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Effects of nutritional intervention strategies in the primary prevention of overweight and obesity in school settings: systematic review and network meta-analysis

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ABSTRACT

OBJECTIVE To examine the effects of different nutritional intervention strategies in the school setting on anthropometric and quality of diet outcomes by comparing and ranking outcomes in a network meta-analysis.

DESIGN Systematic review and network meta-analysis.

DATA SOURCES PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, Education Resources Information Centre (ERIC), PsycInfo, CAB Abstracts, Campbell Library, Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI-Centre) BiblioMap, Australian Education Index, Joanna Briggs Institute Evidence-Based Practice (JBI EBP) database, Practice-based Evidence in Nutrition (PEN) database, ClinicalTrials.gov, Current Controlled Trials, and World Health Organization International Clinical Trials Registry Platform.

ELIGIBILITY CRITERIA FOR SELECTING STUDIES A systematic literature search was performed from inception to 2 May 2022. Cluster randomised controlled trials meeting these study criteria were included: generally healthy school students aged 4-18 years; intervention with ≥1 nutritional components in a school setting; and studies that assessed anthropometric measures (eg, body mass index, body fat) or measures related to the quality of diet (eg, intake of fruit and vegetables), or both. Random effects pairwise meta-analyses and network meta-analyses were performed with a frequentist approach. P scores, a frequentist analogue to surface under the cumulative ranking curve, ranging from 0 to 1 (indicating worst and best ranked interventions, respectively) were calculated. Risk of bias was assessed with Cochrane's RoB 2 tool. The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework was used to rate the certainty of evidence.

RESULTS 51 cluster randomised controlled trials involving 75 954 participants and seven intervention nodes were included. Inconsistency could not be assessed (except for intake of fruit and vegetables) because the network meta-analyses were based mainly on star shaped networks with no direct evidence for specific pairs of nutritional interventions. Overall, little or no evidence was found to support a difference in body mass index, body weight, body fat, or waist circumference and moderate improvements in intake of fruit and vegetables with nutritional interventions in a school setting. Low to moderate certainty of evidence further suggested that multicomponent nutritional interventions likely reduced the prevalence (odds ratio 0.66, 95% confidence interval 0.55 to 0.80) and incidence (0.67, 0.47 to 0.96) of overweight compared with a control group. Based on low certainty of evidence, nutrition education and multicomponent interventions may be more effective than a control group (ie, usual practice) for increasing intake of fruit and vegetables. Multicomponent nutritional interventions were ranked the most effective for reducing body mass index (P score 0.76) and intake of fat (0.82). Nutrition education was ranked as best for body mass index z score (0.99), intake of fruit and vegetables (0.82), intake of fruit (0.92), and intake of vegetables (0.88).

CONCLUSIONS The findings suggest that nutritional interventions in school settings may improve anthropometric and quality of diet measures,

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Overweight and obesity in children and adolescents are serious and rapidly growing public health concerns worldwide
- ⇒ Schools as important living environments offer opportunities for the primary prevention of overweight and obesity through a range of nutritional interventions
- ⇒ No network meta-analysis has been conducted so far to compare all of the available nutritional interventions in the school setting

WHAT THIS STUDY ADDS

- ⇒ Specific nutritional interventions in the school setting may be effective in improving weight and dietary intake outcomes and could contribute to the prevention of overweight and obesity in childhood and adolescence
- ⇒ Effects on anthropometric and quality of diet outcomes differed across single and multicomponent nutritional interventions
- ⇒ Nutrition education and literacy, and multicomponent interventions seemed to be the most effective and ranked higher than other nutritional interventions in the school setting for many of the anthropometric and quality of diet outcomes

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE, OR POLICY

- ⇒ Findings of this network meta-analysis could be useful for public health authorities and policy makers in developing and implementing effective, evidence based nutritional intervention strategies in school settings

potentially contributing to the prevention of overweight and obesity in childhood and adolescence. The findings should be interpreted with caution because the certainty of evidence was often rated as low. The results of the network meta-analysis could be used by policy makers in developing and implementing effective, evidence based nutritional intervention strategies in the school setting.

SYSTEMATIC REVIEW REGISTRATION PROSPERO CRD42020220451.

Introduction

Overweight and obesity in children and adolescents are serious and rapidly growing public health concerns worldwide.[1] Recent global estimates show that there are about 39 million (6%) overweight or obese children aged <5 years[2 3] and nearly 340 million (18%) aged 5-19 years.[4–6] Children and adolescents with overweight and obesity more often have cardiovascular and metabolic risk factors (eg, hypertension, dyslipidaemia, and insulin resistance)[7 8] and adverse psychosocial health outcomes (eg, depression).[9 10] These children and adolescents also have an increased risk of non-communicable diseases, such as cardiovascular disease or type 2 diabetes, as well as premature mortality later in life.[11 12] Suboptimal diet is a major risk factor for increased weight gain in children and adolescents.[13] High consumption of sugar sweetened beverages[14–18] and dietary sugars,[19] and low intake of fruit and vegetables[20] are particularly important dietary risk factors for childhood obesity.[21]

Children's and adolescents' understanding of health and their behaviours related to health are influenced by the living environments where they spend most of their time,[22] and these environments should be healthy. Schools are important living environments for children and adolescents and provide many opportunities for the promotion of healthy behaviours and primary prevention of overweight and obesity by implementing nutritional interventions. Several systematic reviews and pairwise meta-analyses have investigated the effects of nutritional interventions (eg, nutrition education) in school settings.[23–36] These systematic reviews, however, did not consider overweight or obesity as outcomes,[23 24] included randomised controlled trials without a nutrition component,[26 27] were limited to children aged ≤5 years,[28 29] focused on a combination of nutrition and physical activity or sedentary behaviour interventions,[32–35] or only compared a specific nutritional intervention (ie, school food environment policies) with a control group.[30]

These systematic reviews used a standard pairwise meta-analysis to compare two interventions (eg, nutrition education *v* control), and currently no network meta-analysis on the effects of different nutritional interventions in the school setting for the primary prevention of overweight and obesity exists. A network meta-analysis is an extension of a traditional pairwise meta-analysis and offers additional methodological advantages, such as simultaneous comparison and ranking of multiple interventions, and a combination of available direct and indirect evidence. Therefore, the aim of our study was to investigate the effect of different nutritional interventions in the school setting, combining direct and indirect evidence, and to rank the different nutritional interventions for their effects on various anthropometric and quality of diet outcomes in a network meta-analysis.

Methods

Study design

This systematic review and network meta-analysis was registered in PROSPERO (CRD42020220451) and the protocol has been published.[37] Online supplemental table 1 describes deviations from the protocol. The study was designed, conducted, and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[38 39]

Eligibility criteria

Studies meeting all of the following criteria were considered and included in this systematic review.

