Abstract

Background

The impact of obesity interventions on dietary intake in children and adolescents with overweight or obesity is unclear. This systematic review aimed to investigate the impact of the dietary component of weight management interventions on the change in diet in children and adolescents with overweight or obesity.

Methods

Eligible RCTs published between 1975 and 2020 were identified by a systematic search following PRISMA guidelines. Meta-analyses of eligible study outcomes was performed using R statistical software. A multi-level random effects model was used with three significant random effects fitted using Restricted Maximum Likelihood estimation.

Results

This review identified 109 RCTs, including 95 that reported at least one statistically significant dietary outcome change, and 14 reporting no significant dietary change. Results from the meta-analyses (n= 29 studies) indicated that compared to control groups, intervention groups achieved significantly greater reductions in mean total energy intake at ≤6 months (-194kcal/day, 95%CI -275.80 to -112.90kcal/day, p<0.001) and up to 12 months (-112k cal/ day 95% CI -218.92 to -5.83kcal/ day)p=0.038), increases in fruit and/or vegetable intakes over 2-12 months (*n*=34, range +0.6 to +1.5 servings/day) and reductions in consumption of sugar-sweetened beverages (*n*=28, range -0.25 to -1.5 servings/day) at 4-24 months follow-up.

Conclusions

Obesity interventions with a dietary component have a modest, but sustained impact on reducing total energy intake and improving intakes of specific food groups in children and adolescents with overweight or obesity. High quality RCTs that are powered to detect change in diet as a primary outcome are warranted.

INTRODUCTION

The global prevalence of overweight and obesity among 5-19 year olds increased from 4% to 18% between 1975 and 2016 [(1)]. Modification of dietary intake is recommended as a key strategy for the management of childhood overweight and obesity [(2-4)]. However, previous systematic reviews of interventions in children and adolescents with overweight and obesity have focused on weight related outcomes. None have targeted the impact of interventions on change in dietary intake, even among evidence-based interventions that include nutrition education components and based on age-appropriate obesity treatment principles [(1, 5, 6)].

Systematic synthesis of dietary outcomes from randomised controlled trials (RCTs) across all follow-up time points is lacking, so the overall impact of dietary interventions on changes to dietary intake remains unclear. Dietary intervention features in studies with significant improvements in post-intervention dietary intake include: use of dietary intake monitoring, such as a food diary or diet application; self or family evaluation of dietary intake compared with recommendations; use of specific strategies targeting improved dietary rather than generic healthy eating advice [(5-7)].

Whether and how dietary intake improves post intervention is important to health organisations and policy makers, including the World Health Organization [(7)], in order to inform the development of evidence-based dietary guidelines for childhood obesity management. Systematic reviews [(5, 6)] utilising data published prior to 2010 recommended improvements in: study design related to reporting of dietary outcomes, the administration of and adherence to intervention components, in future trials. Achieving consistent reporting of all aspects of study implementation and outcome data would allow robust meta-analyses of intervention effects. It would also evaluate: whether targeting intervention strategies to specific dietary intake patterns or behaviours leads to sustained improvements in dietary intake and diet-related outcomes; and which intervention components (such as adherence, specific dietary strategies, or involvement of nutrition and health professionals) influence efficacy.

There is a gap in the evidence about the dietary intervention features, contribution to and impact of these dietary components of interventions aimed at overweight and obesity in children and adolescence. The aim of this systematic review is to assess the impact of weight management interventions in children and adolescents with overweight and obesity, that include a dietary intervention, on change in dietary intake (as measured by total energy, nutrients, food groups, diet quality or food-related behaviours).

METHODS

The reporting of this review follows the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement[8]. The review protocol was prospectively submitted to PROSPERO International Prospective Register of Systematic Reviews for registration (CRD 42018104895).

Eligibility criteria

RCTs that evaluated the impact of an intervention that included a dietary component, for children or adolescents aged two to 20 years who were classified as having overweight or obesity were eligible if they reported pre and post-intervention results for at least one dietary intake variable i.e. energy, nutrients, food group intake or diet quality.. Studies were excluded if they were not an RCT or the dietary intervention was the same in multiple study arms, involved dietary supplements, or focused on eating habits (e.g.meal times) rather than dietary intake .

Systematic literature search

Eligible RCTs published from 1975 up to January 2020 were screened by two reviewers with conflicts resolved though consensus or a third reviewer. Approximately 10% of titles, and 20% of full text articles required a third reviewer. The PRISMA flow diagram is displayed in Figure 1. Table 1 reports inclusion criteria for participants, interventions, comparisons, outcomes, and study design (PICOS).

Data extraction

Data extraction was informed by the Template for Intervention Description and Replication (TIDieR) checklist [9]. Data were extracted from eligible RCTs using a standardized Microsoft Excel spreadsheet extraction tool to extract data on study population characteristics; intervention characteristics; intervention implementation features; dietary intervention characteristics and adherence; dietary intake assessment method/s and tool/s; dietary intake outcome/s and weight status assessment measure/s (Table 3, Supplementary Table 2, Supplementary Table 3). One reviewer (RT, KB, KD, VS) extracted the data while the second reviewer (VS, KD) checked data s for completeness and accuracy.

Critical appraisal

Two reviewers (LKC, KB, RT, VS, KD) independently assessed study quality using the 13-item Joanna Briggs Institute (JBI) Checklist for RCTs [(10)]. The item "Were outcomes measured in a reliable way" was divided into two items asking about weight outcomes and diet outcomes. Appraisal results (Supplementary Table 1) informed synthesis and interpretation of review findings.

Synthesis of results and analytic strategy

Preliminary data extraction indicated that most dietary outcomes could not be meta-analysed due to substantial heterogeneity. Alternative methods for synthesis of intervention effects for quantitative data were informed by Synthesis Without Meta-analysis (SWiM) guidelines [(11)].

Two reviewers (LKC, KB, RT, VS, KD) categorised intervention, participant and dietary component characteristics using a process of consolidation, preliminary grouping, discussion and consensus, as outlined in Table 2. The extracted dietary intake outcome/s were categorised by consensus. Conversion of food items reported as servings/day into grams or millilitres was not possible due to international variations in definitions of a 'serving' [(12)]. Table 2 reports how 'serving' data were categorised. Changes in dietary intake were reported as differences between baseline data and data from the longest follow-up time point.

Changes in dietary intake within included RCTs were categorised as either significant between group changes, significant pre-post changes within at least one group only, or not statistically significant. Data on within group changes were extracted to allow for exploratory analyses that could be used to inform sample size calculations in future fully powered RCTs. Studies were categorised as intention-to-treat (ITT) if data was reported for all participants who commenced the study or as completer-only (CO) if analyses only included those participants who had data at the final collection point. Other categories used for sensitivity analysis included: dietary assessment method type (i.e. 24-hour recall, weighed food record, food frequency questionnaire), comparison type (i.e. personalised, specific or general dietary advice)study quality, age of children and also those with true control groups.

Meta-analyses was conducted to evaluate overall intervention impact on change in dietary intake using the ‘metafor’ package (11) (V 2.1-0) in R statistical software (10) (V 3.6.1). For each study, effects were estimated as the mean difference between groups at each time point as Hedges’ g (standardized mean difference and mean difference) using the unbiased option for variance estimates. Negative signs for the study effects indicate a reduction in energy intake in the treatment group relative to the control group. Uncertainty in effect estimates was expressed as 95% confidence intervals (CI). Meta-regression was carried out via multilevel modelling using the rma.mv program to determine fixed moderator effects for time-based effects and other grouping variables. A multi-level random effects model was used with 3 significant random effects fitted using Restricted Maximum Likelihood (REML) estimation. The highest level random effect was for study differences with two additional random effects nested within study, level 2 (a group variable to address possible correlation due to multiple study arms that used the same control group as a reference) and level 3 (time for possible correlation between multiple time points within a study arm). Fixed effect moderators tested were dietary assessment type, comparison (Intervention or Control), study quality, age group of children, true control group, analysis type (ITT or CO) and time, all treated as categorical variables and then tested both as main effects and as an interaction with the fixed time effect. Non-significant effects were not retained in the model. The final model contained only time as an explanatory variable and was used to combine the numerous different time endpoints into broad groupings (baseline, 6 months or less, 7-12 months and >12months). Residual plots were used to examine homogeneity of variance and normality assumptions. Effect plots and their confidence intervals for time and other variables were based on marginal mean effects from the fitted model. Forest plots do not include an overall effect when there are moderator variables in the model as individual effects might not be from the same population. To assess for publication bias, funnel plots were produced and visually inspected and supported with rank correlation tests for funnel plot asymmetry.

