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Review Article

Outcome evaluation of fruits and vegetables distribution interventions in schools: a systematic review and meta-analysis

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Abstract

Objective: Fruits and vegetables (FV) distribution interventions have been implemented as a public health strategy to increase children's intake of FV at school settings. The purpose of this review was to examine whether snack-based FV distribution interventions can improve school-aged children's consumption of FV.

Design: Systematic review and meta-analysis of articles published in English, in a peer-reviewed journals, were identified by searching six databases up to August 2020. Standardised mean differences (SMD) and 95 % CI were calculated using a random effects model. Heterogeneity was quantified using I^2 statistics.

Setting: Population-based studies of interventions where the main focus was the effectiveness of distributed FV as snacks to schoolchildren in North America, Europe and Pacific were included.

Results: Forty-seven studies, reporting on fifteen different interventions, were identified; ten studies were included in the meta-analysis. All interventions were effective in increasing children's consumption of FV, with only one intervention demonstrating a null effect. Pooled results under all classifications showed effectiveness in improving children's consumption of FV, particularly for multi-component interventions at post-intervention (SMD 0·20, 95 % CI 0·13, 0·27) and free distribution interventions at follow-up (SMD 0·19, 95 % CI 0·12, 0·27).

Conclusions: Findings suggest that FV distribution interventions provide a promising avenue by which children's consumption can be improved. Nonetheless, our results are based on a limited number of studies, and further studies should be performed to confirm these results. More consistent measurement protocols in terms of rigorous study methodologies, intervention duration and follow-up evaluation are needed to improve comparability across studies.

Keywords
Fruit
Vegetable
Schoolchildren
Snacks
Systematic review
Meta-analysis

Fruits and vegetables (FV) are important components of a healthy diet, and sufficient daily consumption is associated with nutritional adequacy[1,2] and the prevention of the majority of non-communicable chronic diseases[3]. Recommended consumption of FV for children aged 4 to 13 years is five to six servings;[4] however, children are consuming less than the recommended amounts[5–9]. Low FV consumption in children is concerning, considering that dietary habits established in childhood tend to carry into later adulthood[5,10,11], thus making childhood an opportune time for health promotion initiatives to instill healthy dietary behaviours.

Schools are the optimal setting for implementing health-promoting interventions because of the amount of time

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children spend in school, as well as the large percentage of food consumption that occurs during school hours[12,13]. It is reasonable to suggest then, that with significant time allotment, the school system has a responsibility to enhance the health and well-being of children. In addition, a large number of children can be reached through schools, regardless of their ethnicity, socio-economic background and/or nutritional status, thus reducing social inequalities[14]. Given that low FV intake is one of the lifestyle factors that may contribute to the health inequalities within society, providing/distributing FV to children within the school environment has the potential to reduce social inequalities[14,15].

Numerous systematic reviews aimed at increasing children's consumption of FV have been conducted; however, most have been conducted in only one region;[16] using only one study design[17,18]; with children under 5 years of age[19]; or using a broad scope of intervention strategies[20–26]. None, to our knowledge, have focused on FV distribution-based interventions that address the strategies of *availability and accessibility* – two important environmental mediators that have been identified as consistent and positive predictors of children's FV consumption[21,27,28]. While availability is defined as the presence of FV in the home or school environment, accessibility is defined as FV that are prepared, presented and/or maintained in a form that enables or motivates children to consume them (e.g. cutting up FV or designating time to eat FV)[27].

With the rapid influx of research on school food programming, a synthesis of the literature on this age group is needed. As such, the aim of this systematic review and meta-analysis was to evaluate the effectiveness of FV distribution interventions as a snack on school-aged children's intake of FV. Primarily, the review focuses on studies that provided children with readily accessible and available nutritious FV during school hours as snacks (outside of breakfast or lunch time), as most of these programmes were conducted in a non-canteen system where no school-supplied or provided meals are offered. Additionally, results are pooled in a meta-analysis, which quantifies the evidence provided by the different studies, giving a precise estimate of the effect, and increasing the generalisability of the individual studies. Additionally, conducting such analyses would guide the design of future snack-based FV distribution-based interventions and would provide valuable findings to inform future research, practice and policy.

Methods

The authors followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines during all stages of design, implementation and reporting[29].

Search strategy

Relevant studies were identified by searching PUBMED, ProQuest, EMBASE, CINAHL, Web of Science Core Collection and Scopus databases. The initial database searches were conducted in February 2019, with an updated search in August 2020. No date limit, language or geographic location restriction was applied; however, the search primarily yielded studies from the last 20 years. The search strategy was designed to be comprehensive by including different keywords selected from previously published literature in the area of school food programming. In consultation with an experienced librarian and informed by published literature in this area, searches were carried out combining four different search arms: *(school* OR 'school-based') AND (intervention* OR program* OR scheme* OR campaign* OR initiative*OR project*) AND (fruit* OR vegetable*) AND (provision OR subsidised OR distribution OR free OR availability OR exposure OR accessibility)*. This method was adapted when Medical Subject Headings (MeSH) terms were not available. One reviewer screened the titles of the studies and imported all relevant titles into a citation manger (Mendeley v1.17.10). Duplicates were then removed and from the remaining studies, and abstract screening was completed independently by two reviewers. For any potentially relevant studies, full texts were assessed for eligibility independently by two reviewers. Once eligible studies were identified, a manual search of the reference lists of the included studies was conducted to identify any missed relevant studies. If consensus could not be achieved between the two independent reviewers, the senior corresponding author discussed, elucidated and resolved the adjudication process with the reviewers.

Study selection

To be included in the present review, studies needed to meet the following eligibility criteria: *Population*: school-aged children aged 4–14 years; *Intervention*: FV distribution as a snack solely or combined with another intervention approach (e.g. nutrition education, parental involvement) within the school environment; *Comparator*: no intervention (control) or an alternative intervention; and *Outcome*: FV consumption. All study designs were considered. Studies were excluded if they were reviews, conference proceedings/abstracts, design protocols or studies that reported on interventions that used other intervention approaches to increase children's consumption of FV.