Types of studies

We included cluster randomised controlled trials with clusters at the school, district, or other geographical area level. Because some nutritional interventions involve an holistic school approach (eg, improving the quality of school cafeteria food), we excluded studies with clusters only at the classroom level.

Types of participants

Generally healthy children and adolescents aged 4-18 years who attended schools, including primary schools, secondary schools, and schools for children with special educational needs, were included. Studies that included preschool and school aged children were excluded when the study results were not reported separately. Because our network meta-analysis focused on the primary prevention of overweight and obesity, cluster randomised controlled trials with a study population of only children with obesity were not included. Cluster randomised controlled trials that mainly included children with overweight and obesity (without presenting the results separately for overweight and obesity) were also excluded, unless the proportion of children with obesity was ≤30% of the total study population.

Types of interventions

Eligible interventions included the whole school environment (eg, classrooms, cafeterias and canteens, vending machines, and tuck shops).[30] We considered cluster randomised controlled trials including one or more of the following nutritional interventions (more details are available in the published protocol[37]):

- Nutrition education and literacy (eg, classroom curriculum, educational games, tasting sessions)
- Food preparation in the school setting (eg, common preparation and consumption of fruit, vegetables, and (small) meals by children, parent-child cooking)
- School garden programmes (eg, growing and consuming school garden vegetables)
- Social marketing campaigns (eg, increased promotion and point-of-purchase advertising of healthy foods and beverages, and incentivising consumption of healthy foods)
- Nutrition friendly school initiatives (eg, improving the quality of school cafeteria food, improving the availability and affordability of healthy foods in school, and improving visibility, accessibly, and attractiveness of healthy foods in school cafeterias)
- Multicomponent intervention (eg, a comprehensive nutritional intervention strategy combining two or more of these interventions or nutritional components).

Cluster randomised controlled trials comparing nutritional interventions with one another or with a control (no or minimal intervention, wait-list or delayed intervention, and usual practice), or both, were included. We allowed for the presence of co-interventions (such as physical activity) if they were balanced across study arms within a cluster randomised controlled trial. All other cluster randomised controlled trials with no nutritional components were excluded. Interventions or measures focusing on health and safety measures, food fortification for micronutrient deficiencies, legislation on food and plant production or agricultural policy, regulation of body mass index (school report cards), regulation of alcohol of any kind, and on eating disorders (eg, anorexia nervosa, bulimia) were excluded.

Types of outcome measures

Primary outcomes included anthropometric measures: incidence and prevalence of obesity or overweight; body weight; body mass index or body mass index z score (body mass index z score is a measure of relative weight or body mass index, adjusted for the child's age and sex, compared with a reference standard[40]; online supplemental table 2 gives the definitions of overweight and obesity); body fat; and waist circumference. Secondary outcomes concerned quality of diet: daily intake of fruit and vegetables (separately and combined), fat, and sugar sweetened beverages.

Outcome data were extracted for outcomes that were assessed up to immediately after the intervention (or closest to this time point, with a maximum of six months after the intervention). Outcome data available and presented for >6 months after completion of the intervention were considered post-intervention follow-up data and were also extracted.

Search strategy

We conducted comprehensive systematic literature searches without restrictions on date or language in the following electronic databases, from inception to 2 May 2022: PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, Education Resources Information Centre (ERIC) from Proquest, PsycInfo from Ebscohost, CAB Abstracts from Ovid, Campbell Library from Rowan University Libraries Website, Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI-Centre) BiblioMap, Australian Education Index, Joanna Briggs Institute Evidence-Based Practice (JBI EBP) database, and Practice-based Evidence in Nutrition (PEN) Database. Also, reference lists from eligible studies and retrieved systematic reviews were screened, citations were tracked, and retrieved study protocols examined to identify relevant articles. Ongoing or unpublished studies were searched for in ClinicalTrials.gov, Current Controlled Trials, and World Health Organization International Clinical Trials Registry Platform (ICTRP). Online supplemental table 3 lists the search strategies for all electronic databases.

Study selection

All identified references were imported into Endnote reference manager[41] for removal of duplicates before they were uploaded to Covidence (http://www.covidence.org) for screening of the title, abstract, and full text. Selection of studies was performed in a two step process. Firstly, titles and abstracts of all identified references were screened based on the eligibility criteria; a pilot study was conducted with 100 records, and screening criteria were standardised in meetings with the reviewers. After exclusion of non-eligible records, the full texts of potentially eligible references were retrieved in the second selection step and examined in more detail. If an abstract was missing and the title of a reference seemed to be potentially relevant, the full text was reviewed. Selection of studies was based on the recommendations of the *Cochrane Handbook for Systematic Reviews of Interventions*,[42] and was carried out independently by at least two reviewers (EN, JS, or JM) in both selection steps. Any disagreements between reviewers were resolved by discussion, with involvement of a fourth reviewer (LS) if agreement could not be reached.

Data extraction

Data were independently extracted in duplicate by four reviewers (EN, JS, JM, and BN). A data extraction sheet was created and piloted a priori with three studies; data extraction was discussed and standardised in multiple meetings with reviewers. These study characteristics were extracted for each included study into a standardised Excel spreadsheet: first author (last name), year of publication, country, study acronym, study design, description of setting or school type, number of schools, length of the study (total, intervention, and follow-up), number and type of clusters, number of participants, characteristics of participants (age, sex, body mass index, proportion with overweight or obesity, socioeconomic status, and migration background), description of intervention and control arms, adherence and compliance with the intervention, description of (possible) additional components of the intervention and control arms, description of outcomes (outcomes reported, assessment instrument used, validation of assessment instrument, outcome assessor or measurer, and time of measurement), and funding source.

We extracted odds ratios with 95% confidence intervals for dichotomous (binary) data, and change from baseline values (change scores) with standard deviations for continuous data. Where available, we extracted adjusted odds ratios and adjusted change scores from an analysis of the covariance model, followed by unadjusted odds ratios or change scores, and post-intervention values; if values for the standard deviation were missing and no suitable statistics were available for their calculation or estimation, standard deviations were imputed from similar studies in the meta-analysis, as described in the Cochrane handbook.[43] If the same endpoint was considered in studies but measured with different scales or instruments, we first standardised the results and then calculated standardised mean differences; we only used post-intervention values to calculate standardised mean differences and did not combine change and post-intervention value scores together as standardised mean differences, according to Cochrane guidance.[44] Study authors were contacted (n=12, of which seven responded) for missing or unclear primary (study) data (online supplemental table 4).