RESULTS

Of 340 RCTs of child obesity treatment identified up to January 2020, including RCTs in the previous systematic reviews, 109 (32%) RCTs reported dietary intake outcomes and were included. Two of the 109 (1.8%) included studies reported dietary outcomes as the primary study outcome. Sixty-seven (61%) of the included RCTs reported a statistically significant between-group change in at least one dietary outcome variable over time (Table 3). Of the remaining 42 trials that reported no statistically significant between group change in dietary intake, exploratory analysis identified 28 RCTs where there was significant change in intake within one intervention arm (Supplementary Table 3).Fourteen studies reported no statistically significant change in any dietary outcome variables (13-26).

Methodological quality

A summary of JBI quality assessment of 109 included RCTs is reported in Supplementary Table 1. Overall 82% (*n*=89) of RCTs met at least half the JBI study quality criteria (10). Eight studies (27-34) met all methodological quality criteria, except for 'not applicable' ratings for blinding of participants and interventionists to group allocation, which is commonly reported as not possible in a food-based dietary intervention. Another 19 studies (15, 20, 25, 35-50) met all criteria except for 'not applicable' and one 'no' or 'unsure' rating.

Study characteristics

Detailed study characteristics of included RCTs are reported in Supplementary Table 2. (13-25, 27-121). Sixty-six percent were published from 2011 onward, and 47% conducted in the USA. There were a total of 12867 participants, with studies predominately (40%) in children aged 5-12 years. Mean participant retention rate was between 74% and 89% for study durations from less than three months to three years.

Detailed characteristics of dietary interventions in included RCTs are summarised in Supplementary Table 2. Key intervention aspects included delivery of dietary intervention components by dietitians in 46 studies, of which 31 (67%) included specific or personalised dietary advice in addition to general nutrition guidance. Seven studies (18, 23, 30, 45, 57, 85, 119) reported adherence to dietary intervention components separately from study dietary outcomes (e.g. actual intake versus prescribed dietary intake). Forty-three percent of studies (*n*=47) did not specifically mention diet adherence, 27% (*n*=29) described diet adherence methods in the methodology, and 21% (*n*=21) reported adherence based on program attendance or log-ins. Dietary intake assessment was primarily conducted using repeat 24 hour recalls (*n*=25) (16, 20, 22, 30, 35, 39, 40, 46, 56, 58, 60, 65, 70, 74, 83, 88, 89, 92, 99-101, 104, 105, 112, 114) or ≥3-day WFRs or food diaries (*n*=25) (48, 51, 53, 54, 57, 61, 62, 67-69, 73, 74, 78, 84-86, 91, 95, 97, 98, 107-109, 111, 113). Eighteen studies used multiple dietary assessment methods (19, 29, 39, 44, 45, 57, 58, 60, 62, 74, 82, 86, 92, 95, 101, 103, 112, 116). Sixty-six studies involved comparison of dietary outcomes between at least one intervention group and a wait list or standard care control group, and 43 employed a parallel (head-to-head) intervention group design.

Dietary outcomes

The most commonly reported dietary outcome variables were total energy intake (TEI) (*n*=77), energy-dense, nutrient-poor foods (EDNP) (*n*=40), fruit and/or vegetable intakes (*n*=34) and sugar-sweetened beverages (SSBs) (*n*=28) (Table 3, Supplementary Table 3).

Meta-analyses results

RCTs that reported TEI in kilojoules (kJ) or kilocalories (kcal) per day at each time point for intervention and control/comparison groups (*n*=29) were included in a meta-analysis [(26, 31, 35, 46, 61, 68, 70, 73, 78, 80, 83, 89, 95, 106, 108, 116, 120)]. Results from the meta-analyses showed that compared to control groups, intervention groups achieved significantly greater reductions in mean total energy intake at ≤6 months (-194kcal/day, 95%CI -275.80 to -112.90kcal/day, p<0.001) and up to 12 months (-112k cal/ day 95% CI -218.92 to -5.83kcal/ day)p =0.038 but not ≥ 12 month -19 kcal / day 95% CI -263.63 to 224.06 p= 0.87) (Figure 2).

For the sensitivity analysis undertaken result did not change when analysed separately based on, analysis approach (ITT vs CO) (Figure 3), study quality, dietary assessment type, age group or true control (Supplementary figures). The funnel plot (Figure 4) demonstrated symmetry, indicating there no evidence of publication bias.

Narrative synthesis results

TEI - All included studies

In addition to the 29 RCTs included in the meta-analyses, a further 40 reported a statistically significant change in TEI and 21 reported no significant change in TEI (Table 3, Supplementary Table 3). These RCTs were not eligible for meta-analyses due to not meeting TEI meta-analyses criteria. Nine RCTs reported a significant between group effect on TEI before 6 months [(36, 44, 48, 70, 84, 85, 105, 107, 109)] and six RCTs after at least six months (Table 3) [(28, 38, 62, 69, 101, 110)]. Studies that employed 24 hour recalls or food records reported TEI reductions from baseline of up to 500 kilocalories per day at six months [(101, 104)].

Twelve RCTs reported within group TEI reductions from baseline up to at least six months [(31, 34, 45, 56, 60, 78, 88-91, 111, 120)] and another 13 [(46, 49, 51, 55, 57, 65, 66, 68, 73, 74, 97, 106, 119)] reported within group

TEI reductions from baseline up to less than six months (Supplementary Table 3). Within group reductions in TEI were reported in control/comparator groups in 15 RCTs [31, 34, 43, 45, 56, 68, 74, 80, 90, 91, 97, 106, 111, 119, 120] and intervention group arms in 25 RCTs [31, 33, 34, 43, 45, 46, 51, 56, 57, 60, 65, 66, 68, 73, 74, 78, 80, 88, 90, 91, 97, 106, 111, 119, 120]. TEI reductions of over 500 kilocalories per day from baseline to 6-12 months were reported in both control/comparator and intervention groups [56, 111, 120].

Fruit and vegetables

Changes in fruit and vegetable intakes are summarised in Table 3 and Supplementary Table 3. Twenty-one out of 34 RCTs (62%) that measured vegetable and/or fruit intake reported a statistically significant increase in consumption (Table 3, Supplementary Table 3). Across studies fruit and/or vegetable intake was reported as: servings per day (s/d) (*n=11*), grams per day (g/d) (*n*=5), intake 'score' or measure (*n*=9) or percentage of TEI (*n*=1).

Between group increases in fruit and/or vegetable intake ranged from 2.3 servings per day at 2 months [81], to 0.3 to 0.5 servings per day at 8-12 months (Table 3)[47, 114]. Five studies reported a between group improvement in a fruit and vegetable score or measure [29, 43, 94, 101, 115].

Five RCTs reported a significant within group change in fruit intake in an intervention group including increased servings per day at 12 months [28]; increased g/d at 12 months [90]; increased g/d at 2-3 months [68, 119]; and decreased cups of fruit (including juice) at 12 months (Supplementary Table 3) [110]. The increase in fruit intake ranged from 1.0 serving per day at 2 months [119] to 0.3 servings per day at 6 months [31].

Seven RCTs reported significant within group increases in vegetable intake. These included: increased vegetable intake of 0.3 to 0.5 servings per day at 3-12 months (*n=3*) [31, 34, 102, 119]; higher vegetable score at 12 months (*n=1*); increased vegetables (g/d) at 2-3 months (*n=2*) [68, 119]; increased intake associated with decreased BMI (*n=1*) [37]; and an increased percentage TEI from vegetables (*n=1*) [34].

Nutrient-dense foods other than vegetables and fruit

Eight RCTs reported statistically significant between group changes in nutrient-dense food groups, including wholegrain foods or dairy/alternatives (Table 3). Dietary intervention strategies that focused on specific nutrient-dense food/s reported significant changes to intake of targeted food groups in 11 studies [38, 45, 46, 52, 63, 75, 90, 115, 116, 119, 120]. Nutrient-dense foods were reported as grams per day (*n=7*) [38, 68, 82, 90, 116, 119, 120], servings per day (*n=2*) [52, 75], a percentage of TEI (%TEI) (*n*=1) [45] or using a diet quality score (*n=2*) [63, 115].

Four RCTs reported increased dairy food intake [68, 90, 115, 119]. Between group differences included increased dairy intake at two months (+94g/d, p<0.001) [119], increased milk intake at six months (+194g/d, p<0.01) [90] and higher diet quality dairy score at 12 months [115]. One RCT reported a within group increase in dairy intake (+28g/d, p<0.05) after three months [68]. One study that aimed for lower dairy intake reported a within group decrease in milk products at 12 months (-2s/d, p<0.05) [75].

Three RCTs reported decreased meat intake [75, 90, 119]. Between group decreases in meat intake (-53g/d, p<0.001) and increased fish (+32g/d, p<0.001) at 2 months was reported in one study [119]. Within group effects on daily meat intake included a reduction in meat product intake (-2 s/d, p<0.05) at 12 months [75], and decreased meat intake in two intervention arms of one study at 12 months (-23g/d, -24g/d, both p<0.05) [90].