Data extraction and abstraction

The following information was extracted from each study: (1) basic identifying information about the study (authors, year of publication, programme name and country); (2) participants; (3) study design; (4) intervention group(s); (5) data collection methods and (6) findings.

Public Health Nutrition

The Effective Public Health Practice Project (EPHPP) tool was used to assess the quality of each study on six criteria: selection bias, study design, confounding, blinding, data collection methods and withdrawals, and dropouts. Each criterion was rated as strong, moderate or weak, and these ratings were summed to obtain an overall score for each study. A 'strong' quality study had no weak rating, a 'moderate' quality study had one weak rating and a 'weak' quality study had two or more weak ratings[30]. Each study was rated independently by two reviewers and disagreements were amended following discussion. In remaining cases of disagreement or uncertainty, the senior corresponding author discussed and resolved final scoring with the two independent reviewers.

Data synthesis

As FV consumption was assessed using multiple methods, the effect size for the meta-analysis was measured as a standardised mean difference (SMD) with a 95 % CI. We used SMD because the primary outcome was continuous, and we expected some variability in the way outcomes were measured. Heterogeneity was assessed using the I^2 statistic, which describes the proportion of total variation attributable to between-study heterogeneity[31]. I^2 values <30 % were considered to be low, values between 30 % and 50 % were considered to be low to moderate, values between 50 % and 75 % were considered to be moderate to high, and values >75 % were considered to be high[31]. I^2 values >50 % indicate that caution should be used when drawing conclusions from the data[32]. A random effects model was used to estimate the SMD in FV consumption because of its ability to statistically control for heterogeneity and to provide for wider 95 % CI than the fixed-effects model when significant heterogeneity is expected.

To be considered for inclusion in the meta-analysis, studies needed to provide the standard deviation (or sufficient information to calculate these) and the sample size. Where information on FV consumption in grams was missing, it was assumed that one portion of fruit and/or vegetable was equivalent to 100 g[3,33,34]. When standard error was reported in place of standard deviation, standard deviation were estimated using $\text{SD} = \sqrt{n}\, x$ (upper limit − lower limit)/3·92 where n is the number of participants in each group[35]. If interested outcomes were presented as interquartile range (IQR), standard deviation was calculated using IQR/1·35. This is generally only possible when the data are normally distributed. Given IQR is typically only reported in lieu of standard deviation when the data are non-normal, standard deviation was recorded in the data set for this study, assuming a normal distribution[36]. Pooled standard deviations[32] were estimated for two studies[37,38], and studies with multiple intervention arms[39,40] were combined to estimate the sample size, mean and standard deviation using the method described by Higgins[35]. One study reported the total sample size but did not provide the sample size for each group. In this case, the sample size was estimated by assuming equal numbers of children in each group and the study was included[39].

To evaluate the influence of each study on the overall effect size, sensitivity analysis was conducted using the leave-one-out method (i.e. removing a single study at a time and repeating the analysis)[41,42]. All analyses were conducted using Review Manager 5.3 (The Cochrane Corp.).

Results

Literature search

Of the 5413 titles retrieved, 129 remained after title screening and removal of duplicates. Abstract screening left seventy-seven studies, as fifty-two did not meet the pre-specified eligibility criteria. Full-text screening left thirty-four studies, as forty-three did not meet the eligibility criteria. An additional thirteen studies were identified (nine from a reference list of the included studies; three from contacting the authors and one from a review paper) (Fig. 1). Following an update of the search (for articles published after February 2019), two additional studies from online database searches met the inclusion criteria. In total, this search identified forty-seven studies, all of which were included in the qualitative synthesis to give a comprehensive overview of published research in this study area. However, only ten studies met criteria to be included in the quantitative synthesis. The remaining studies (n 37) were not included in the meta-analysis because of various factors: necessary information could not be obtained (i.e. no control group[43–56]; control is another intervention[57,58]; unstandardised effect size[49,59,60]; not an actual consumption[15,61–68] and no sample size)[69]; tracking studies (i.e. dietary intervention initiated in childhood and tracked/followed up into adulthood)[34,70] and studies were rated as weak[71–77]. While seventeen out of the forty-seven studies provided enough information to be included in the quantitative synthesis, seven out of those seventeen studies were excluded due to being rated weak, leaving ten studies in the quantitative analyses to provide meaningful, rigorous conclusions.

Study characteristics

The studies were predominantly conducted in Europe (n 30), North America (n 15) and Pacific (n 2), reporting on fifteen different interventions, published between 2003 and 2019. Study designs varied, and where reported, sample sizes ranged from 1 to 38 schools, 2–50 classes or <100 to >1000 children. The duration of the intervention ranged from <1 month (n 4) to > 1 month (n 43), while frequency of exposure ranged from <5x (n 12) to 5x a week (n 35) (see online supplemental Table 1).