Risk-of-bias assessment

Risk of bias was assessed independently in duplicate by four reviewers (EN, JS, JM, and BN) with the cluster randomised controlled trial variant of the revised Cochrane risk-of-bias tool for randomised trials (RoB 2)[45] and any disagreements were resolved by consensus. Based on RoB 2 guidance, we conducted separate risk-of-bias judgments for different types of outcomes (dietary and anthropometric). The RoB 2 tool has five domains: bias arising from the randomisation process, bias caused by deviations from the intended interventions, bias from missing outcome data, bias in the measurement of the outcome, and bias in the selection of the reported results. The variant for cluster randomised controlled trials includes an additional domain (bias arising from the timing of identification and recruitment of participants (at randomisation)). Further guidance was used to facilitate and standardise the risk-of-bias assessment among reviewers (online supplemental table 5). The overall risk of bias for a study was judged as low, some concerns, or high risk. More details are available in the published protocol.[37] Results of the risk-of-bias assessments were visualised with the risk-of-bias visualisation (robvis) tool.[46]

Data synthesis

Statistical analysis

The available direct comparisons between different nutritional interventions and control groups were illustrated with network graphs[47] (online supplemental figure 1a–m). Nodes (circles) represent the different intervention types available, and their size is proportional to the sample size of each intervention; edges (lines) represent the available direct comparisons between pairs of interventions.[48] Direct and indirect treatment effects across the cluster randomised controlled trials were then pooled and effect estimates (odds ratio, mean difference, and standardised mean difference) calculated for the outcome measures.

Reported effect estimates adjusted for clustering were used when study authors adopted an appropriate analysis method to adjust their analyses for the effect of clustering.[49] When cluster adjusted effect measures were not available, we adjusted for clustering according to Cochrane guidance[50] by reducing the sample size of the cluster randomised controlled trial to its effective sample size, taking into account the design effect (which depends on average cluster size and intracluster correlation coefficient). Because intracluster correlation coefficients were not reported in the cluster randomised controlled trials, we assumed a conservative intracluster correlation coefficient of 0.05 based on the reported assumed intracluster correlation coefficients in the included cluster randomised controlled trials. When the average cluster size for a cluster randomised controlled trial could not be determined, the effective sample size was calculated by assuming the maximum of all design effects across the other included cluster randomised controlled trials.

Random effects pairwise meta-analyses were performed for each outcome to estimate all possible pairwise comparisons. Heterogeneity of results between studies was explored with τ^2 and Cochran's

Q statistic.[51 52] Forest plots were created to display study specific and total effect estimates with corresponding 95% confidence intervals.

All available evidence was then synthesised with a random effects network meta-analysis in a contrast based frequentist framework with the R package netmeta, version 2.0-0.[53] A common variance between studies was assumed for all comparisons and estimated with a method of moment approach; 95% confidence intervals were based on the classic random effects model with quantiles from the standard normal distribution.[54] The results of the network meta-analyses are presented as summary effect estimates with 95% confidence intervals using league tables, where the network meta-analysis effects were compared with the direct pairwise effects. Interventions were then ranked with P scores according to the probability of being the most effective for a certain outcome. P scores are a frequentist analogue of the bayesian surface under the cumulative ranking curve, with values ranging from 0 to 1, indicating the worst and best ranked interventions, respectively.[55 56] For the primary outcomes overweight and obesity (separately and combined) and for the secondary outcome intake of sugar sweetened beverages, only a pairwise meta-analysis was possible because a network meta-analysis could not be performed (ie, for each of these outcomes, only one intervention (multicomponent) was compared with a control). Studies reporting intake of fruit or vegetables as portions, cups, pieces, or servings were also included in the network meta-analyses after conversion to grams per day for the calculation of mean difference effect estimates.[57]

Assessment of transitivity

To evaluate the assumption of transitivity,[58] the distribution of possible effect modifiers across the available direct comparisons was assessed. We compared the similarity of included populations and study settings in terms of age, sex, body mass index, socioeconomic status, and length of study, and found no serious imbalances in their distribution across comparisons, suggesting that no clear indication of intransitivity existed.

Assessment of consistency

To assess inconsistency, we adopted the node splitting approach, where the effect estimate for each comparison is divided into the contribution of direct and indirect evidence to see whether differences (ie, inconsistency) exist. We also created net heat plots to identify and display inconsistency in the network by applying a full treatment design interaction model[59]; a design is defined as the subset of treatments which are compared in a trial.[59]

Subgroup analyses and sensitivity analyses

Subgroup analyses were carried out when a sufficient number of studies (≥10 cluster randomised controlled trials) was available, and were performed for geographic location (continents), length of the intervention (<6 *v* ≥6 months), and age (<10 *v* ≥10 years). Subgroup analyses were planned for sex, socioeconomic status, and migration background but could not be performed because of the low number of studies reporting stratified outcomes. Post hoc sensitivity analyses were conducted for outcomes with at least 10 cluster randomised controlled trials (ie, secondary outcomes) by repeating the analyses with reported standardised mean differences instead of mean differences, post-intervention values instead of

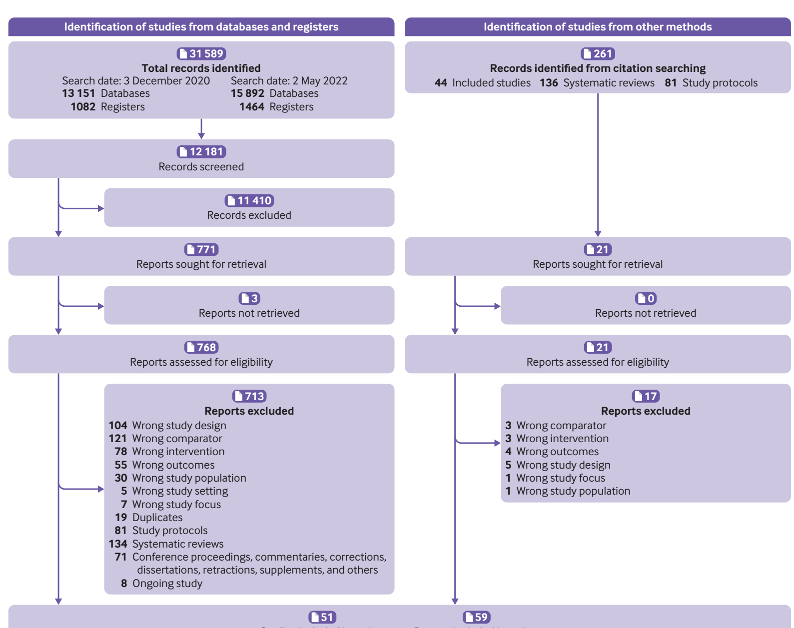

Figure 1 | Flow diagram of the study search and selection process

change scores, and by excluding cluster randomised controlled trials rated as high risk of bias.

Dissemination bias

We used comparison adjusted funnel plots and Egger's linear regression test for funnel plot asymmetry[60 61] to evaluate dissemination bias and small study effects for each outcome with at least 10 comparisons.