Three RCTs reported increased wholegrain intake [82, 115, 119]. A between group effect in favour of the comparator group was reported in one RCT (+1.4s/d, p<0.05) [82]. Other RCTs reported within group increases in both arms (+48.6g/d, +28.0g/d, both p<0.01) [119] and within group increase in the intervention group only for the ‘friendly’ grains score (p<0.05) [115]. Five RCTs reported increased fibre intake [95, 106, 116, 119, 120], including one between group effect (+4g/d, p<0.05) [116]. Within group increased fibre intakes in the intervention group ranged from +3.4g/1000cal (p<0.05) at four months [38] to +2.8g/d (p<0.05) at six months [120].

Four RCTs reported significant within group increases in total nutrient-dense food intakes, including increased servings of nutrient-dense foods per day at six months [52], an increase in percentage TEI from nutrient-dense foods at 12 months [45]; and increased diet quality scores at 12 [115] and 15 months [63].

Energy-dense beverages

i) Sugar sweetened beverages

Twenty of 28 RCTs (71%) that measured SSB intake reported a statistically significant reduction of between 0.25 and 1.5 servings per day, at post-baseline time points ranging from 4-24 months (Table 3, Supplementary Table 3). Seven studies targeted reducing SSB intake as a specific dietary intervention strategy [45, 58, 83, 89, 98, 101, 103].

Seven RCTs reported a between-group effect on SSB intake, including decreased SSB servings per day at 4-24 months [28, 41, 47, 83], a decreased %TEI from SSB at five months [66] and reduced proportion of students with high SSB intake at 24 months [37]. Ebbeling et al. [83] reported that home delivery of artificially sweetened beverages for 12 months reduced SSBs intake after 12 months (−0.7±0.1s/d, $p<0.001$), and was sustained for a further 12 months post-intervention (−0.4±0.1s/d, $p<0.01$). The usual care control group in one RCT reported a significant between group reduction compared to the intervention group after 6 months (-2.3 vs +0.34s/d, $p<0.05$).

Thirteen RCTs reported a within group change in SSB intake in an intervention group, including decreased SSB (g/d) at three months [68], decreased SSB home availability at six months [101], a reduction in daily SSB servings at 6-12 months [31, 50, 58, 75, 89, 98, 110], decreased %TEI from SSB at 12 months [34, 45], reduced intake of SSB (and desserts) at 12 months and reduced odds of consuming >2 servings of SSB per day at 24 months [103] (Table 3, Supplementary Table 3) [115].

ii) Fruit juice

Four RCTs reported a significant between-group effect on fruit juice intake, with a reduced daily fruit juice millilitres (ml/d) at three months in two intervention arms (-65ml/d, -64ml/d, both $p<0.05$) [27, 68], mean reduction in daily kilocalories from fruit juice (−45ml/d, $p<0.01$) at 12 months [83], a 1.2% decreased %TEI from fruit juice in intervention groups ($p<0.05$) at 12 and 24 months [45], increased odds of intervention group consuming fruit juice never/rarely (OR 2.5 (1.6, 3.8)) at 24 months [103].

Energy-dense, nutrient-poor foods

Of 40 RCTs that measured intake of energy-dense, nutrient-poor (EDNP) foods, 17 (43%), reported a statistically significant between group reduction in intake, as summarised in Table 3.

Five RCTs reported significant between-group effect on total EDNP food intake including decreased servings of high fat/sugar foods (-1.4 vs. -0.5s/d, $p<0.01$) at six months [82] and 12 months [115], a decreased number of EDNP foods per day at six months [104] and 24 months [29], and improved nutrient-dense versus EDNP foods ratio at 24 months (-0.9 vs −3.1, $p<0.05$) [64]. Another nine RCTs [31, 34, 45, 52-54, 56, 67, 78] reported significant within group effect on the proportion of EDNP food intake. One RCT reported decreased %TEI from EDNP foods at 12 months (-8%, p<0.01) [78] and 24 months (-7%, p<0.01) [34]. A within group decrease in total or snack EDNP food servings (-0.5 to -2.0 s/d) was reported at 2-3 months in two RCTs [52, 53] and 6-12 months in four RCTs [31, 54, 56, 67].

Two studies reported significant between-group effects, specific ‘savoury’ EDNP foods intake with decreased servings of fast food per week (-0.17 vs +0.28, p<0.05) [39], and decreased fried foods (-0.3s/d, p<0.05) at 12 months [28]. Eight studies reported significant within group effects on specific savoury EDNP foods intake [27, 37, 58, 87, 90, 115, 117, 119]. These changes include decreased fried potato/potato crisp at 4-12 months [27, 37, 58, 87], decreased fast food at 6-24 months [37, 58, 117], and improved food group choices at 2-12 months [90, 115, 119].

Four studies reported a significant between-group effect on sugar intake [45, 67, 83, 86], ranging from -48 g/d at four months (p<0.05) [67], and -49 g/d at 12 months (p<0.01) [45] to -105 g/d at 12 months (p<0.001) and -58 g/d at 24 months (p<0.01) [83]. Six studies reported a significant within group effects on sugar intake [66, 68, 90, 91, 110, 120], ranging from -15 g/d at six months (p<0.05) [120] to -9.5 g/d at 24 months [91].

Other ‘sweet’ EDNP food outcomes were reported in six RCTs [32, 37, 68, 96, 101, 107] from study durations of two to four months [68, 96, 107] to 12 to 24 months [32, 37, 101] and included reduced desserts or sweets [37, 96, 119], reduced ‘empty calorie’, ‘high calorie’ or ‘problematic’ foods [32, 68, 101].

Macronutrients

i) Macronutrient proportions

Fifteen out of 17 RCTs that assessed macronutrient intakes reported significant changes (Table 3, Supplementary Table 3), and two reported no significant changes [30, 116]. Macronutrient intakes were reported as daily grams (*n*=7) [45, 57, 60, 61, 66, 100, 105], percentage of TEI (*n*=9) [36, 38, 45, 57, 67, 73, 78, 89, 113], and glycaemic load (*n*=3) [40, 46, 92].

Intake of Dietary fats

Two RCTs reported a significant between-group effects on dietary fat intake, including an intervention effect of -4-5%E (both p<0.01) for dietary fats at three [36] or four months [38]. A dietary intervention that aimed to achieve ketosis reported a significant between-group effect on dietary fat at three months (+106g/d, p<0.001) [57].

Eleven RCTs reported a significant within group decreases in dietary fat intake, including a reduced %TEI from fat in the intervention group at 1-3 months [73, 113, 119] and 4-12 months [45, 78, 89, 115], a lower fat intake of seven to 45g/d at three to five months [61, 66, 100, 119], and a decrease of 15g/d (p<0.01) at 12 months [45]. One RCT reported a decrease in daily fat intake in control and intervention groups (-34g/d, –18 grams, p<0.05) at three months [49].

Seven out of 17 RCTs that targeted dietary fat intake reported a significant effect for dietary fats [36, 38, 57, 73, 113, 115, 119] and 10 reported no significant change [30, 40, 46, 62, 80, 99, 106, 108, 116, 120].

ii) Carbohydrate intake

Five RCTs [45, 49, 61, 66, 113] reported between-group effects on carbohydrate intake that ranged from a decrease of nine grams carbohydrate per week (p<0.05) at three months [49], to a 72 grams per day decrease at 12 months (p<0.01) [45]. Two other dietary interventions reported a significant between-group difference in daily carbohydrate intake at three months, one prescribed different nutrient proportions at breakfast (+38g/d, +25g/d, -51g/d, p<0.01) [105] and another aimed to achieve ketosis (-118 grams, p<0.001) [57]. Within group changes in carbohydrate intake were reported in both arms of two RCTs (−91g/d, p<0.001 and −71.7, p<0.001) at two months [119] and (-73g/d, p<0.01 and -72g/d, p<0.001) at six months [120].

Three studies reported a significant between-group effect on glycaemic load of -18 grams/1000 kcal (p<0.05) at five weeks [46], -22.4 grams/1000 kcal (p<0.001) at two months [40], and -13.8 grams/1000 kcal (p<0.05) at three months [92]. The %TEI from carbohydrate was higher at two to three months (p<0.05) in four studies [36, 73, 115, 119] and lower in one RCT at 12 months (p<0.05) [45]. One study reported no significant change in glycaemic load [95].

