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Systematic review and meta-analysis of strategies to increase vegetable consumption in preschool children aged 2–5 years

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ABSTRACT

Background: Most children do not meet daily recommendations for fruit and vegetable intake, and consumption of vegetables remains especially low. Eating habits track from childhood to adulthood hence establishing liking and intake of vegetables is important.
Objective: To identify the most successful strategies to enhance vegetable intake in preschool children aged 2–5 years.
Design: The research was a systematic review and a meta-analysis of published studies. A comprehensive search strategy was performed using key databases such as Medline, Embase, PsychINFO, EBSCO and CENTRAL. Articles published between 2005–January 2016, specifically with measured vegetable consumption were included.
Results: 30 articles and 44 intervention arms were identified for inclusion (n = 4017). Nine dominant intervention strategies emerged to promote vegetable intake in preschool children. These included; choice, pairing (stealth), education, food service, modelling, reward, taste exposure, variety and visual presentation. The meta-analysis revealed that interventions implementing repeated taste exposure had better pooled effects than those which did not. Intake increased with number of taste exposures and intake was greater when vegetables offered were in their plain form rather than paired with a flavor, dip or added energy (e.g. oil). Moreover, intake of vegetables which were unfamiliar/disliked increased more than those which were familiar/liked.
Conclusions: Repeated taste exposure is a simple technique that could be implemented in childcare settings and at home by parents. Health policy could specifically target the use of novel and disliked vegetables in childcare settings with emphasis on a minimum 8–10 exposures.

The systematic review protocol was registered on the PROSPERO (number: CRD42016033984).

1. Introduction

The World Health Organization suggests consuming 400 g or more of fruit and vegetables per day to improve overall health; current recommendations for adults vary between countries from 400 g to 800 g (Aune et al., 2017; WHO, April 2011). In the UK preschool children are recommended to eat a variety and minimum of five 40 g portions (200 g) of fruit and vegetable a day (First Steps Nutrition Trust, 2016; National Health Service. NHS, 2015). Eating recommended amount of fruits and vegetables can reduce the risk of cardiovascular disease, diabetes, some cancers and obesity, yet most consumers across different countries do not meet dietary recommendations for daily fruits and vegetable intake (Aune et al., 2017; Hall, Moore, Harper, & Lynch, 2009; WHO, April 2011). For example Health Survey England reported a decrease in 5–15 year old children's '5 a day' fruit and vegetable intake from 20% in 2011 to 17% in 2013 (Roberts, 2013). In comparison, the Vital Signs report by the Centers for Disease Control and Prevention showed that while US children aged 2–18 years were eating more fruits in 2010 than they did in 2003, vegetable intake remained low and unchanged as 93% of the children did not meet the daily recommended intake (Kim et al., 2014). Evidence from large cohort studies strongly suggests that preschoolers' intake of vegetables is insufficient (Angelopoulos, Kourlaba, Kondaki, Fragiadakis, & Manios, 2009; Huybrechts et al., 2008; Manios et al., 2009). Increasing vegetable

Abbreviation: CENTRAL, Cochrane Central Register of Controlled Trials; CI, Confidence Interval; CINAHL, Cumulative Index of Nursing and Allied Health Literature; EPHPP, Effective Public Health Practice Project; ERIC, Educational Resource Information Center Database; FFL, Flavor-Flavor Learning; FFQ, Food Frequency Questionnaire; FNL, Flavor Nutrient Learning; g, Hedges g; I^2, Inconsistency; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analyses; RCT, randomized control trial; RE, Repeated Exposure; SE, Standard Error

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intake is more important than increasing fruit intake because fruits are high in natural occurring sugars and according to Oyebode, Gordon-Dseagu, Walker, and Mindell (2014) vegetables have a greater protective effect than fruit (reducing death by 16% per each daily portion compared to 4% for fruit).

One explanation for low vegetable intake is that vegetables are disliked due to their strong or bitter taste, unfamiliar texture, low energy density and lack of availability/accessibility (Bell & Tepper, 2006; Blanchette & Brug, 2005; Cooke et al., 2004; Di Noia & Byrd-Bredbenner, 2014; Johnson, McPhee, & Birch, 1991; Rasmussen et al., 2006). In addition, low consumption may be attributed to child eating behavior traits such as food fussiness; generally defined as eating more selectively, being picky and likely to refuse foods which are unfamiliar as well as those which are familiar and food neophobia which is avoidance of new foods (Cooke, Haworth, & Wardle, 2007; Dovey, Staples, Gibson, & Halford, 2008; Holley, Haycraft, & Farrow, 2017b). Fussiness peaks in children aged 2–5 years, yet this is also a time when children acquire novel food preferences since eating habits are still developing (Addessi, Galloway, Visalberghi, & Birch, 2005; Cooke et al., 2007; Cooke & Wardle, 2005). Vegetable intake may be doubly disadvantaged by liking and child fussiness, however, strategies such as repeated taste exposure, modelling, flavor enhancement, stealth, tangible rewards (non-food) or social praise have been shown to promote vegetable intake (Anzman-Frasca, Savage, Marini, Fisher, & Birch, 2012; Caton et al., 2013; Cooke, Chambers, Añez, & Wardle, 2011). It is important to understand which strategies are most successful in early years to promote liking and intake of vegetables, as eating habits developed during childhood track into adulthood (Harris, 2008; Ventura & Worobey, 2013).