Assessing the certainty of the evidence

We followed the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach to rate the certainty of evidence derived from the network meta-analysis.[62] For all outcomes, the certainty of evidence in the direct, indirect, and network estimates was rated independently by two authors (EN and LS). Direct estimates were evaluated for the GRADE domains risk of bias, indirectness, inconsistency, and publication bias. According to the GRADE working group, considering imprecision is not necessary when rating direct and indirect estimates to inform the rating of network meta-analysis estimates.[62] Assessment of indirect estimates was based on the certainty of direct estimates (ie, the lowest of the ratings of the two direct comparisons forming the most dominant first order loop), and potentially rated down in the case of serious intransitivity. The certainty of network estimates was based on the respective certainty ratings for direct and indirect estimates (ie, the one with higher certainty was used for the certainty ratings of network meta-analysis estimates), and rated down if incoherence or imprecision was present.[62]

When a network meta-analysis could not be performed (eg, for the outcome overweight and obesity), the GRADE approach was used to assess the certainty of evidence for pairwise comparisons.[63] Overall, GRADE distinguishes four levels of certainty of evidence: high, moderate, low, and very low. Findings were interpreted and reported taking into account the magnitude and certainty of an effect, based on the recommendations of the most recent GRADE guidance on communicating findings of systematic reviews.[64]

Patient and public involvement

Patients or the public were not involved in setting the research question or the outcome measures, nor were they involved in developing plans for design or implementation of the study. No patients were asked to advice on interpretation or writing up of results. We have no plans to disseminate the results of the research to study participants or the relevant patient community.

Results

Search results

Figure 1 shows the PRISMA flow diagram for the study search and selection process.[39] Our search identified 31 589 records. After removing duplicates, we screened 12 181 records by title and abstract and excluded 11 410 records. We assessed 789 full text records (768 identified through database searches and 21 identified through hand searches) and excluded 730 records that did not meet our inclusion criteria (online supplemental table 6). This systematic review included 51 cluster randomised controlled trials[65–115] published between 1993 and 2021, with 42 included in the meta-analyses[65–74 76–80 82 83 86–89 91 92 94–100 103–107 109–115] (figure 1). Findings from cluster randomised controlled trials that were not included in the meta-analyses are summarised qualitatively in online supplemental table 7. We also identified eight ongoing studies (online supplemental table 6). Five cluster randomised controlled trials[68 72 74 99 106] were published in duplicate and one cluster randomised controlled trial[71] had four publications; these were referenced as one study, but all publications[116–122] of each cluster randomised controlled trial provided data for this review.

Included studies

Online supplemental tables 7–9 summarise the characteristics of the 51 identified cluster randomised controlled trials, including 75 954 children and adolescents. Most of the cluster randomised controlled trials[65–76 78–83 87–115] had two relevant arms (n=47), three[84–86] had three arms, and in one cluster randomised controlled trial[77] four arms were used. Total length of study was 1-68 months, with three studies lasting one month and one study lasting 68 months. Also, in most cluster randomised controlled trials[65 67 69 74 76–78 82 84–89 91–96 99 102–104 106–108 111 112 114 115] (n=31), follow-up concluded with a final data collection immediately after completion of the intervention; length of follow-up after the intervention in the remaining 20 cluster randomised controlled trials[66 68 70–73 75 79–81 83 90 97 98 100 101 105 109 110 113] was 0.5-24 months.

Setting

Of the 51 included studies, almost half (n=22) were conducted in the US,[68 69 74 75 77–79 82 84 85 88–90 92 98 101–106 110] four in the UK[65 80 93 96] and Australia,[70 76 99 111] and three in Norway,[67 71 72] the Netherlands,[73 94 108] and Iran[83 97 109]; online supplemental table 7 lists the other countries where studies were conducted. Most studies (n=34) were conducted in primary or elementary schools (ages 6-11 years).[65 66 68–72 76 78–81 84 86 88–93 95–97 100–102 104–107 109–112] Three studies were conducted in middle schools (ages 11-13 years),[74 75 85] two in high schools (ages 13-15 years),[83 98] and five in secondary schools (ages 12-17 years).[67 73 87 94 99] Some studies[77 82 103 108 113–115] were carried out in more than one school type.

Study populations

The sample size of the studies ranged from 129 to 21 261 children. Mean age of children and adolescents was 7-14.8 years in studies where age was reported (n=25).[65 66 68 71–73 75 77 78 80–82 86–88 90–92 100 103 105 106 108 112 113] Other studies reported school grades (n=14)[67 69 74 76 79 85 93 97 98 101 102 104 107 109] (n=14) or general age groupings and age group percentages (n=12).[70 83 84 89 94–96 99 110 111 114 115] Almost half of the studies (n=24) were conducted in adolescents.[67 71–77 81–83 85–88 91 92 98 99 103 108 111–113] On average, girls accounted for 48% of the study populations. Baseline body mass index in children was reported in only 10 studies[67 76 78 80 82 89 92 95 107 111] and ranged from 16.4 to 21.4. Only 12 studies[67 70 75 78 82 92 100 103 110 111 113 115] reported the percentage of children with obesity (1-30% across studies), with most studies reporting <22% and only one study reporting 30% (online supplemental table 7). Also, among studies that reported any measures for participants' socioeconomic status[65 66 70 73–75 77–79 82–85 95 101–104 106 107 110 112 115] (n=23), about half mainly focused on low income populations.[66 70 75 77–79 82 85 101 103 104 110] With the exception of three studies,[94 100 115] no information on the migration background of participants was reported in the included studies.

Intervention characteristics

Online supplemental table 8 and the methods section provide a detailed description of the nutritional interventions. Interventions included nutrition education and literacy (n=17), food preparation in the school setting (n=1), social marketing campaigns (n=1), nutrition friendly school initiatives (n=7), and multicomponent interventions (n=25), combining two or more of the nutritional intervention types; school gardening was not implemented as a standalone intervention, but was used as part of a multicomponent intervention in two studies.[78 110] Online supplemental figure 1a–m shows the network graphs for all of the intervention comparisons; most networks were based on indirect evidence.