Eleven studies that reported a significant reduction in carbohydrate intake, provided an intervention with a nutrient target for daily carbohydrate intake (*n*=2) [57, 113], and food-based guidance or behaviour change strategies (*n*=9) [36, 45, 46, 49, 61, 66, 67, 92, 116]. Six other studies did not report a significant finding related to carbohydrate intake but used an intervention with a nutrient target for daily carbohydrate intake [38, 40, 48, 80, 84, 99, 109, 116, 120].

iii) Protein intake

No studies reported a significant between group effects on protein intake. Seven studies reported significant within group effect on protein intake [38, 45, 60, 113, 115, 119, 120]. Decreased grams of protein of 15 to 20g/d were reported in two RCTs, at two months follow up [119] and six months [60], and an increased %TEI from protein at three to 12 months (*n*=3) [38, 45, 113].

Dietary intake behaviour outcomes

Statistically significant changes in dietary intake related behaviours following use of behaviour/inventory/habit tools were reported in nine studies, summarised in Table 3 and Supplementary Table 3. Three studies reported a significant between-group effect on dietary behaviour changes, including a smaller decrease in family meals per week over 12 months (-0.4 vs -1.1, p<0.05) [39], reduced hunger two and three hours after a high protein breakfast compared to control (p<0.001) [109], and less daily hunger (p<0.05) after a high protein breakfast. [105] Six studies reported a significant within group differences in dietary behaviour outcomes by the intervention group, with increased odds of lunch everyday (OR 0.49 (0.30, 0.82)) [27], improved scores for restrained eating at four months [72], decreased snacking between meals at six months [42], increased odds of daily breakfast intake [103], increased proportion consuming breakfast (p<0.01) [37], and decreased grams of food consumed in a meal (-45, p<0.05) at 12 months [77].

Associations between dietary intervention features and post-intervention dietary change

Secondary analysis of dietary intervention features and dietary outcomes identified that 67% of RCTs in which a dietitian administered dietary interventions reported significant reductions in TEI, compared to 43% (X^2(1) 6.65, p<0.05) that were not dietitian-administered. Dietitians delivered a higher percentage of interventions that involved personalised dietary advice than other interventionist (69% vs, 42%, p<0.01), and similar percentages of interventions that resulted in changes in sugar-sweetened beverages (26% vs 31%), energy-dense, nutrient-poor foods (46% vs. 47%) and core foods or nutrients (67% vs. 55%).

However, no associations were identified between a dietitian administered intervention and a significant change in intake of other foods or beverages, or between the type of dietary advice (general, specific or personalised) and significant change in dietary outcomes.

DISCUSSION

This review provides a comprehensive evidence summary from RCTs published to January 2020 and the impact of dietary interventions for treatment of children and adolescents with overweight or obesity on change in dietary intake. Although meta-analyses was only possible for TEI, qualitative synthesis summarizes the impact on changes in nutrients, food groups, diet quality and dietary intake-related behaviours.

Study characteristics

Each decade has seen a marked increase in number of RCTs published (Supplementary Table 2). This parallels the worldwide increase in child obesity prevalence, particularly from 1980 to early 2000s [(2)]. The predominance of studies conducted in North America, Australia and Europe reflects the earlier rise in child obesity prevalence in these regions. More studies from Asia, the Middle East and Eastern Europe have been conducted since 2010 as prevalence of child obesity in these regions rises [(2, 122)]. However, the transferability of western interventions is questionable.

The majority of studies only included participants with obesity rather than overweight, which suggests that children and adolescents may not be identified or targeted for interventions until substantially above healthy weight ranges. A recent review by Steinbeck et al (2018) [(123)] indicated that adolescents aged 12–15 years had a 41% lower odds of successful weight reduction and maintenance compared to interventions in children aged 5–11 years. This finding highlights the importance of early treatment for established obesity, and the need for studies that target prevention and treatment earlier in childhood. The majority of RCTs were conducted in a clinical or primary care setting, with the introduction of home and technology components becoming more common in interventions published since 2016. Combining clinic-based interventions with a home-based intervention components that involve the whole family, or using methods facilitated by technology to link participants with clinicians or evidence-based resources could be targeted in future interventions [(124)], particularly given the COVID-19 pandemic has highlighted the importance of providing appropriate treatments remotely [(125)].

In RCTs included in the current review, only 2% reported dietary intake as the primary outcome. The remaining 98% included dietary intake as a secondary outcome, meaning that studies are underpowered to detect dietary change. Although recommendations for childhood obesity intervention studies suggest that only between group results be reported [(126)], exploratory analyses of within group change were reported as a supplementary file in order to guide researchers when selecting potential dietary variable to target in future fully powered trials. Included study designs predominantly compared two active intervention groups or include a comprehensive ‘standard care’ control group rather than having a ‘no intervention’ or wait list control group. This is understandable given the potential ethical implications of identifying but not treating children and adolescents with overweight or obesity, although this presents challenges when evaluating the intervention impact on dietary outcomes, and seeking to quantify true intervention effect compared with 'no intervention'. To facilitate future evidence synthesis, it is recommended that RCTs report between group non-significant findings for primary and secondary study outcomes and all within group findings in supplementary files, particularly in studies that compare two or more alternate intervention conditions in the comparison arms.

Dietary outcomes

Energy intake

Although most studies taken individually did not have a statistically significant impact on caloric intake, the summary meta-analyses reported a statistically significant reduction in TEI of between 112 kcal to 194 kcal per day at six to 12 months, with no significant reduction detected beyond 12 months from baseline. These changes in energy intake, although modest are potentially important at the population level. For example, the increase in population obesity prevalence has been modelled dynamically as corresponding to an energy imbalance of 100-200 kcal excess per person per day [(127)]. Although dietary intake reporting is prone to error and bias [(128)], these findings indicate that reduction in TEI contributes to weight change reported in the systematic reviews from which the current RCTs were drawn [(5, 6, 129)]. To demonstrate the clinical practice implications of minor dietary adjustments, Lal et al (2020) modelled the impact of a small reduction in energy-dense, nutrient-poor food consumption in Australia [(130)]. Substituting or replacing specific EDNP foods resulted in an estimated six to 57 kilojoules per day per food serve reduction in total energy intake for children aged 7-18 years. Importantly, further modelling identified that these change were associated with significant population level health improvements and substantial healthcare cost savings [(130)].

The modest long term TEI change suggests that there is a need for additional long-term interventions targeting improved dietary intake in children and adolescents with obesity. Given trial participants are likely to have been on a weight gain trajectory prior to participation in an intervention, reversing or stabilising weight gain is a positive clinical outcome [122]. Therefore, the long-term maintenance of an energy deficit needs to be prioritised in future trials for treating overweight and obesity.

Changes in food patterns and food groups

Studies reported increases in total fruit and vegetable intakes ranging from 0.6 to 1.5 servings per day at time periods up to 12 months from baseline. Future studies could consider further tailoring of dietary fruit and vegetable intake targets using personalised dietary advice and coaching to facilitate behaviour change and address barriers to increasing vegetable intakes. It is recommended that future interventions report post-intervention change in fruit and vegetable intake separately and that fruit juice and fried potato also be reported separately in order to further refine dietary intervention components.

Dietary interventions targeting intakes of specific nutrient-dense food groups were more likely to result in the intended change in the targeted food(s). In addition to the positive changes when fruit and vegetables were targeted within interventions, an increase in daily intake of servings of specific nutrient-dense foods was reported in the intervention arm of six studies (Table 3) [30, 52, 54, 58, 64, 119]. This provides some support for future interventions testing the impact of focussing on increasing specific foods, or groups of foods, as an intervention strategy, and in combination with a target to reduce intake of EDNP foods. One study [75] highlights a need to differentiate between 'nutrient-dense' lean meat and reduced fat dairy foods from 'energy-dense, nutrient-poor' meat and dairy food options in order to optimise diet quality.

The reported changes in SSBs and EDNP foods indicate that these aspects of dietary intake are amenable to change and importantly, provide support for targeting dietary components that have the potential to positively influence child weight status. Although the dietary assessment measures used to quantify SSB intake were highly variable, Ebbeling et al. found that maintenance of unsweetened beverage consumption at 12 months post-intervention was achievable [83].

Meta-analyses of EDNP results was not possible due to heterogeneity across methods used to assess EDNP foods and intake and inconsistent reporting of serving size data. It is recommended that consistent and explicit reporting of EDNP food intake be used across studies.

Future studies should report SSB intake in millilitres and EDNP foods be reported in grams and/or daily number of servings with dietary data collected across multiple days. When servings are reported, the reference database or objective serving size units, such as grams/millilitres should also be reported. These practical recommendations for reporting dietary outcomes, in combination with more explicit descriptions of dietary intervention components would facilitate future meta-analyses of study outcomes.