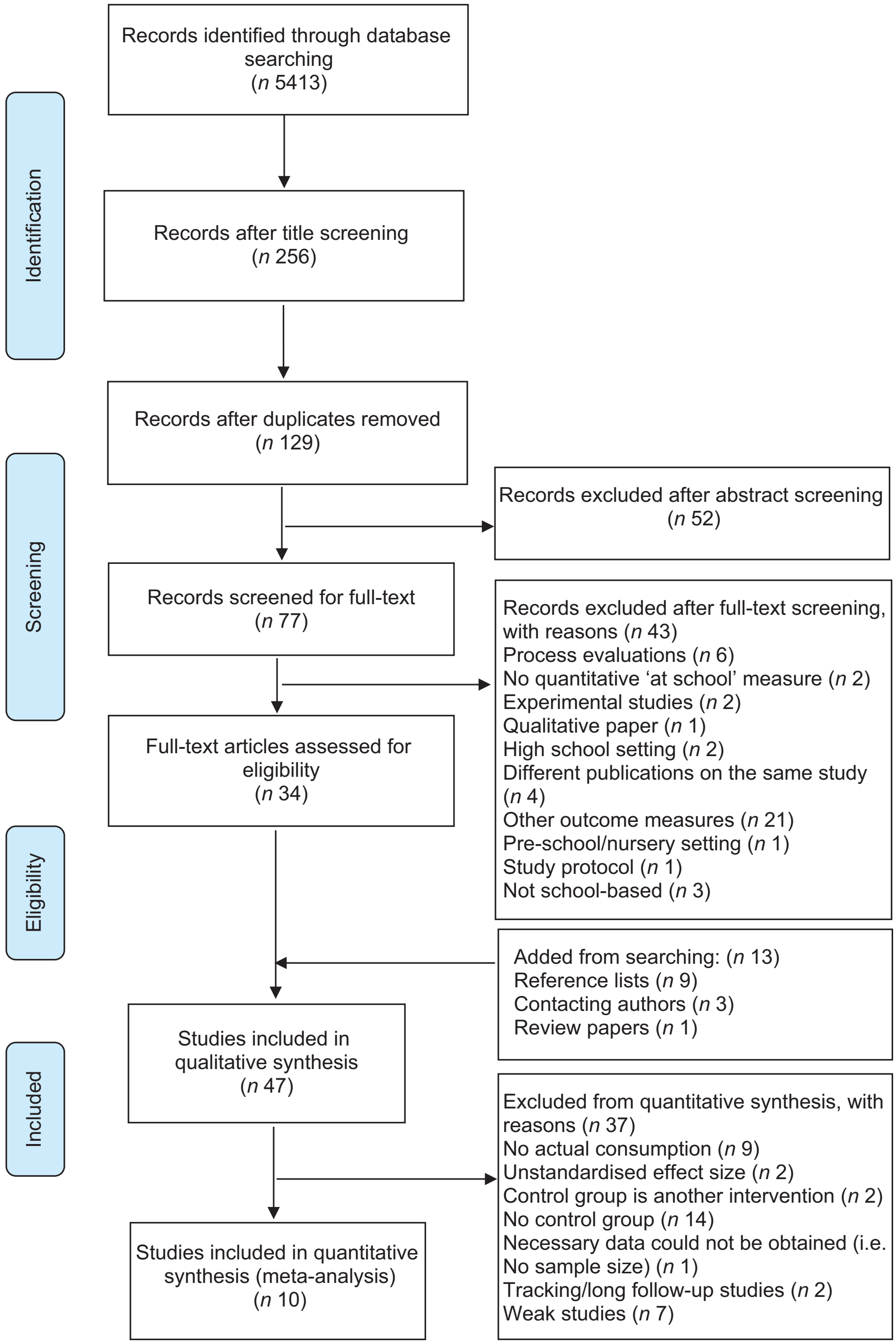

Fig. 1 (colour online) Flow diagram of search strategy and review process based on PRISMA statement. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Follow-up of the studies ranged from 1 to 14 years, and four of the forty-seven studies had a follow-up of less than 1 year. In the forty-seven studies, twelve were classified as randomised controlled trials, twenty were classified as controlled clinical trials, eleven were classified as cohort trials (pre-post) and four were classified as cross-sectional studies. All intervention studies distributed free FV as a snack during breaktime within the school environment, with the exception of three studies[33,39,40] in which FV were provided at parental costs (subsidised). The majority of the studies distributed solely FV as a snack (i.e. stand-alone intervention), whereas some studies in addition to providing FV, integrated other supplementary/reinforcement components such as nutrition education[34,38,60,67,78], parental involvement[33,44,49,56,68,79], peer modelling and rewards[46,50,57,58]. Most of the study interventions were

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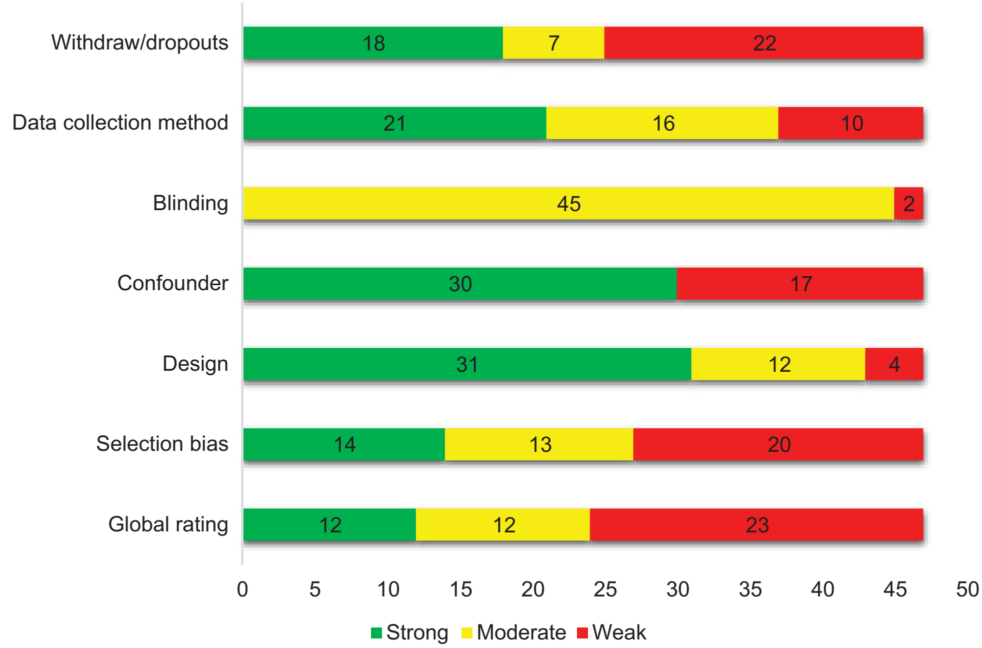

Fig. 2 (colour online) Summary of study quality assessment using the Effective Public Health Practice Project (EPHPP) quality assessment tool for quantitative studies. Criteria Scale: 1 – strong, 2 – moderate, 3 – weak, N/A – not applicable. Global Rating System: 1 – strong (no weak ratings), 2 – moderate (one weak rating), 3 – weak (two or more weak ratings). QA Tool accessible through http://www.ephpp.ca/PDF/Quality%20Assessment%20Tool_2010_2.pdf

guided by the constructs of social cognitive theory (SCT) (n 13)[80], Intervention Mapping Protocol (IMP) (n 7)[81] and utilisation-focused Participatory Approach[82].