Risk of bias

Online supplemental figure 2 shows the results of the assessements of risk of bias. Fifty eight risk-of-bias assessments were carried out, including two separate assessments for the anthropometric and quality of diet outcomes for seven cluster randomised controlled trials[76 78 82 89 99 106 111]; for individual cluster randomised controlled trials, the worst risk-of-bias rating was used as the overall assesssement of the risk of bias. No cluster randomised controlled trials were judged as having a low risk of bias, 23 cluster randomised controlled trials[68 70 71 76 78 82 85–88 90 93 95–97 101 102 104 105 107–109 113] (45%) had some concerns, and 28 cluster randomised controlled trials[65–67 69 72–75 77 79–81 83 84 89 91 92 94 98–100 103 106 110–112 114 115] (55%) had a high risk of bias. Most cluster randomised controlled trials[66 68–72 75–80 83 85–92 95 97 99–103 105–107 109 110 112–115] (n=37; 73%) were judged to have a low risk of bias based on the randomisation process; for about half of the cluster randomised controlled trials[65–68 71–73 75–77 79 81 83 84 86 89 97 100 101 106–111] (n=25), some concerns or a high risk of bias existed, related to the timing of identification and recruitment of participants; only four cluster randomised controlled trials[92 102 112 113] were judged to have a low risk of bias because of deviations from the intended interventions; and 17 cluster randomised controlled trials[65 66 72 75 77 79–81 89 91 92 94 98 103 106 112 115] were judged to have a high risk of bias because of missing outcome data. In almost all cluster randomised controlled trials[65–69 71–83 85–94 96–98 100–102 104–110 112 113 115] (n=44), some concerns existed for the risk of bias in measurement of the outcome.

Primary outcomes

Overweight and obesity

For overweight and obesity, only a pairwise meta-analysis was possible. Compared with a control group, we found that a multicomponent intervention likely results in a reduction in the prevalence of overweight (odds ratio 0.66, 95% confidence interval 0.55 to 0.80, $\tau^2=0$, n=3 cluster randomised controlled trials; moderate certainty of evidence) and may result in a reduction in the incidence of overweight (0.67, 0.47 to 0.96, n=1 cluster randomised controlled trial; low certainty of evidence) (table 1 and online supplemental figure 3). Also, multicomponent interventions may result in little to no difference in the prevalence of obesity (1.21, 0.97 to 1.51, $\tau^2=0.01$, n=4 cluster randomised controlled trials; low certainty of evidence) (table 1 and online supplemental figure 4). The effect of multicomponent interventions on the incidence of obesity and on the combined prevalence of overweight and obesity and the combined incidence of overweight and obesity compared with a control group was very uncertain (table 1 and online supplemental figures 4 and 5).

Body mass index and body mass index z score

Findings from the pairwise meta-analysis of all interventions together versus a control group suggested no or little difference of body mass index or body mass index z score in favour of the interventions (online supplemental tables 10 and 11). We saw no benefits of multicomponent interventions, nutrition education and literacy, nutrition friendly school initiatives, and food preparation in a school setting over a control group (very low to low certainty of evidence) (online supplemental figure 6 and online supplemental table 12). We found that multicomponent interventions may be slightly more effective in reducing body mass index than nutrition friendly school initiatives (mean difference −0.30, 95% confidence interval −0.64 to 0.04; low certainty of evidence) although this finding

Table 1 | Grading of Recommendations Assessment, Development, and Evaluation (GRADE) evidence profile for pairwise (multicomponent intervention *v* control group) comparisons on dichotomous outcomes

Assessment of certainty							No of patients/total No of patients (%)		Effect		
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Multicomponent intervention	Control group	Relative (odds ratio (95% CI))	Absolute (95% CI)	Certainty of evidence
Prevalence of obesity (length of study 11-68 months)											
4[70 82 92 103]	Randomised trials	Serious*	Not serious	Not serious	Serious†	None	257/947 (27.1)	209/922 (22.7)	1.21 (0.97 to 1.51)	35 more per 1000 (from 5 fewer to 80 more)	Low
Incidence of obesity (length of study 24-68 months)											
2[82 103]	Randomised trials	Serious*	Serious‡	Not serious	Serious§	None	51/614 (8.3)	32/608 (5.3)	1.78 (0.56 to 5.68)	37 more per 1000 (from 22 fewer to 187 more)	Very low
Prevalence of overweight (length of study 11-31.5 months)											
3[70 82 92]	Randomised trials	Serious¶	Not serious	Not serious	Not serious	None	92/597 (15.4)	97/479 (20.3)	0.66 (0.55 to 0.80)	59 fewer per 1000 (from 80 fewer to 34 fewer)	Moderate
Incidence of overweight (length of study 24 months)											
1[82]	Randomised trials	Serious**	Not serious	Not serious	Serious††	None	20/268 (7.5)	31/208 (14.9)	0.67 (0.47 to 0.96)	44 fewer per 1000 (from 73 fewer to 5 fewer)	Low
Prevalence of obesity and overweight (length of study 6-68 months)											
3[95 99 103]	Randomised trials	Very serious‡‡	Not serious	Not serious	Serious§§	None	169/412 (41.0)	187/489 (38.2)	1.19 (0.95 to 1.49)	42 more per 1000 (from 12 fewer to 97 more)	Very low
Incidence of obesity and overweight (length of study 68 months)											
1[103]	Randomised trials	Very serious¶¶	Not serious	Not serious	Serious§§	None	24/205 (11.7)	24/263 (9.1)	1.42 (0.82 to 2.45)	34 more per 1000 (from 15 fewer to 106 more)	Very low

CI=confidence interval.
*Downgraded by one level for risk of bias because half of the included randomised controlled trials were rated as high risk of bias.
†Downgraded by one level for imprecision, 95% confidence interval overlaps null effect and includes harm (odds ratio >1.25).
‡Downgraded by one level for inconsistency because point estimates and 95% confidence interval did not overlap between randomised controlled trials.
§Downgraded by one level for imprecision because number of events <400, and 95% confidence interval overlaps null effect and includes benefit (odds ratio <0.75) and harm (odds ratio >1.25).
¶Downgraded by one level for risk of bias because one of three randomised controlled trials was rated as high risk of bias.
**Downgraded by one level for risk of bias because included randomised controlled trial was rated as some concerns for risk of bias.
††Downgraded by one level for imprecision because number of events was low (n=51).
‡‡Downgraded by two levels for risk of bias because two of three randomised controlled trials were rated as high risk of bias.
§§Downgraded by one level for imprecision because number of events <400, and 95% confidence interval overlaps null effect and includes harm (odds ratio >1.25).
¶¶Downgraded by two levels for risk of bias because included randomised controlled trial rated as high risk of bias.