Guidance or goal setting targeted to individual foods and food groups was associated with improved intake of specific foods and nutrients in the short term, but sustained change in dietary intake beyond 12 months post baseline was not as commonly reported. Investigating the long-term impact of interventions that provide specific dietary advice about nutrient density of foods needs to be a research priority. This could be achieved if current and future studies implemented the suggestions for strengthening dietary intervention components in line with recommendations made in the current review. In addition, dietary strategies should focus on food-based guidance be delivered as part of a behaviour change strategy, rather than involving nutrient-focused advice.

The findings from this review indicate that participation in moderate to high intensity interventions can result in short-term changes in total dietary intake and proportions of fat, protein and carbohydrate. However, severe nutrient restrictions, such as a very low carbohydrate intake, were not sustained [85]. Food based guidance appears to be more effective in achieving longer-term dietary changes in studies where the dietary intervention focused on macronutrient-specific targets or proportions of TEI.

Summarising dietary intake behaviour outcomes was limited by the diversity of variables and assessment tools used. The favourable results reported in studies targeting increased dietary protein relative to carbohydrate suggest that increasing the proportion of protein relative to carbohydrate in isocaloric weight reduction dietary interventions for children and adolescents warrants further research. It is recommended that interventions targeting changes in macronutrient intakes also report the corresponding changes in food group intakes to inform which food patterns are more effective and sustainable post-intervention. Use of a taxonomic framework for the methodological terminology would allow for consistency and comparability when collating data from interventions, particularly for behaviour change factors that have a wide range of descriptors [131, 132].

Maintenance of dietary change post-intervention

Longer term maintenance of multiple dietary changes post-intervention were more common in RCTs that involved provision of personalised dietary advice, although this finding may have been influenced by follow-up duration. Nevertheless, the efficacy of personalised versus specific dietary advice on maintenance of dietary change could be investigated in larger studies, along with assessment of whether the involvement of a trained health professional such as dietitian, facilitates sustained dietary change.

Reporting of dietary intervention adherence would be substantially improved if it was reported for intended dietary outcomes rather than general intervention compliance measures (eg. session attendance). Dietary adherence should be reported separately for intermediate time points, and where appropriate, include use of dietary biomarkers. For example, Sondike et al measured urinary ketones when evaluating adherence to a very low carbohydrate diet [(57)]. The availability of this data would improve the quality of results, improve understanding of participants' capacity to comply with specific dietary targets, and address reporting bias [(133)]. Improving adherence measures could improve interventions outcomes. For example, electronic communication could be used to collect adherence data and simultaneously generate personalised feedback and/or be used to develop an adherence incentive strategy. Emerging technologies for non-invasive objective approximation of fruit and vegetable intake have the potential to decrease participant burden and increase accuracy in dietary assessment [(134, 135)].

Dietary intervention personnel

The association between dietitian delivery of dietary intervention components and a statistically significant reduction in TEI ($p=0.036$) highlights a need for increased specialist skills in intervention delivery. While this finding may be related to higher percentage of dietitian-delivered interventions that employed a personalised diet approach, it does warrant further investigation. This highlights an opportunity to evaluate the impact of obesity treatment interventions delivered by specialised and/or health professionals trained in roles 'fit for purpose'. The findings of the current review support dietitian-delivered, personally tailored dietary advice for individuals and their families as a strategy to improve dietary compliance, optimize nutrient intake adequacy and achieve dietary intervention goals. Further, dietitians that deliver behaviour change interventions should be experienced in behaviour change intervention delivery. Given the resource implication of delivering interventions, utilising interventionists mostly likely to facilitate families making cost-effective changes is warranted in future research.

Limitations

Some caution is warranted when interpreting the current review's findings. Despite the large number of RCTs included, the number of high methodological quality remains limited. RCTs were unlikely to be powered to detect statistically significant changes in diet as dietary intake was not usually the primary outcome. Prioritisation of reporting statistically significant results may have influenced whether or what dietary intake results were reported [(136)]. Additionally, some studies only tested for significant between-group changes in dietary outcomes, whereas others evaluated both significant and non-significant group and/or time effects. It is therefore recommended that between and within group non-significant findings for primary and secondary study outcomes be reported in supplementary files. The obesity research evidence base will develop more rapidly if results about how amenable dietary intake is to change are reported. When multiple food group or nutrient comparisons aren't adjusted for in analyses, results should be interpreted with caution. The distribution of significant findings may have been skewed because other obesity-related factors, for example physical activity and sleep were not necessarily adjusted for in the included RCTs. Finally, few studies analysed adiposity change in relation to dietary changes, which further limited secondary analysis of dietary outcomes.

Recommendations for future research and clinical practice

This review highlights the urgent need for large, comprehensive, high-quality dietary intervention trials that include specific and personalised dietary advice. Dietary advice should be delivered by qualified dietitians and have long term follow up and that are powered to detect change in dietary intake. Recommendations for reporting on dietary interventions components are shown in Supplementary Table 4. The implications of this review for practitioners who deliver interventions to address overweight and obesity for children and adolescents are summarised in Supplementary Table 5.

CONCLUSIONS

Interventions aimed at reducing overweight and obesity in children and adolescents show a modest, but clinically important reductions in intakes of total energy, SSBs and EDNP foods, increases in fruit and vegetable intakes, and altered proportion of macronutrients. Interventions that tailor dietary advice for individuals or families and that target specific dietary outcomes appear to be associated with greater improvement in dietary intake compared to provision of general dietary advice only. However, given current study limitations, results should be interpreted with caution. Future large scale trials that use robust, specific dietary intervention components should be powered to detect change in dietary intake.

REFERENCES

1. Ells LJ, Rees K, Brown T, et al. Interventions for treating children and adolescents with overweight and obesity: an overview of Cochrane reviews. Int J Obes. 2018;42(11):1823-33.
2. Bleich SN, Vercammen KA, Zatz LY, et al. Interventions to prevent global childhood overweight and obesity: a systematic review. Lancet Diabetes Endocrinol 2018;6(4):332-46.
3. Styne DM, Arslanian SA, Connor EL, et al. Pediatric Obesity-Assessment, Treatment, and Prevention: An Endocrine Society Clinical Practice Guideline. J Clin Endocrinol Metab 2017;102(3):709-57.
4. Bryant M, Ashton L, Brown J, et al. Systematic review to identify and appraise outcome measures used to evaluate childhood obesity treatment interventions (CoOR): evidence of purpose, application, validity, reliability and sensitivity. Health Technol Assess. 2014;18(51):1-380.
5. Collins CE, Warren JM, Neve M, et al. Systematic review of interventions in the management of overweight and obese children which include a dietary component. Int J Evid Based Healthc. 2007;5(1):2-53.
6. Ho M, Jensen ME, Burrows T, et al. Best practice dietetic management of overweight and obese children and adolescents: a 2010 update of a systematic review. JBI Database System Rev Implement Rep. 2013;11(10):190-293.
7. Duncanson. K., Shrewsbury VA, Collins C, et al. Interim Report on the Effectiveness of Dietary Interventions for Children and Adolescents with Overweight and Obesity for the World Health Organization. WHO, 2017 ISBN 978-0-7259-0013-7.
8. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Med. 2009;6(7):e1000097.
9. Hoffmann TC, Glasziou PP, Boutron I, et al. JBI Database System Rev Implement RepBetter reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. BMJ 2014;348:1687.
10. Joanna Briggs Institute. Critical Appraisal Tools: Checklist for Randomised Controlled Trials Adelaide, SA Joanna Briggs Institute; 2017. Available from: https://joannabriggs.org/sites/default/files/2019-05/JBI_RCTs_Appraisal_tool2017_0.pdf.
11. Campbell M, McKenzie JE, Sowden A, et al. Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline. BMJ. 2020;368:l6890.