Assessment of study quality resulted in twelve studies that were rated as strong, twelve studies as moderate and twenty-three studies as having a weak quality. The primary reason for assigning a rating of 'weak' was that these studies lacked adequate information (i.e. under-reporting and/or lack of clarity) in the published manuscript to fulfil on all quality criteria (i.e. selection bias, blinding, confounders, withdrawals and dropouts) (Fig. 2).

Effects of interventions

Even though the measurement of FV consumption was often combined, making it difficult to determine the effectiveness with respect to each, all studies noted that fruits were served more frequently than vegetables. As a result, this review defined a positive outcome as having a measurable effect on children's consumption of FV at either post-intervention (i.e. immediately following the end of an intervention), follow-up (i.e. after a period of time from the end of an intervention) or both time points. Conversely, a negative or null outcome indicates no effect on children's consumption of FV. Given the considerable heterogeneity/variability across the studies in terms of intervention characteristics (i.e. study design, intervention duration, follow-up length, distribution frequency, geographical location, type of FV served and diet assessment methodology), synthesis of the results was challenging. Thus, we used SMD to account for heterogeneity and therefore, evidence synthesis was established a priori subgroups by stratifying/classifying studies on three principal outcome summary measures: intervention sustainability (i.e. post-intervention or follow-up), approach of intervention (i.e. stand-alone, or multi-component) and type of distribution (free or subsidised).

Intervention sustainability

Twenty-six out of forty-seven studies measured FV consumption among children, reported an increase in consumption at post-intervention[15,39,40,43,45–50,53,54,56,57,60–63,66–69,72,74,83,84], while only three studies reported an increase in FV consumption at follow-up[44,64,65]. The remaining sixteen studies reported an increase in FV consumption at post-intervention, with a loss of effectiveness at follow-up (i.e. not sustainable)[34,37,38,51,52,58,59,70,71,73,75–78], except for two studies[33,79] in which there were null effects at both time points[33], and an increase in FV at both time points (sustainable)[79].

Pooled analysis was performed with nine studies (11 322 participants)[33,38–40,78,79,83–85]. Significant differences were found between intervention and control groups at post-intervention (SMD 0·17, 95 %, CI 0·07, 0·26; $I^2 = 81\,\%$, $P = 0{\cdot}0006$). Pooled analysis was performed with four studies (3085 participants)[33,37,78,79]. Significant differences were found between intervention and control groups at follow-up (SMD 0·14, 95 % CI 0·04, 0·25, $I^2 = 50\,\%$, $P = 0{\cdot}008$) (Fig. 3).

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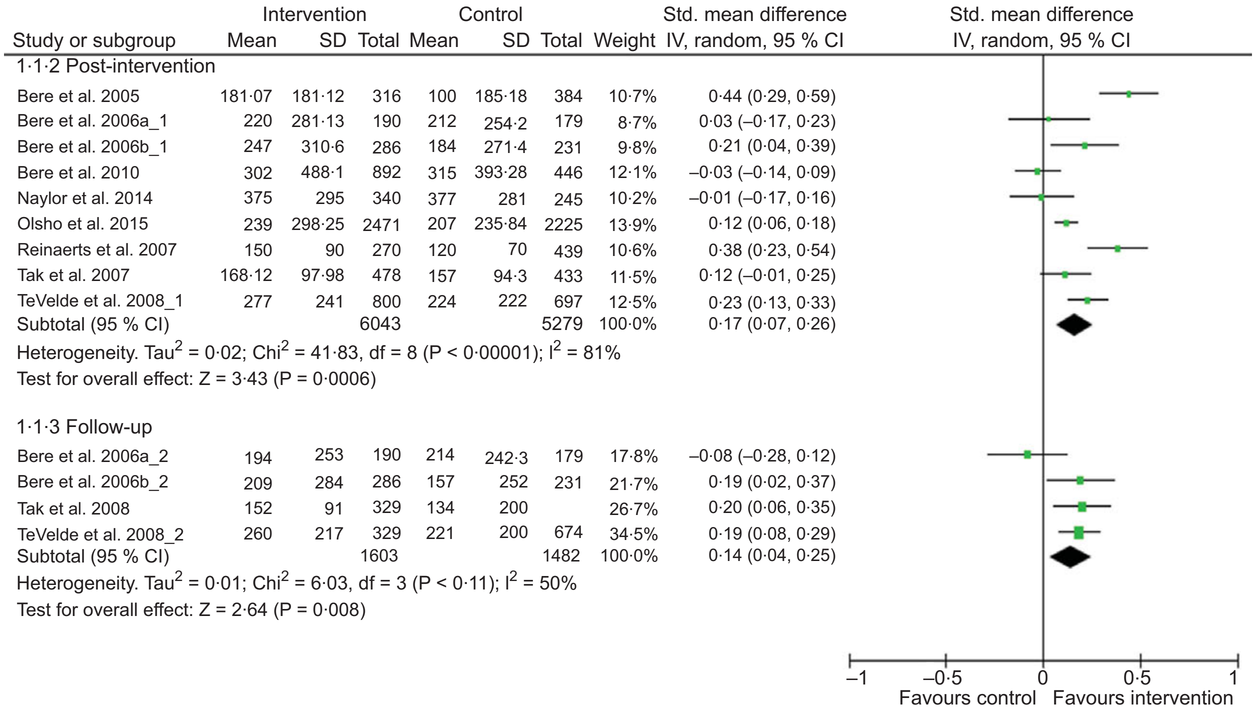

Fig. 3 (colour online) School-based interventions to promote fruit and vegetable consumption. Meta-analysis of intervention sustainability at post-intervention and at follow-up. (Standardised mean differences and 95 % CI). [1]Measurement at post-intervention time point; [2]measurement at follow-up time point

Intervention approach

Among the forty-seven studies, twenty-seven distributed FV solely (referred to as stand-alone interventions), while the remaining twenty supplied FV along with another supplementary component (referred to as multi-component interventions). Nine studies distributed FV with nutrition education alone[34,37,38,48,55,60,67,74,78], while five studies included FV distribution, nutrition education and another supplementary component[49,56,62,68,79]. The remaining five multi-component studies distributed FV in combination with peer modelling and rewards[46,50,57,58], and parental involvement[44]. All studies reported a positive effect on children's FV consumption, except for one multi-component intervention[33], where a null effect was reported, despite including FV distribution, nutrition education and parental involvement.