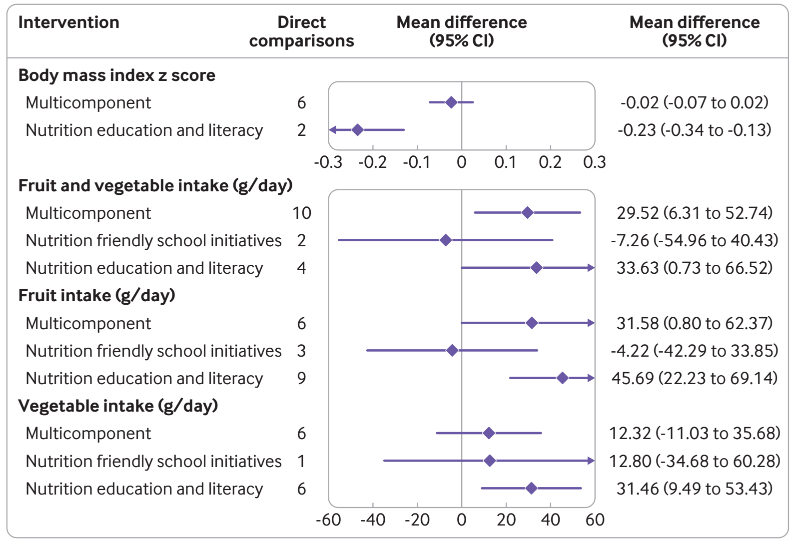

Figure 2 | Forest plots summarising mean differences with 95% confidence intervals for body mass index z score, intake of fruit and vegetables, intake of fruit, and intake of vegetables, estimated from network meta-analysis. Mean difference is comparison of other versus control (random effects model). CI=confidence interval

was not significant. Findings for the other comparisons (ie, multicomponent interventions, nutrition education and literacy, and nutrition friendly school initiatives *v* food preparation in a school setting) were very uncertain because these comparisons were based on very low certainty of evidence (online supplemental table 12).

For reducing body mass index z score, nutrition education and literacy was likely to be more effective than a control group (mean difference −0.23, 95% confidence interval −0.34 to −0.13, τ^2=0, n=2 cluster randomised controlled trials; moderate certainty of evidence) (figure 2). Little or no difference was seen between multicomponent interventions and a control group (−0.02, −0.07 to 0.02, τ^2=0, n=6 cluster randomised controlled trials; low certainty of evidence). Also, a multicomponent intervention was likely to be less effective in reducing body mass index z score than nutrition education and literacy (0.21, 0.10 to 0.32; moderate certainty of evidence) (online supplemental table 13).

Body weight, body fat, and waist circumference

Findings from the pairwise meta-analysis of all interventions compared with a control group suggested no or little difference in body weight and body fat, and a reduction (not significant) in waist circumference (mean difference −1.35 cm, 95% confidence interval −3.10 to 0.40, τ^2=1.33) (online supplemental tables 14–16). The network meta-analysis showed no benefits of multicomponent interventions, nutrition friendly school initiatives, and food preparation in a school setting over a control group for body weight (online supplemental figure 7) but the findings were based on very low to low certainty of evidence (online supplemental table 17).

For body fat (online supplemental figure 8), the certainty of evidence was low for all comparisons except for nutrition friendly school initiatives versus control, and multicomponent interventions versus nutrition friendly school initiatives (online supplemental table 18). Based on indirect evidence, a multicomponent intervention likely results in a higher reduction in percentage body fat than nutrition friendly school initiatives (mean difference −1.39%, 95% confidence interval −2.46 to −0.32; moderate certainty of evidence).

For waist circumference, we found no effect for most comparisons. However, findings from the network meta-analysis suggested that nutrition friendly school initiatives were likely more effective in reducing waist circumference than a control group (mean difference −2.62 cm, 95% confidence interval −4.68 to −0.56; moderate certainty of evidence) or a multicomponent intervention (−2.25 cm, −0.06 to −4.44; moderate certainty of evidence) (online supplemental figure 9 and online supplemental table 19).

Secondary outcomes

Fruit and vegetable intake

Pairwise meta-analyses of all interventions versus a control group suggested moderate increases in intake of fruit and vegetables (mean difference 28.42 g/day, 95% confidence interval −1.61 to 58.45, τ^2=3147.77; low certainty of evidence), intake of fruit (32.26 g/day, 13.28 to 51.23, τ^2=1461.03; low certainty of evidence), and intake of vegetables (20.82 g/day, 8.87 to 32.78, τ^2=307.58; low certainty of evidence) in favour of the nutritional interventions (online supplemental tables 20–22). Overall, findings from the network meta-analysis suggested that nutrition education and literacy (33.63 g/day, 0.73 to 66.52,

τ^2=978.57, n=4 cluster randomised controlled trials; low certainty of evidence) and multicomponent interventions (29.52 g/day, 6.31 to 52.74, τ^2=821.53, n=10 cluster randomised controlled trials; low certainty of evidence) may be more effective than a control group in increasing intake of fruit and vegetables (figure 2). The results of other comparisons (eg, nutrition friendly school initiatives *v* control, multicomponent interventions *v* nutrition education and literacy) were very uncertain (online supplemental table 23).

Likewise, the network meta-analysis showed that nutrition education and literacy (mean difference 45.69 g/day, 95% confidence interval 22.23 to 69.14, τ^2=1982.78, n=9 cluster randomised controlled trials; low certainty of evidence) and multicomponent interventions (31.58 g/day, 0.80 to 62.37, τ^2=459.42, n=6 cluster randomised controlled trials; low certainty of evidence) may result in a moderate increase in fruit intake compared with a control (figure 2). Findings for other comparisons (eg, nutrition friendly school initiatives *v* control, multicomponent interventions *v* nutrition education and literacy) were very uncertain (online supplemental table 24).

The findings of the network meta-analysis suggested that nutrition education and literacy may also result in a moderate increase in intake of vegetables compared with a control group (mean difference 31.46 g/day, 95% confidence interval 9.49 to 53.43, τ^2=749.73, n=6 cluster randomised controlled trials; low certainty of evidence) (figure 2). Findings for all other comparisons (ie, multicomponent interventions *v* control, nutrition friendly school initiatives *v* control, multicomponent interventions *v* nutrition education and literacy, multicomponent interventions *v* nutrition friendly school initiatives, and nutrition education and literacy *v* nutrition friendly school initiatives) were very uncertain (online supplemental table 25).

Fat intake

Comparison of all interventions versus a control group suggested no difference in fat intake (mean difference −0.30 g/day, 95% confidence interval −2.36 to 1.77, τ^2=3.83) (online supplemental table 26). The findings of the network meta-analysis suggested no effect of multicomponent interventions on intake of fat compared with a control group (−1.21 g/day, −3.97 to 1.55, τ^2=2.16, n=4 cluster randomised controlled trials; low certainty of evidence) (online supplemental figure 10; online supplemental table 27). Findings for all other comparisons (ie, nutrition education and literacy *v* control, multicomponent interventions *v* nutrition education and literacy) were very uncertain

Sugar sweetened beverage intake

For intake of sugar sweetened beverages, only a pairwise meta-analysis was possible. Findings suggested that multicomponent interventions may result in no difference (mean difference −0.08 times/day, 95% confidence interval −0.28 to 0.12, τ^2=0, n=2 cluster randomised controlled trials (low certainty of evidence) and −30.27 mL/day, −92.67 to 32.13, τ^2=0, n=2 cluster randomised controlled trials (very low certainty of evidence)) in intake of sugar sweetened beverages compared with a control group (online supplemental figure 11 and online supplemental table 28) but the findings were based on very low to low certainty of evidence (online supplemental table 29). Qualitative findings were more heterogeneous because two cluster randomised controlled trials[77 90] found no differences in intake of sugar sweetened beverages between the intervention (ie, nutrition friendly school initiatives or nutrition education and literacy) and the control group. One study[81] comparing nutrition education and literacy with a control group reported a reduction in intake of sugar sweetened beverages (odds ratio 0.36, 95% confidence interval 0.15 to 0.86), and another study[108] found increased intake of sugar sweetened beverages in both the nutrition education and literacy and control group (online supplemental table 7).