12. Bucher T, Weltert M, Rollo ME, et al. The international food unit: a new measurement aid that can improve portion size estimation. Int J Behav Nutr Phys Act. 2017;14(1):124.
13. Estabrooks PA, Shoup JA, Gattshall M, et al. Automated telephone counseling for parents of overweight children: a randomized controlled trial. Am J Prev Med. 2009;36(1):35-42.
14. Kulik N, Ennett ST, Ward DS, et al. Brief report: A randomized controlled trial examining peer support and behavioral weight loss treatment. J Adolesc. 2015;44:117-23.
15. McCormack S, McCarthy M, Harrington S, et al. Effects of exercise and lifestyle modification on fitness, insulin resistance, skeletal muscle oxidative phosphorylation and intramyocellular lipid content in obese children and adolescents. Pediatr Obes. 2014;9(4):281-91.
16. O'Connor T, Hilmers A, Watson K, et al. Feasibility of an obesity intervention for paediatric primary care targeting parenting and children: Helping HAND. Child Care Health Dev. 2013;39(1):141-9.
17. Rifas-Shiman SL, Taveras EM, Gortmaker SL, et al. Two-year follow-up of a primary care-based intervention to prevent and manage childhood obesity: The High Five for Kids study. Pediatr Obes. 2016;12(3):e24-e7.
18. Williams CL, Strobino BA, Brotanek J. Weight control among obese adolescents: a pilot study. Int J Food Sci Nutr. 2007;58(3):217-30.
19. Bocca G, Corpeleijn E, Stolk RP, et al. Results of a multidisciplinary treatment program in 3-year-old to 5-year-old overweight or obese children: a randomized controlled clinical trial. Arch Pediatr Adolesc Med. 2012;166(12):1109-15.
20. Moore SM, Borawski EA, Love TE, et al. Two family interventions to reduce BMI in low-income urban youth: a randomized trial. Pediatrics. 2019;143(6):e20182185.
21. Armstrong S, Mendelsohn A, Bennett G, et al. Texting Motivational Interviewing: a Randomized Controlled Trial of Motivational Interviewing Text Messages Designed to Augment Childhood Obesity Treatment. Child Obes. 2018;14(1):4-10.
22. Boutelle K, Rhee K, Liang J, et al. Effect of Attendance of the Child on Body Weight, Energy Intake, and Physical Activity in Childhood Obesity Treatment: a Randomized Clinical Trial. JAMA Pediatr 2017;171(7):622-8.
23. Cohen TR, Hazell TJ, Vanstone CA, et al. Changes in eating behavior and plasma leptin in children with obesity participating in a family-centered lifestyle intervention. Appetite. 2018;125:81-9.

24. Hinton EC, Birch LA, Barton J, et al. Using neuroimaging to investigate the impact of Mandolean® training in young people with obesity: a pilot randomised controlled trial. BMC Pediatr. 2018;18(1):366.

25. Robertson W, Fleming J, Kamal A, et al. Randomised controlled trial and economic evaluation of the 'Families for Health' programme to reduce obesity in children. Arch Dis Child. 2016;102:415-26.

26. Saelens BE, Grow HM, Stark LJ, et al. Efficacy of increasing physical activity to reduce children's visceral fat: A pilot randomized controlled trial. Int J Pediatr Obes. 2011;6(2):102-12.

27. Nguyen B, Shrewsbury VA, O'Connor J, et al. Two-year outcomes of an adjunctive telephone coaching and electronic contact intervention for adolescent weight-loss maintenance: the Loozit randomized controlled trial. Int J Obes. 2013;37(3):468-72.

28. Pakpour AH, Gellert P, Dombrowski SU, et al. Motivational interviewing with parents for obesity: an RCT. Pediatrics. 2015;135(3):e644-52.

29. Taylor R, Cox A, Knight L, et al. A Tailored Family-Based Obesity Intervention: A Randomized Trial. Pediatrics. 2015;136(2):281-9.

30. Wong JMW, Ebbeling CB, Robinson L, et al. Effects of Advice to Drink 8 Cups of Water per Day in Adolescents With Overweight or Obesity: A Randomized Clinical Trial. JAMA Pediatr. 2017;171(5):e170012.

31. Raynor HA, Osterholt KM, Hart CN, et al. Efficacy of US paediatric obesity primary care guidelines: two randomized trials. Pediatr Obes. 2012;7(1):28-38.

32. Warschburger P, Kroeller K, Haerting J, et al. Empowering Parents of Obese Children (EPOC): A randomized controlled trial on additional long-term weight effects of parent training. Appetite. 2016;103:148-56.

33. Wright J, Phillips B, Watson B, et al. Randomized trial of a family-based, automated, conversational obesity treatment program for underserved populations. Obesity. 2013;21(9):E369-78.

34. Burrows T, Janet WM, Collins CE. Long-term Changes in Food Consumption Trends in Overweight Children in the HIKCUPS Intervention. J Pediatr Gastroenterol Nutr. 2011;53(5):543-7.

35. Bean MK, Ingersoll KS, Powell P, et al. Impact of motivational interviewing on outcomes of an adolescent obesity treatment: results from the MI Values randomized controlled pilot trial. Clin Obes. 2018;8(5):323-6.

36. Bonham M, Dordevic A, Ware R, et al. Evaluation of a Commercially Delivered Weight Management Program for Adolescents. J Pediatr 2017;185:73-80.
37. Broccoli S, Davoli AM, Bonvicini L, et al. Motivational interviewing to treat overweight children: 24-month follow-up of a randomized controlled trial. Pediatrics. 2016;137 (1):e20151979.
38. Chan DFY, So HK, Hui SCN, et al. Dietitian-led lifestyle modification programme for obese Chinese adolescents with non-alcoholic fatty liver disease: a randomized controlled study. Int J Obes. 2018:1-11.
39. DeBar LL, Stevens VJ, Perrin N, et al. A primary care-based, multicomponent lifestyle intervention for overweight adolescent females. Pediatrics. 2012;129(3):e611-20.
40. Ferranti S, Milliren C, Denhoff E, et al. Providing food to treat adolescents at risk for cardiovascular disease. Obesity. 2015;23(10):2109-17.
41. Gerards SMPL, Dagnelie PC, Gubbels JS, et al. The effectiveness of lifestyle triple P in the Netherlands: A randomized controlled trial. PloS one. 2015;10 (4):e122240.
42. Golan M, Kaufman V, Shahar DR. Childhood obesity treatment: targeting parents exclusively v. parents and children. Br J Nutr. 2006;95(5):1008-15.
43. Li B, Pallan M, Liu WJ, et al. The CHIRPY DRAGON intervention in preventing obesity in Chinese primaryschool-aged children: A cluster-randomised controlled trial. PLoS Med. 2019;16(11):e1002971.
44. Mameli C, Brunetti D, Colombo V, et al. Combined use of a wristband and a smartphone to reduce body weight in obese children: randomized controlled trial. Pediatr Obes. 2018;13(2):81-7.
45. Okely AD, Collins CE, Morgan PJ, et al. Multi-Site Randomized Controlled Trial of a Child-Centered Physical Activity Program, a Parent-Centered Dietary-Modification Program, or Both in Overweight Children: The HIKCUPS Study. J Pediatr. 2010;157(3):388-94.e1.
46. Rhodes E, Vernacchio L, Mitchell A, et al. A telephone intervention to achieve differentiation in dietary intake: a randomized trial in paediatric primary care. Pediatr Obes. 2017;12(6):494-501.
47. Serra-Paya N, Ensenyat A, Castro-Viñuales I, et al. Effectiveness of a Multi-Component Intervention for Overweight and Obese Children (Nereu Program): A Randomized Controlled Trial. PloS one. 2015;10(12):e0144502.
48. Shelton D, Le Gros K, Norton L, et al. Randomised controlled trial: A parent-based group education programme for overweight children. J Paediatr Child Health. 2007;43(12):799-805.

49. Tjonna AE, Stolen TO, Bye A, et al. Aerobic interval training reduces cardiovascular risk factors more than a multitreatment approach in overweight adolescents. Clin Sci. 2009;116(4):317-26.
50. Wake M, Baur LA, Gerner B, et al. Outcomes and costs of primary care surveillance and intervention for overweight or obese children: The LEAP 2 randomised controlled trial. BMJ. 2009;339(7730):1132.
51. Senediak C, Spence SH. Rapid versus Gradual Scheduling of Therapeutic Contact in a Family Based Behavioural Weight Control Programme for Children. J Cogn Psychother. 1985;13(4):265-87.
52. Graves T, Meyers AW, Clark L. An evaluation of parental problem-solving training in the behavioral treatment of childhood obesity. J Consult Clin Psychol. 1988;56(2):246-50.
53. Duffy G, Spence SH. The effectiveness of cognitive self-management as an adjunct to a behavioural intervention for childhood obesity: a research note. J Child Psychol Psychiatry. 1993;34(6):1043-50.
54. Epstein LH, Valoski A, Wing RR, et al. Ten-year outcomes of behavioral family-based treatment for childhood obesity. Health Psychol. 1994;13(5):373-83.
55. Epstein LH, Valoski AM, Vara LS, et al. Effects of decreasing sedentary behavior and increasing activity on weight change in obese children. Health Psychol. 1995 Mar;14(2):109-15.
56. Goldfield GS, Epstein LH, Kilanowski CK, et al. Cost-effectiveness of group and mixed family-based treatment for childhood obesity. Int J Obes Relat Metab Disord. 2001;25(12):1843-9.
57. Sondike SB, Copperman N, Jacobson MS. Effects of a low-carbohydrate diet on weight loss and cardiovascular risk factor in overweight adolescents. J Pediatr. 2003 Mar;142(3):253-8.
58. De Mello ED, Luft VC, Meyer F. Individual outpatient care versus group education programs. Which leads to greater change in dietary and physical activity habits for obese children? J Pediatr (Rio J). 2004;80(6):468-74.
59. Epstein LH, Paluch RA, Kilanowski CK, et al. The effect of reinforcement or stimulus control to reduce sedentary behavior in the treatment of pediatric obesity. Health Psychol. 2004;23(4):371-80.
60. White MA, Martin PD, Newton RL, et al. Mediators of weight loss in a family-based intervention presented over the internet. Obes Res. 2004;12(7):1050-9.