Pooled analysis was performed with five studies (8028 participants)[39,40,83–85]. Significant differences were found between stand-alone interventions and control groups at post-intervention (SMD 0·18, 95 % CI 0·02, 0·34, $I^2 = 89$ %, $P = 0·03$). As for stand-alone intervention at follow-up, no summary estimate was found due to the absence of studies reported under this classification.

With respect to multi-component interventions, pooled analysis was performed with four studies (3294 participants)[33,38,78,79] and four studies (3085 participants)[33,37,78,79] at both post-intervention and follow-up. Significant differences were found between multi-component interventions and control group at post-intervention (SMD 0·20, 95 % CI 0·13, 0·27, $I^2 = 0$ %, $P < 0·00001$) and at follow-up (SMD 0·14, 95 % CI 0·04, 0·25, $I^2 = 50$ %, $P = 0·008$) (Fig. 4).

Type of distribution

A total of forty-one out of forty-seven studies distributed FV at no parental cost (free), while the remaining six studies distributed FV either at a parental cost (subsidised)[21,33] or a combination[39,40,78,79]. All studies demonstrated a positive effect on school-aged children's FV consumption, except for one study[33] in which FV were provided at a subsidised cost.

Pooled analyses were performed with eight studies (10 363 participants)[38–40,78,79,83–85] and three studies (2716 participants)[37,78,79] both at post-intervention and follow-up. Significant differences were found between free intervention and control groups at both post-intervention (SMD 0·20, 95 % CI 0·09, 0·30, $I^2 = 83$ %, $P = 0·0003$) and follow-up (SMD 0·19, 95 %, CI 0·12, 0·27, $I^2 = 0$ %, $P < 0·00001$) (Fig. 5).

As for subsidised interventions, pooled analyses were performed with three studies (1798 participants)[33,39,40] at post-intervention only. This is because one study was indicated at follow-up measurement and, as a result, pooled analysis cannot be conducted[33]. No significant differences were found between subsidised intervention and control groups at post-intervention (SMD 0·02, 95 % CI -0·12, 0·16, $I^2 = 47$ %, $P = 0·75$) (Fig. 5).

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Study or subgroup	Intervention Mean	Intervention SD	Intervention Total	Control Mean	Control SD	Control Total	Weight	Std. mean difference IV, random, 95 % CI
2·1·2 Stand-alone intervention post-intervention								
Bere et al. 2005	181·07	181·12	316	100	185·18	384	19·2%	0·44 (0·29, 0·59)
Bere et al. 2010	302	488·1	892	315	393·28	446	20·7%	–0·03 (–0·14, 0·09)
Naylor et al. 2014	375	295	340	377	281	245	18·6%	–0·01 (–0·17, 0·16)
Olsho et al. 2015	239	298	2471	207	235	2225	22·5%	0·12 (0·06, 0·18)
Reinaerts et al. 2007	150	90	270	120	70	439	19·1%	0·38 (0·23, 0·54)
Subtotal (95 % CI)			4289			3739	100·0%	0·18 (0·02, 0·34)
Heterogeneity. $Tau^2 = 0·03$; $Chi^2 = 37·14$, df = 4 (P < 0·00001); $I^2 = 89\%$								
Test for overall effect: Z = 2·18 (P = 0·03)								
2·1·3 Stand-alone intervention follow-up								
Subtotal (95 % CI)			0			0		Not estimable
Heterogeneity. Not applicable								
Test for overall effect: Not applicable								
2·1·4 Multi-component intervention post-intervention								
Bere et al. 2006a_1	281·3	281	190	212	254·2	179	11·2%	0·26 (0·05, 0·46)
Bere et al. 2006b_1	249	310	286	184	271·4	231	15·6%	0·21 (0·04, 0·39)
Tak et al. 2007	168·12	97·98	478	157	94·3	433	27·8%	0·12 (–0·01, 0·25)
TeVelde et al. 2008_1	277	241	800	224	222	697	45·4%	0·23 (0·13, 0·33)
Subtotal (95 % CI)			1754			1540	100·0%	0·20 (0·13, 0·27)
Heterogeneity. $Tau^2 = 0·00$; $Chi^2 = 2·24$, df = 3 (P < 0·52); $I^2 = 0\%$								
Test for overall effect: Z = 5·65 (P = 0·00001)								
2·1·5 Multi-component intervention folloe-up								
Bere et al. 2006a_2	194	253	190	214	242	179	17·8%	–0·08 (–0·28, 0·12)
Bere et al. 2006b_2	209	284	286	157	252	231	21·7%	0·19 (0·02, 0·37)
Tak et al. 2008	152	91	329	134	87	398	26·0%	0·20 (0·06, 0·35)
TeVelde et al. 2008_2	260	217	798	221	200	674	34·5%	0·19 (0·08, 0·29)
Subtotal (95 % CI)			1603			1482	100·0%	0·14 (0·04, 0·25)
Heterogeneity. $Tau^2 = 0·01$; $Chi^2 = 6·03$, df = 3 (P < 0·11); $I^2 = 50\%$								
Test for overall effect: Z = 2·64 (P = 0·008)								