Ranking of effectiveness of nutritional interventions

P score values suggested that multicomponent interventions may be the most effective for reducing body mass index (0.76) and fat intake (0.82). Nutrition education and literacy might be the most effective for reducing body mass index z score (0.99), improving intake of fruit and vegetables (0.82), intake of fruit (0.92), and intake of vegetables (0.88), and nutrition friendly school initiatives for reducing waist circumference (0.85) (online supplemental table 30).

Heterogeneity and inconsistency

Statistical heterogeneity was large for combined and separate intake of fruit and vegetables, and was mainly driven through the nutrition education and literacy comparisons. For all other outcomes, statistical heterogeneity was low. Evaluation of inconsistency was only possible for intake of fruit and vegetables because all other network meta-analyses were based on star shaped networks without indirect evidence. The net heat plot showed low inconsistency for mean difference and standardised mean difference (online supplemental figures 12 and 13).

Dissemination bias

Dissemination bias was assessed for body mass index, and for combined and separate intake of fruit and vegetables (online supplemental figures 14–17). Visual examination of comparison adjusted funnel plots did not suggest serious asymmetry for body mass index, intake of vegetables, and combined intake of fruit and vegetables, but some asymmetry was found for intake of fruit. The results of Egger's linear regression tests provided an indication of the presence of small study effects for standardised mean difference results for intake of fruit (P<0.05). Because of the small number of cluster randomised controlled trials, investigating dissemination bias for any other outcomes was not possible.

Subgroup and sensitivity analyses

Online supplemental tables 31–55 and online supplemental figures 18–21 show the results of the subgroup and sensitivity analyses. Sensitivity analyses with standardised mean difference instead of mean difference, and post-intervention values instead of change scores, confirmed the results of the main analysis for combined and separate intake of fruit and vegetables (online supplemental tables 31–36 and online supplemental figures 18–20); for these outcomes (pairwise) standardised mean difference results for all interventions versus a control group were also in line with the (pairwise) mean difference results (online supplemental tables 32, 34, 36). Because of the low number of studies available, sensitivity analyses excluding cluster randomised controlled trials with a high risk of bias, and subgroup analyses by age, length of study, and geographical location, were conducted only for four outcomes (ie, body mass index, intake of fruit and vegetables, intake of fruit, and intake of vegetables). The sensitivity analyses excluding studies with a high risk of bias confirmed the findings of the primary analysis (online supplemental tables 40–43). For the subgroup analyses, we saw no major differences between age categories, length of study, and geographical location (online supplemental tables 44–55).

Discussion

This systematic review and network meta-analysis summarised data from 51 cluster randomised controlled trials comparing different nutritional interventions in school settings on multiple anthropometric and quality of diet outcomes in children and adolescents. For the primary outcomes, we found that nutritional interventions had little or no effect on body mass index, body mass index z score, body weight, body fat, or waist circumference compared with a control group. The results for specific nutritional interventions suggested that multicomponent interventions might reduce the prevalence and incidence of overweight compared with a control group; a multicomponent intervention was also found to be possibly more effective in reducing body mass index and likely more effective in reducing body fat than nutrition friendly school initiatives. For reducing body mass index z score, we found moderate certainty evidence that nutrition education and literacy is likely more effective than a control group. Likewise, moderate certainty evidence suggested that nutrition friendly school initiatives are likely more effective than a control group and multicomponent interventions in reducing waist circumference.

Findings for the secondary outcomes suggested that nutritional interventions were more effective than a control group for intake of fruit and vegetables, alone and combined, with no difference between groups for intake of fat and sugar sweetened beverages. For specific interventions, nutrition education and literacy and multicomponent interventions may be more effective than a control group for improving combined intake of fruit and vegetables. Findings with a low certainty of evidence further suggested that nutrition education and literacy and multicomponent interventions may be more effective than a control group for improving intake of fruit and that nutrition education and literacy may result in a larger increase in intake of vegetables than a control group.

Comparison with other studies

This is the first network meta-analysis on the effects of different nutritional interventions in the school setting on anthropometric and quality of diet outcomes in children and adolescents. A recently published network meta-analysis focused on nutrition, physical activity, and lifestyle interventions for the treatment of childhood obesity rather than prevention of obesity in school settings.[123] The meta-analysis reported that nutritional interventions and comprehensive approaches with parental involvement were superior to no intervention in reducing anthropometric measures (ie, body mass index, body mass index z score, percentage body fat, or percentage overweight), which partly matches our results. Involving parents can have a positive effect on the nutritional environment (eg, in school canteens).[124 125] Parents can bring about changes by influencing school management in parent-teacher conferences. On the other hand, a link between parental obesity and weight gain in their children exists,[126] and comments by parents (even if well intentioned) about children's efforts towards healthy weight management can be counterproductive.[127–129] These concerns should be taken into account when implementing measures involving parents.

Consistent with our findings, a meta-analysis[35] reported a small reduction in body mass index in adolescents after interventions in a school setting compared with a control group. A meta-analysis[23] of nutritional interventions in a school setting for improving the eating habits of primary school children found that, compared with a control, experiential learning strategies (ie, school garden, cooking and food preparation activities), cross curricular approaches (ie, learning experiences delivered in ≥2 learning areas or subjects), and approaches based on the curriculum (ie, nutrition education programmes), were associated with medium to large effects for improving intake of fruit and vegetables, supporting our findings that nutritional interventions may be more effective than a control group for increasing both combined and separate intake of fruit and vegetables.

In another meta-analysis,[24] all types of nutritional interventions in school settings were estimated to improve children's daily intake of fruit and vegetables by an average of 0.25-0.33 portions (corresponding to a daily increase of 20-30 g) compared with a control group. Multicomponent programmes were found to be more likely to result in greater improvements in intake of fruit and vegetables than single component programmes, which also agrees with our results. Also, a meta-analysis[30] on the effect of school food policies on dietary habits and obesity in children reported that direct provision of food and beverages increased daily intakes of fruit and vegetables (combined and separate) compared with a control group. Nutritional quality standards for school meals were also found to increase intake of fruit and reduce intake of total fat.In contrast with our results, no improvements were seen in the prevalence of overweight and obesity combined, overweight, body mass index, or body mass index z score compared with a control group. Similar to our study, conflicting qualitative findings were found for intake of sugar sweetened beverages. In contrast, another meta-analysis[130] of food environment interventions in a school setting reported a small reduction in body mass index z score and small increases in intake of fruit, but no differences in intake of vegetables. Although we also found only a small decrease in body mass index z score, our findings showed larger increases in intake of fruit and vegetables.