61. Nemet D, Barkan S, Epstein Y, et al. Short- and long-term beneficial effects of a combined dietary-behavioral-physical activity intervention for the treatment of childhood obesity. Pediatrics. 2005;115(4):e443-9.
62. Golan M, Crow S. Targeting parents exclusively in the treatment of childhood obesity: long-term results. Obes Res. 2004;12(2):357-61.
63. McCallum Z, Wake M, Gerner B, et al. Outcome data from the LEAP (Live, Eat and Play) trial: a randomized controlled trial of a primary care intervention for childhood overweight/mild obesity. Int J Obes. 2007 Apr;31(4):630-6.
64. Epstein LH, Paluch RA, Beecher MD, et al. Increasing healthy eating vs. reducing high energy-dense foods to treat pediatric obesity. Obesity. 2008;16(2):318-26.
65. Nemet D, Barzilay-Teeni N, Eliakim A. Treatment of childhood obesity in obese families. J Pediatr Endocrinol Metab. 2008;21(5):461-7.
66. Tsiros MD, Sinn N, Brennan L, et al. Cognitive behavioral therapy improves diet and body composition in overweight and obese adolescents. Am J Clin Nutr. 2008;87(5):1134-40.
67. Davis JN, Tung A, Chak SS, et al. Aerobic and strength training reduces adiposity in overweight Latina adolescents. Med Sci Sports Exerc. 2009;41(7):1494-503.
68. Garipagaoglu M, Sahip Y, Darendeliler F, et al. Family-based group treatment versus individual treatment in the management of childhood obesity: randomized, prospective clinical trial. Eur J Pediatr. 2009;168(9):1091-9.
69. Kelishadi R, Zemel MB, Hashemipour M, et al. Can a dairy-rich diet be effective in long-term weight control of young children? J Am Coll Nutr. 2009;28(5):601-10.
70. Kitzman-Ulrich H, Hampson R, Wilson DK, et al. An adolescent weight-loss program integrating family variables reduces energy intake. J Am Diet Assoc. 2009;109(3):491-6.
71. Resnick EA, Bishop M, O'Connell A, et al. The CHEER study to reduce BMI in Elementary School students: a school-based, parent-directed study in Framingham, Massachusetts. J Sch Nurs. 2009;25(5):361-72.
72. Sarvestani RS, Jamalfard MH, Kargar M, et al. Effect of dietary behaviour modification on anthropometric indices and eating behaviour in obese adolescent girls. J Adv Nurs. 2009;65(8):1670-5.
73. Ben Ounis O, Elloumi M, Zouhal H, et al. Effect of individualized exercise training combined with diet restriction on inflammatory markers and IGF-1/IGFBP-3 in Obese children. Ann Nutr Metab. 2010;56(4):260-6.

74. Codoñer-Franch P, López-Jaén A, Mano-Hernández A, et al. Oxidative markers in children with severe obesity following low-calorie diets supplemented with mandarin juice. Acta Paediatr. 2010;99(12):1841-6.
75. Duggins M, Cherven P, Carrithers J, et al. Impact of family YMCA membership on childhood obesity: A randomized controlled effectiveness trial. J Am Board Fam Med. 2010;23(3):323-33.
76. Ellis DA, Janisse H, Naar-King S, et al. The Effects of Multisystemic Therapy on Family Support for Weight Loss Among Obese African-American Adolescents: Findings From a Randomized Controlled Trial. J Dev Behav Pediatr. 2010;31(6):461-8.
77. Ford AL, Bergh C, Sodersten P, et al. Treatment of childhood obesity by retraining eating behaviour: randomised controlled trial. BMJ. 2010;340:b5388.
78. Reinehr T, Schaefer A, Winkel K, et al. An effective lifestyle intervention in overweight children: findings from a randomized controlled trial on "Obeldicks light". Clin Nutr. 2010;29(3):331-6.
79. Coppins D, Margetts B, Fa J, et al. Effectiveness of a multi-disciplinary family-based programme for treating childhood obesity (the Family Project). Eur J Clin Nutr. 2011;65(8):903-9.
80. Elloumi M, Makni E, Ounis OB, et al. Six-minute walking test and the assessment of cardiorespiratory responses during weight-loss programmes in obese children. Int J Physiother. 2011;16(1):32-42.
81. Gunnarsdottir T, Sigurdardottir ZG, Njardvik U, et al. A randomized-controlled pilot study of Epstein's family-based behavioural treatment for childhood obesity in a clinical setting in Iceland. Nord Psychol. 2011;63(1):6-19.
82. Wengle JG, Hamilton JK, Manlhiot C, et al. The 'Golden Keys' to health - A healthy lifestyle intervention with randomized individual mentorship for overweight and obesity in adolescents. J Paediatr Child Health. 2011;16(8):473-8.
83. Ebbeling CB, Feldman HA, Chomitz VR, et al. A randomized trial of sugar-sweetened beverages and adolescent body weight. N Engl J Med. 2012;367(15):1407-16.
84. Hasson RE, Adam TC, Davis JN, et al. Randomized controlled trial to improve adiposity, inflammation, and insulin resistance in obese African-American and Latino youth. Obesity. 2012;20(4):811-8.
85. Kirk S, Brehm B, Saelens BE, et al. Role of carbohydrate modification in weight management among obese children: a randomized clinical trial. J Pediatr. 2012;161(2):320-7.e1.

86. Waling M, Bäcklund C, Lind T, et al. Effects on metabolic health after a 1-year-lifestyle intervention in overweight and obese children: A randomized controlled trial. Ann Nutr Metab. 2012;2012:913965.

87. Wright K, Norris K, Newman GJ, et al. Improving healthy dietary behaviors, nutrition knowledge, and self-efficacy among underserved school children with parent and community involvement. Child Obes. 2012;8(4):347-56.

88. Boutelle K, Norman G, Rock C, et al. Guided self-help for the treatment of pediatric obesity. Pediatrics. 2013;131(5):e1435-42.

89. Davis AM, Sampilo M, Gallagher KS, et al. Treating rural pediatric obesity through telemedicine: outcomes from a small randomized controlled trial. J Pediatr Psychol. 2013;38(9):932-43.

90. Esfarjani F, Khalafi M, Mohammadi F, et al. Family-based intervention for controlling childhood obesity: An experience among iranian children. Int J Prev Med. 2013;4(3):358-65.

91. Hystad HT, Steinsbekk S, Odegård R, et al. A randomised study on the effectiveness of therapist-led v. self-help parental intervention for treating childhood obesity. Br J Nutr. 2013;110(6):1143-50.

92. Mirza N, Palmer M, Sinclair K, et al. Effects of a low glycemic load or a low-fat dietary intervention on body weight in obese Hispanic American children and adolescents: a randomized controlled trial. Am J Clin Nutr. 2013;97(2):276-85.

93. Patrick K, Norman GJ, Davila EP, et al. Outcomes of a 12-month technology-based intervention to promote weight loss in adolescents at risk for type 2 diabetes. J Diabetes Sci Technol. 2013;7(3):759-70.

94. Berry DC, Schwartz TA, McMurray RG, et al. The family partners for health study: a cluster randomized controlled trial for child and parent weight management. Nutr Diabetes. 2014;4(1):e101.

95. Kong A, Choi K, Chan R, et al. A randomized controlled trial to investigate the impact of a low glycemic index (GI) diet on body mass index in obese adolescents. BMC Public Health. 2014;14:180.

96. Lee A, Ho M, Keung V, et al. Childhood obesity management shifting from health care system to school system: intervention study of school-based weight management programme. BMC Public Health. 2014;14:1128.