Test for subgroup differences: $Chi^2 = 0·69$, df = 2 (P < 0·71); $I^2 = 0\%$

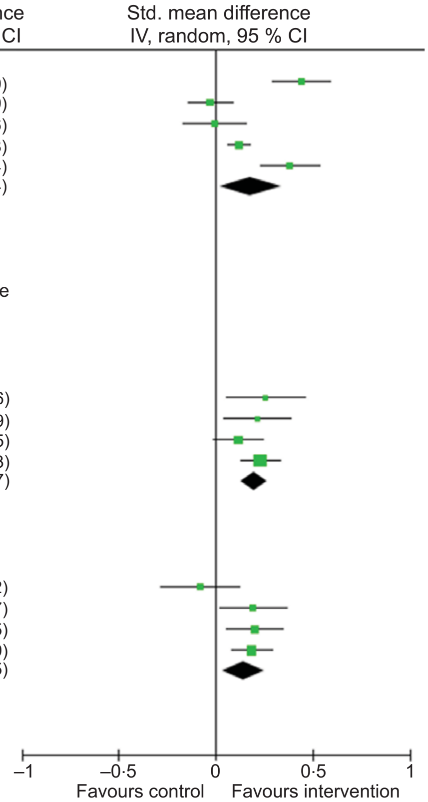

Fig. 4 (colour online) School-based interventions to promote fruit and vegetable consumption. Meta-analysis of intervention approach (stand-alone or multi-component) at post-intervention and at follow-up. (Standardised mean differences and 95 % CI). [1]Measurement at post-intervention time point; [2]measurement at follow-up time point

Exploration of heterogeneity

Heterogeneity among the included studies was significantly reduced when sensitivity analysis was applied for all principal outcome summary, apart from classifications reported under stand-alone and multi-component post-intervention and free distribution at follow-up. In particular, the statistically significant effect size for the impact of FV distribution interventions was found to be sensitive to the studies eliminated, except for studies pooled under the classification of stand-alone at post-intervention in which elimination of the studies did not influence the robustness of the calculated effect size ($I^2 = 90\,\%$, $P = 0·001$). This indicates the significant heterogeneity among the limited number of studies included under this classification. As for multi-component interventions at post-intervention and free distribution interventions at follow-up, sensitivity analysis could not be applied as the heterogeneity among studies were null. This was evident by the calculated effect size of ($I^2 = 0\,\%$, $P = 0·52$) for studies under the multi-component at post-intervention classification and ($I^2 = 0\,\%$, $P = 0·98$) for studies under the classification of free distribution at follow-up. As for the classifications of subsidised and stand-alone interventions at follow-up, sensitivity analysis could not be applied because of the absence of studies reported under these classifications. Notwithstanding the application of a random effects approach, the overall rate of heterogeneity was high, and the majority of the studies contributed to this heterogeneity (see online supplemental Table 2).

Discussion

This was the first systematic review and meta-analysis to explore the effectiveness of snack-based FV distribution interventions to promote school-aged children's consumption of FV. The findings demonstrated the positive effects that distributing FV as a snack within the school environment can have on children's consumption of FV, particularly fruit consumption. Nonetheless, this outcome may not be surprising given that children have more access, exposure and repeated opportunities to try new FV, which are all factors that have been shown to improve children's consumption of FV[86–90].

The preference for fruit is consistent with studies that demonstrate an increased consumption for fruit in school-aged children[87,88,90]. For example, among the included studies, there appears to be a greater impact on children's fruit than vegetable consumption. There are several reasons why this could be the case. First, most of the studies were of European origin, where it is the social norm to consume fruit as a snack and vegetables at main

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Study or subgroup	Intervention Mean	Intervention SD	Intervention Total	Control Mean	Control SD	Control Total	Weight	Std. mean difference IV, random, 95 % CI
3·1·2 Free_post-intervention								
Bere et al. 2005	200	148·1	172	100	185·18	384	10·2%	0·57 (0·39, 0·76)
Bere et al. 2006b_1	247	310·6	286	184	271·4	231	11·1%	0·21 (0·04, 0·39)
Bere et al. 2010	318	571·06	446	315	393·28	446	12·8%	0·01 (–0·13, 0·14)
Naylor et al. 2014	378	295	340	377	281	245	11·5%	–0·01 (–0·17, 0·16)
Olsho et al. 2015	239	298·25	2471	207	235·84	2225	15·2%	0·12 (0·06, 0·18)
Reinaerts et al. 2007	150	90	270	120	70	439	11·9%	0·38 (0·23, 0·54)
Tak et al. 2007	168·12	97·98	478	157	94·3	439	12·8%	0·12 (–0·01, 0·25)
TeVelde et al. 2008_1	277	241	800	224	222	697	13·9%	0·23 (0·13, 0·33)
Subtotal (95 % CI)			5263			5100	100·0%	0·20 (0·09, 0·30)
Heterogeneity. $Tau^2 = 0·02$; $Chi^2 = 41·48$, df = 7 (P < 0·00001); $I^2 = 83\%$								
Test for overall effect: Z = 3·62 (P = 0·0003)								
3·1·3 Free_follow-up								
Bere et al. 2006b_2	209	284	286	157	252	231	19·0%	0·19 (0·02, 0·37)
Tak et al. 2008	152	91	329	134	87	398	26·7%	0·20 (0·06, 0·35)
TeVelde et al. 2008_2	260	217	798	221	200	674	54·3%	0·19 (0·08, 0·29)
Subtotal (95 % CI)			1413			1303	100·0%	0·19 (0·12, 0·27)
Heterogeneity. $Tau^2 = 0·00$; $Chi^2 = 0·03$, df = 2 (P = 0·98); $I^2 = 0\%$								
Test for overall effect: Z = 4·96 (P < 0·00001)								
3·1·4 Subsidizied_post-intervention								
Bere et al. 2005	130	214	144	100	185·18	384	29·7%	0·15 (–0·04, 0·35)
Bere et al. 2006a_1	220	281·3	190	212	254·2	179	27·6%	0·03 (–0·17, 0·23)
Bere et al. 2010	286	387·8	446	315	393·28	446	42·7%	–0·07(–0·21, 0·06)
Subtotal (95 % CI)			780			1009	100·0%	0·02 (–0·12, 0·16)
Heterogeneity. $Tau^2 = 0·01$; $Chi^2 = 3·80$, df = 2 (P = 0·15); $I^2 = 47\%$								
Test for overall effect: Z = 0·32 (P < 0·75)								
3·1·5 Subsidizied_follow-up								
Bere et al. 2006a_2	194	253	190	214	242·3	179	100·0%	–0·08(–0·28, 0·12)
Subtotal (95 % CI)			190			179	100·0%	–0·08(–0·28, 0·12)
Heterogeneity. Not applicable								
Test for overall effect: Z = 0·77 (P < 0·44)								
Test for subgroup differences: $Chi^2 = 10·05$, df = 3 (P = 0·02); $I^2 = 70·2\%$								

