -0.08)	91%	26
	Overall change	-0.17 (-0.25; -0.09)	86%	19
First-level moderators				
Gender	Girls	-0.11 (-0.17; -0.06)	41%	5
	Boys	-0.09 (-0.18; 0.01)	77%	3
Age	Participants ≤12	-0.12 (-0.20;-0.05)	94%	10
	Participants >12	-0.17 (-0.32; -0.03)	80%	6
Duration	Interventions ≤12 months	-0.11 (-0.18; -0.03)	93%	11
	Interventions >12 months	-0.16 (-0.28; -0.04)	69%	8
Parental involvement	None	-0.08 (-0.10; -0.06)	10%	3
	Minimal	-0.13 (-0.16; -0.09)	0%	2
	Moderate	-0.11 (-0.20; -0.03)	75%	2
	High	-0.21 (-0.28; -0.13)	35%	2
Type of intervention	Single component	-0.15 (-0.21; -0.08)	82%	16
	Multi-component	-0.14 (-0.20;-0.07)	90%	13
ROB interventions	Low	-0.15 (-0.37; 0.07)	97%	3
	Unclear	-0.19 (-0.46; 0.07)	95%	3
	High	-0.13 (-0.21; -0.06)	1%	3
Second-level moderators				
Intervention goal	Obesity prevention	-0.08 (-0.11; -0.06)	63%	22
	Obesity treatment	-0.48 (-0.60;-0.36)	1%	4
Intervention setting	School	-0.08 (-0.11; -0.05)	76%	12
	Family	-0.12 (-0.32; 0.09)	0%	2
Methodological quality	Score of <3	-0.13 (-0.17; -0.09)	73%	4
	Score of ≥3	-0.12 (-0.19; -0.06)	91%	22