97. Liber A, Szajewska H. Effect of oligofructose supplementation on body weight in overweight and obese children: a randomised, double-blind, placebo-controlled trial. Br J Nutr. 2014;112(12):2068-74.
98. Looney S, Raynor H. Examining the effect of three low-intensity pediatric obesity interventions: a pilot randomized controlled trial. Clin Pediatr. 2014;53(14):1367-74.
99. Luna-Pech J, Torres-Mendoza B, Luna-Pech J, et al. Normocaloric diet improves asthma-related quality of life in obese pubertal adolescents. Int Arch Allergy Immunol. 2014;163(4):252-8.
100. Mazzeo SE, Kelly NR, Stern M, et al. Parent skills training to enhance weight loss in overweight children: evaluation of NOURISH. Eat Behav. 2014;15(2):225-9.
101. Stark L, Clifford L, Towner E, et al. A pilot randomized controlled trial of a behavioral family-based intervention with and without home visits to decrease obesity in preschoolers. J Pediatr Psychol. 2014;39(9):1001-12.
102. Stovitz S, Berge J, Wetzsteon R, et al. Stage 1 treatment of pediatric overweight and obesity: a pilot and feasibility randomized controlled trial. Child Obes. 2014;10(1):50-7.
103. van Grieken A, Renders CM, Veldhuis L, et al. Promotion of a healthy lifestyle among 5-year-old overweight children: health behavior outcomes of the 'Be active, eat right' study. BMC Public Health. 2014;14:59.
104. Epstein L, Kilanowski C, Paluch R, et al. Reducing variety enhances effectiveness of family-based treatment for pediatric obesity. Eat Behav. 2015;17:140-3.
105. Leidy HJ, Hoertel HA, Douglas SM, et al. A high-protein breakfast prevents body fat gain, through reductions in daily intake and hunger, in "Breakfast skipping" adolescents. Obesity. 2015;23(9):1761-4.
106. Macknin M, Kong T, Weier A, et al. Plant-based, no-added-fat or American Heart Association diets: impact on cardiovascular risk in obese children with hypercholesterolemia and their parents. J Pediatr. 2015;166(4):953-9.e1.
107. Ptomey L, Sullivan D, Lee J, et al. The use of technology for delivering a weight loss program for adolescents with intellectual and developmental disabilities. J Acad Nutr Diet. 2015;115(1):112-8.
108. Visuthranukul C, Sirimongkol P, Prachansuwan A, et al. Low-glycemic index diet may improve insulin sensitivity in obese children. Pediatr Res. 2015;78(5):567-73.
109. Wang S, Yang L, Lu J, et al. High-protein breakfast promotes weight loss by suppressing subsequent food intake and regulating appetite hormones in obese Chinese adolescents. Horm Res Paediatr. 2015;83(1):19-25.

110. Foster BA, Aquino CA, Gil M, et al. A Pilot Study of Parent Mentors for Early Childhood Obesity. J Obes. 2016;2016:2609504.
111. Mendes MDSD, de Melo ME, Fernandes AE, et al. Effects of two diet techniques and delivery mode on weight loss, metabolic profile and food intake of obese adolescents: a fixed diet plan and a calorie-counting diet. Eur J Clin Nutr. 2016;71(4):549-51.
112. Pbert L, Druker S, Barton B, et al. A School-Based Program for Overweight and Obese Adolescents: A Randomized Controlled Trial. J Sch Health. 2016;86(10):699-708.
113. Truby H, Baxter K, Ware RS, et al. A randomized controlled trial of two different macronutrient profiles on weight, body composition and metabolic parameters in obese adolescents seeking weight loss. PloS one. 2016;11(3):e0151787.
114. Tomayko EJ, Prince RJ, Cronin KA, et al. The Healthy Children, Strong Families intervention promotes improvements in nutrition, activity and body weight in American Indian families with young children. Public Health Nutr. 2016;19(15):2850-9.
115. Wilson TA, Liu Y, Adolph AL, et al. Behavior Modification of Diet and Parent Feeding Practices in a Community- Vs Primary Care–Centered Intervention for Childhood Obesity. Journal of nutrition education and behavior. 2019;51(2):150-61.
116. Moschonis G, Michalopoulou M, Tsoutsoulopoulou K, et al. Assessment of the Effectiveness of a Computerised Decision-Support Tool for Health Professionals for the Prevention and Treatment of Childhood Obesity. Results from a Randomised Controlled Trial. Nutrients. 2019;11(3):706.
117. Yackobovitch-Gavan M, Wolf Linhard D, Nagelberg N, et al. Intervention for childhood obesity based on parents only or parents and child compared with follow-up alone. Pediatr Obes. 2018;13(11):647-55.
118. Warschburger P, Gmeiner M, Morawietz M, et al. Evaluation of an approach-avoidance training intervention for children and adolescents with obesity: a randomized placebo-controlled prospective trial. Eur Eat Disord Rev. 2018;26(5):472-82.
119. Ojeda-Rodríguez A, Zazpe I, Morell-Azanza L, et al. Improved Diet Quality and Nutrient Adequacy in Children and Adolescents with Abdominal Obesity after a Lifestyle Intervention. Nutrients. 2018;10(10):1500.
120. Md Yusop NB, Mohd Shariff Z, Hwu TT, et al. The effectiveness of a stage-based lifestyle modification intervention for obese children. BMC Public Health. 2018;18(1):299.
121. Hoffman J, Frerichs L, Story M, et al. An Integrated Clinic-Community Partnership for Child Obesity Treatment: a Randomized Pilot Trial. Pediatrics. 2018;141(1):e20171444.

122. Kujala U, NCD Risk Factor Collaboration. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128· 9 million children, adolescents, and adults. The Lancet. 2017;390(10113):2627-42.
123. Steinbeck KS, Lister NB, Gow ML, et al. Treatment of adolescent obesity. Nat Rev Endocrinol. 2018;14:331-44.
124. Kelly JT, Allman-Farinelli M, Chen J, et al. Dietitians Australia position statement on telehealth. Nutr Diet. 2020;77(4):406-15.
125. Woo Baidal JA, Chang J, Hulse E, et al. Zooming Towards a Telehealth Solution for Vulnerable Children with Obesity During COVID-19. Obesity 2020;28(7):1184-6.
126. Brown AW, Altman DG, Baranowski T, et al. Childhood obesity intervention studies: A narrative review and guide for investigators, authors, editors, reviewers, journalists, and readers to guard against exaggerated effectiveness claims. Obes Rev. 2019;20(11):1523-41.
127. Hall KD, Sacks G, Chandramohan D, et al. Quantification of the effect of energy imbalance on bodyweight. The Lancet. 2011;378(9793):826-37.
128. Kirkpatrick SI, Collins CE, Keogh RH, et al. Assessing dietary outcomes in intervention studies: Pitfalls, strategies, and research needs. Nutrients. 2018;10(8):1001.
129. Shrewsbury VA, Burrows T, Ho M, et al. Update of the best practice dietetic management of overweight and obese children and adolescents: a systematic review protocol. JBI Database System Rev Implement Rep. 2018;16(7):1495-502.
130. Lal A, Peeters A, Brown V, et al. The Modelled Population Obesity-Related Health Benefits of Reducing Consumption of Discretionary Foods in Australia. Nutrients. 2020;12(3):649.
131. Michie S, Wood CE, Johnston M, et al. Behaviour change techniques: the development and evaluation of a taxonomic method for reporting and describing behaviour change interventions (a suite of five studies involving consensus methods, randomised controlled trials and analysis of qualitative data). Health Technol Assess. 2015;19(99):1-188.
132. Tate DF, Lytle LA, Sherwood NE, et al. Deconstructing interventions: approaches to studying behavior change techniques across obesity interventions. Transl Behav Med. 2016;6(2):236-43.
133. Taren DL, Tobar M, Hill A, et al. The association of energy intake bias with psychological scores of women. Eur J Clin Nutr. 1999;53(7):570.

134. Burrows TL, Rollo ME, Williams R, et al. A systematic review of technology-based dietary intake assessment validation studies that include carotenoid biomarkers. Nutrients. 2017;9(2):140

135. Ermakov IV, Whigham LD, Redelfs AH, et al. Skin carotenoids as biomarker for vegetable and fruit intake: Validation of the reflection-spectroscopy based "Veggie Meter". FASEB J. 2016;30(S1):409.3.

136. Fanelli D. Negative results are disappearing from most disciplines and countries. Scientometrics. 2012;90(3):891-904.

Figure legends

Figure 1: PRISMA Flow Diagram for dietary change and intervention components in Randomised Controlled Trials for treatment of overweight and obesity in children and adolescents

Figure 2a: Forest plot for meta-analysis of mean difference [95% confidence interval] over time (months) in total energy intake in sixteen intention to treat (ITT) and completer only analysis (CO) studies that used either 24-hour recalls, weighed food records, demonstrating the effect of time on daily energy intake (Calories/ day), $p<0.05$ The posterior estimate and credible interval for each study are given by a square and a horizontal line, respectively.

Figure 2b: Standardized mean differences (SMD) showing the effect size by time (months) of total energy intake in randomised controlled trials that used 24-hour recall or weighed food records and intention to treat or completer only analysis.

Figure 3: Standardized mean differences (SMD) showing the effect size by time (months) of total energy intake in randomised controlled trials that used 24-hour recall or weighed food records and intention to treat (ITT) or completer only (CO) analysis

Figure 4: Funnel plot for meta-analysis of effect of time on energy intake in randomised controlled trials that used 24-hour recall or weighed food records