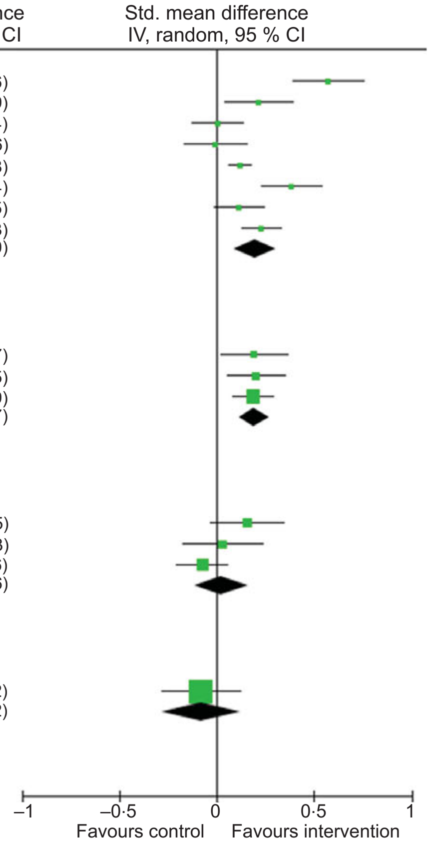

Fig. 5 (colour online) School-based interventions to promote fruit and vegetable consumption. Meta-analysis of intervention type of distribution (free and subsidised) at post-intervention and at follow-up. (Standardised mean differences and 95 % CI). [1]Measurement at post-intervention time point; [2]measurement at follow-up time point

meals[33,49,71]. Second, fruit was more frequently served to children to avoid waste and maintain their interests[43,47,91], contributing to unequal exposure opportunities for behavioural change to occur with respect to each[60]. Third, the most frequently served vegetables were celery sticks, carrots or cherry tomatoes because of ease of preparation and distribution, which might induce feelings of boredom as children were exposed to the same stimuli, which can lead to lower preference and consumption of vegetables[40,92]. Finally, most of these programmes were of short-term duration that could easily impact the dietary behaviour of fruit consumption compared to vegetables, which usually take a long time to influence[43,62,64]. Taken together, these findings indicate that changing children's dietary habits of vegetables consumption is a difficult proposition, and future studies should consider adequate level of exposure to a variety of vegetables to maintain long-lasting effects on changing the dietary behaviours of vegetable consumption.

Our meta-analysis shows effectiveness at increasing children's consumption of FV when pooling studies according to two time points (i.e. post-intervention and follow-up). However, our analyses were not successful at determining whether children's consumption of FV is sustainable (i.e. successful at increasing children's consumption of FV at both post-intervention and follow-up), as the majority of the studies failed to measure effectiveness at both time points (i.e. immediately following an intervention and after a period of time at follow-up). However, a rudimentary comparison among the studies that measured FV intake at both time points[34,37,38,51,52,58,59,70,71,73,75–78] shows that distributing FV to school-aged children was not ultimately sustainable at increasing children's consumption of FV at follow-up, with the exception of one intervention in which a significant effect was noted at 1-year follow-up in Norway[79]. Previous studies have shown an increased consumption of fruit in the intervention group while the intervention was operating[40], 1[78], 3 years[77] and 14 years[34] but not at 7 years[70] after the intervention ended. This indicates that dietary interventions initiated in childhood tend to maintain to a significant extent into adulthood; however, the strength of dietary tracking is often underestimated due to several methodological difficulties including, but not limited to, differences in study design, methods of dietary assessment, use of statistical methods, the duration of an intervention and follow-up, which consequently limits the opportunity to quantify the habitual dietary behaviour trajectories over time[93].

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Several valuable recommendations for successful school food programming have been proposed. These include increased availability and accessibility of FV, education directed at behavioural change, an appropriate theoretical framework, parental involvement, peer and teacher role modelling, messages specifically targeting FV intake as opposed to general healthy eating messages, and adequate time and duration[14,94]. Although the reviewed studies possessed a number of these features, differences related to study design, intervention duration, follow-up length, distribution frequency, geographic location, type of FV served, diet assessment methodology, and implementation processes and practices are likely to be the main reasons for the significant heterogeneity among the included studies. For instance, lack of curricular activity implementation in studies based in the Netherlands and Spain is the result of the workload placed on teachers implementing the programme[95]. This, in turn, resulted in a null intervention effect on children's consumption of FV in the Netherlands and Spain compared to Norway at 1-year follow-up[79]. In a recent systematic review identifying the conditions and resources under which snack-based FV distribution interventions are most likely to be effective and sustainable[96], it was shown that distributing FV to school-aged children as a snack can increase consumption, but only with proper implementation. These include participation of the whole school community, school staff training, involving parents within the school and home environment, and adapting the programme to meet school needs and resources. In addition to the successes, the review also highlighted barriers to implementation which included limited funding, insufficient teachers' time, poor awareness, coordination and communication between key stakeholders (e.g. teachers, school staff, suppliers)[96]. The authors also suggest future recommendations regarding aspects of the intervention that could be adapted or modified to increase the likelihood of success of future snack-based school food programming[96].