Clinical and research implications

Excessive weight gain at an early age is associated with physiological and psychological problems in the subsequent course of childhood and adolescence, and has a considerable financial burden on the public health system. Moreover, childhood obesity increases the risk of non-communicable diseases, such as cardiovascular diseases in adulthood.[7 8 11] Preventing or reducing overweight and obesity in children and adolescents is therefore critical for decreasing the risk of cardiovascular disease and the risk of developing non-communicable diseases. Also, research has shown an inverse relation between higher intake of fruit and vegetables and adiposity among children who are overweight,[131] and a harmful association between unhealthy diets rich in sugar sweetened beverages and fat and the risk of overweight and obesity.[132] Schools are important settings for shaping and promoting lifelong healthy eating habits in children and adolescents, and can provide important opportunities for prevention of overweight and obesity through health and nutrition programmes in the school setting.

That environments where children and adolescents spend time offer good opportunities to promote healting eating habits, has been confirmed in a meta-analysis[133] that synthesised data on intervention strategies to promote healthy meals in restaurants and canteens. The most prominent improvements for intake of healthy food groups were found in studies in children.[133] The school environment is therefore a suitable setting for implementing these strategies. Also, the availability of healthy items in school canteens is associated with an increased willingness of children and adolescents to buy these food groups.[134] According to the WHO Global Nutrition Policy Report, 142 of 160 countries (89%) implemented healthy diet and nutrition programmes in 2016-17, although implementation has generally declined in recent years.[135] Comprehensive or multicomponent nutritional interventions were also rarely implemented.[135] The Commission on Ending Childhood Obesity strongly recommends implementing comprehensive programmes that promote the intake of healthy foods and reduce the intake of unhealthy foods, create healthy school environments, and promote health and nutrition literacy in school aged children and adolescents.[136] Our findings support these recommendations, because we showed that the effects on anthropometric and quality of diet outcomes differed across single and multicomponent nutritional interventions. Although beneficial effects were seen with some single component interventions (eg, nutrition friendly school initiatives), nutrition education and literacy as well as multicomponent interventions mostly ranked highest.

Factors that contribute to childhood overweight and obesity are complex and multifaceted and require a whole system approach, targeting multiple stakeholders and environments to drive behavioural change (eg, nutrition education at the individual, family, community, and school levels). Thus developing multicomponent interventions is essential and should ideally involve multidisciplinary teams with participation of all relevant stakeholders (eg, parents, schools, and municipalities), including experts in nutrition education and didactics.

Strengths and limitations

Our systematic review and network meta-analysis has several strengths and limitations. The strengths include the comprehensive and rigorous literature searches in multiple electronic databases and trial registries, a priori published protocol, network meta-analysis methodology incorporating direct and indirect evidence to compare and rank interventions that have not been previously compared, detailed risk of bias assessment with the new risk of bias 2 tool, extensive subgroup and sensitivity analyses, and the GRADE framework for assessing the certainty of the evidence.

Our results were limited by the exclusion of interventions that combined both nutrition and physical activity or other non-nutritional components, and which were implemented in non-school settings (eg, after school settings). Findings on intake of fruit and vegetables (separately and combined) were limited by large statistical heterogeneity. Also, in nearly all of the networks, interventions were compared with controls, resulting in little or no direct comparative evidence for the different nutritional interventions. This limitation also prevented an assessment of inconsistency because of the lack of both direct and indirect evidence for pairs of nutritional interventions. Also, reporting of outcomes was inconsistent across studies; for example, anthropometric outcomes, such as body mass index, were reported less often and some studies did not report combined intake of fruit and vegetables. Hence selective reporting of outcomes cannot be excluded and might have influenced our analyses. These factors contributed to the small number of trials for many comparisons and might explain why pairwise meta-analyses for most primary outcomes showed little to no effects, with wide confidence intervals. Similarly, most studies did not report baseline data for the prevalence of obesity, restricting the interpretation of findings. However, because the prevalence of obesity was relatively low (<22%), we did not assume that the other studies included >30% of children with obesity.

Most cluster randomised controlled trials differed in study length (range 1-68 months) and lacked longitudinal follow-up data, limiting interpretations of the long term effects of different nutritional interventions. Future research should include well designed (cluster) randomised controlled trials assessing the long term effects of nutritional interventions in the school setting with more rigorous reporting of study characteristics and findings. The studies included in the meta-analyses used different instruments to assess dietary intake outcomes, including 24 hour dietary recalls, food diaries, and food frequency questionnaires on one or multiple days, which might explain some of the observed heterogeneity. Subgroup analyses on sex, socioeconomic status, and migration background could not be conducted in our network meta-analysis, and children and adolescents with differences in these characteristics might respond differently to nutritional interventions; we did not consider subgroup analyses of other factors that might have influenced the results, such as school year, baseline overweight status, and different definitions of overweight and obesity. Hence future research efforts should investigate interactions between nutritional interventions and sex, socioeconomic status, background, and school year.

Finally, many of the interventions (ie, multicomponent interventions) included in our review involved multiple nutritional components which are likely to have had synergistic effects but could also not have been similar enough (in components, content, or extent of implementation) across studies to be combined into one (multicomponent intervention) group. Component network meta-analysis was not possible in this review, however, and only limited conclusions can be drawn about the effects of the individual nutritional components and their combined effect in multicomponent interventions. This problem is not limited to nutritional interventions. Comparable difficulties in assessing the effectiveness of individual strategies in multicomponent interventions were reported[137] in a systematic review of studies investigating the promotion of physical activity during school recess in children and adolescents.

Conclusion

Nutritional interventions in school settings showed beneficial effects on reducing the risk of overweight and on increasing the combined and separate consumption of fruit and vegetables. Future studies should distinguish between the effects of individual strategies within multicomponent interventions so that synergies can be better recognised and implemented in holistic measures. Future studies should also include process evaluations and cost effectiveness analyses of interventions, which could be of interest to policy makers in countries where resources are scarce.[138,139] The results of our network meta-analysis could be of interest to public health authorities and policy makers worldwide in developing and implementing effective, evidence based nutritional intervention strategies in school settings.

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Contributors LS designed the research. KG conducted the systematic literature search. EN, JS, JM, and BN screened records, extracted data, and assessed risk of bias. EN and LS rated the certainty of evidence. EN, GS, and LS analysed the data and wrote the first draft of the paper. EN, JS, JM, BN, KG, GS, GH, CMA, JMS, JW, JC, DS, JJM, and LS interpreted the data, read and substantively revised the manuscript, and approved the final version. EN and LS are guarantors. The

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