In addition, effectiveness was shown in studies that were conducted for greater than 1 month (*n* 43), offered FV five times/week (*n* 35) and employed a theoretical framework (*n* 21) to those that did not, with the exception of one study[33] in which a null effect was observed despite the fact that the intervention lasted a year, offered FV five times a week and was based on theoretical framework (SCT). This indicates that further research is required to determine what is the effective element/component, that if found in an intervention, will be associated with a positive and sustainable FV consumption among children. Therefore, our findings should also be interpreted with caution given the considerable heterogeneity existing between studies grouped under these classifications.

A comparison of FV distribution interventions that employed a stand-alone approach to those that employed a multi-component approach failed to demonstrate more positive effects on children's FV consumption. For example, both approaches were effective at increasing FV, given that children have more access, exposure and repeated opportunities to try new FV[27]. However, our meta-analysis shows that multi-component interventions were more effective in increasing the consumption of FV at post-intervention and follow-up. This was evident particularly in interventions that employed a nutrition education in addition to FV distribution[33,38,74,78,79] or interventions that employed parental involvement as well as nutrition education and FV distribution[33,79]. This is because children spend most of their time at school[12] and most of their education about healthy dietary behaviours occurs while at school[14]. This indicates that simply providing FV to children is not enough to make dietary behaviour change, as children's consumption of FV will decline as soon as they become ineligible for the programme. As a result, incorporating other strategies such as nutrition education that goes along with providing FV may provide children with the skills and knowledge needed to ensure long-lasting improvement in their dietary choices, particularly in terms of FV consumption. Therefore, significant consideration should be given to integrating nutrition and health topics permanently in the regular curriculum and/or integrating parental involvement into the design of an intervention as positive associations with children's consumption of FV were noted when both nutrition education and parental involvement were incorporated into an intervention[44]. Studies have long recognised the positive effects of associating exposure with another reinforcement on children's intake of FV[25,26,97,98]. Nonetheless, our results are only based on five studies[33,37,38,78,79], and consequently, our findings should be treated with caution.

Most of the reviewed studies (41 of 47) that distributed FV at no cost to parents were effective at increasing FV consumption in school-aged children. Our meta-analysis shows that pooling studies under this classification demonstrates a positive effect on children's consumption of FV with free compared to subsidised FV distribution interventions. This was also evident when a rudimentary comparison of the four studies that provided children with FV for free and subsidised costs, all positively increased children's consumption, with a larger impact from the free distribution.[39,40,78,79] The authors suggest that the difference in effectiveness between free and subsidised FV distribution may be because free distribution addresses both availability and accessibility[99], whereas subsidised distribution only increases the accessibility but not the availability of FV[33]. This indicates that free distribution of FV may be the most effective strategy to increase children's FV consumption because it addresses and reduces existing social inequalities[14,100,101].

The I^2 value indicated a high-level of between-study heterogeneity. This was evident particularly for studies grouped under the classification of post-intervention ($I^2 = 81\,\%$), stand-alone (89 %) and free distribution ($I^2 = 83\,\%$) at post-intervention. While we cannot rule out publication bias or small study effects (e.g. negative

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or reverse results might not have published) as an explanation for our findings, sensitivity analyses were therefore conducted. This is to prevent making definite conclusions when included studies had a lot of publication bias. However, this statistical approach has its own limitations as significant findings were reported under different exploratory assumptions[31,35]. This was evident when heterogeneity was significantly reduced to less than 50 % when studies were excluded on all principal outcome summary except for stand-alone intervention at post-intervention classification ($I^2 = 90\,\%$, $P = 0{\cdot}001$). This indicates that elimination of the studies under this classification did not influence the robustness of the calculated effect size which is due to the significant heterogeneity of the studies included under this classification.

This systematic review has several strengths. First, the search was comprehensive, including searches of six electronic databases with no restriction on publication date, country or study design. Second, quality assessments were conducted for each study which allowed for a more rigorous assessment of the validity and weight of the evidence included in the review. This was evident by solely including studies with 'moderate' and 'strong' ratings in the quantitative synthesis which took adequate measures to avoid selection bias and control confounding factors. Third, despite the high variability observed in measurement of FV consumption across studies, the meta-analysis was conducted using the SMD as the effect measure, by accounting for the high heterogeneity observed among studies, giving a more precise estimate of the effect.

Like all studies, the present review is not without limitations. First, our review is limited by the number of studies included in the meta-analysis, which often resulted in less-rigorous study design; therefore, definite conclusions regarding intervention effectiveness remain unknown. Second, all studies were at risk of bias because they relied largely on questionnaires or recall to record dietary consumption rather than objective measures (e.g. weighing). Third, given that all interventions were focused on FV consumption, it is possible that dietary questionnaires were biased (e.g. being over-estimated in the intervention group) or a poor means (insufficiently sensitive) to detect the relatively small changes in FV consumption, reflected in the wide CI. In addition, subgroup analyses had to be undertaken due to heterogeneity, which reduced our statistical power, and as such, concrete conclusions could not be drawn. Finally, external validity of the evidence was also limited because all the reviewed studies were conducted in Europe and North America, potentially limiting the review generalisability to other developed and developing countries.

Conclusions

The findings of this review demonstrate that snack-based FV distribution interventions within the school environment represent a promising avenue to enhance children's consumption of FV. Given the greater success at increasing the consumption of fruit, more emphasis is needed on developing novel interventions to achieve greater effectiveness in terms of vegetable consumption. All interventions were effective in increasing the consumption of FV among elementary school-aged children, except for subsidised interventions. Further research is needed to improve the quality of evidence, including studies with more rigorous study designs, sufficient sample sizes, consistent measures and reporting of FV consumption, and follow-up evaluations to confirm these findings. Overall, to inform appropriate policy-making decisions, it is important to develop adequate interventions within the school environment to improve the physical school food environment, as school-aged children spend a large portion of their day in school.

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Supplementary material

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