Evidence from previous reviews suggests that interventions to encourage fruit and vegetable intake are selectively beneficial for fruits (Evans, Christian, Cleghorn, Greenwood, & Cade, 2012; French & Stables, 2003). For example, the meta-analysis by Evans et al. (2012) in children aged 5–12 years revealed only a small effect of intervention on daily fruit intake (+0.24 portion) and no effect on daily vegetable consumption (+0.07 portion). These selective effects suggest that changing vegetable intake might require different strategies to promote intake. Most reviews of fruit and vegetable intake tend to focus on children aged 5 and over, reporting intakes of both food groups (e.g. Blanchette & Brug, 2005; Delgado-Noguera, Tort, Martinez-Zapata, & Bonfill, 2011; Diep, Chen, Davies, Baranowski, & Baranowski, 2014; Evans et al., 2012; French & Stables, 2003; Krolner et al., 2011; Rasmussen et al., 2006). A systematic research review by Appleton et al. (2016) described vegetable promoting interventions across the lifespan. From their search, 77 studies detailing 140 interventions were found, most (81%) of these were conducted in children. This may be attributable to a greater opportunity to intervene in school settings or to a greater adaptability of children to interventions compared to adults. However, it may also be more important to intervene early to change eating habits since health benefits can only be accrued over time. To date two Cochrane reviews with meta-analysis have been published concerning vegetable intake in children aged 5 and under (Hodder et al., 2018; Wolfenden et al., 2012). The review by Wolfenden et al. (2012) revealed that pairing repeated exposure with a tangible non-food or social reward was effective in increasing intake of targeted vegetables. However only randomized controlled trials were included in their review and only two studies were included in their meta-analysis. Similarly the recent meta-analysis by Hodder et al. (2018) included 11 studies in their meta-analysis. Hence, there may be other effective strategies missed by these reviews. Moreover they also included studies with children younger than two who may be more willing to eat vegetables compared to children who are experiencing the peak food fussy period (2–5 years) (Cashdan, 1994; Caton et al., 2014). Finally a systematic review by Holley, Farrow, and Haycraft (2017a) qualitatively summarized various strategies used for encouraging vegetable intake in 2–5 year olds, however their search returned limited number of studies looking at educational strategies. Therefore the present systematic review and meta-analysis aims to bridge the gap in existing reviews by reporting evidence from education interventions and detailing important aspects of taste exposure strategy using a quantitative approach. The present review aimed to investigate the effectiveness of interventions to increase vegetable intake in children aged between 2 and 5 years by performing a comprehensive search and including a variety of study designs and settings.

2. Methods

The review is reported in accordance with Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines (Liberati et al., 2009). The protocol for the present review was registered on PROSPERO; International Prospective Register for Systematic Reviews (registration number: CRD42016033984).

2.1. Search strategy

The databases searched to identify published articles were OVID (Medline, Embase, PsycINFO, Global Health and CAB Abstracts), EBSCO (Cumulative Index of Nursing and Allied Health Literature; CINAHL and Educational Resource Information Center Database; ERIC), Cochrane Central Register of Controlled Trials (CENTRAL), ProQuest, PubMed, Scopus, and Web of Science. Moreover, grey literature database e.g. SIGLE, Open Grey, Copac, World Cat and the reference lists of relevant previous reviews and retrieved articles were also hand searched. As the food environment and food habits have changed over time and the International Health Regulation (IHR) framework was introduced in 2005 (WHO, 2007), contemporary evidence of studies published since the year 2005 (to January 2016) were sought. The language was limited to English. The key terms highlighted in Table 1 were used and adapted according to the requirements of individual databases for subject field (for example, for some search engines only a few keywords were used to retrieve maximum papers whereas for others most keyword groups were combined using “or” and “and” to maximize retrieval of mainly relevant papers).

2.2. Selection of studies

The screening process was done by a single reviewer (CN). Studies which aimed to increase children's vegetable intake were considered for

Table 1
Search terms used to identify relevant articles for present systematic research review.

Subject	Related keywords
Topic	Vegetable OR vegetables OR veg OR F&V OR FV
Intervention/Outcome	Intervention OR strategy Or strategies OR facilitators OR campaign OR promote OR program OR initiative OR factor OR trial OR liking OR preference OR intake OR consumption OR uptake OR attitude OR behavior OR behavior
Participant	Child OR Children OR infant OR toddler OR pre-schooler OR preschooler OR girl OR girls OR boy OR boys OR mother OR maternal OR father OR parent OR caregiver OR 2 year Or 3 year Or 4 year Or 5 year OR age 2 OR age 3 OR age 4 OR age 5
Setting	School OR nursery OR Nurseries OR daycare OR day-care OR early year OR early years OR preschool OR playschool OR playgroup OR kindergarten OR classroom OR home

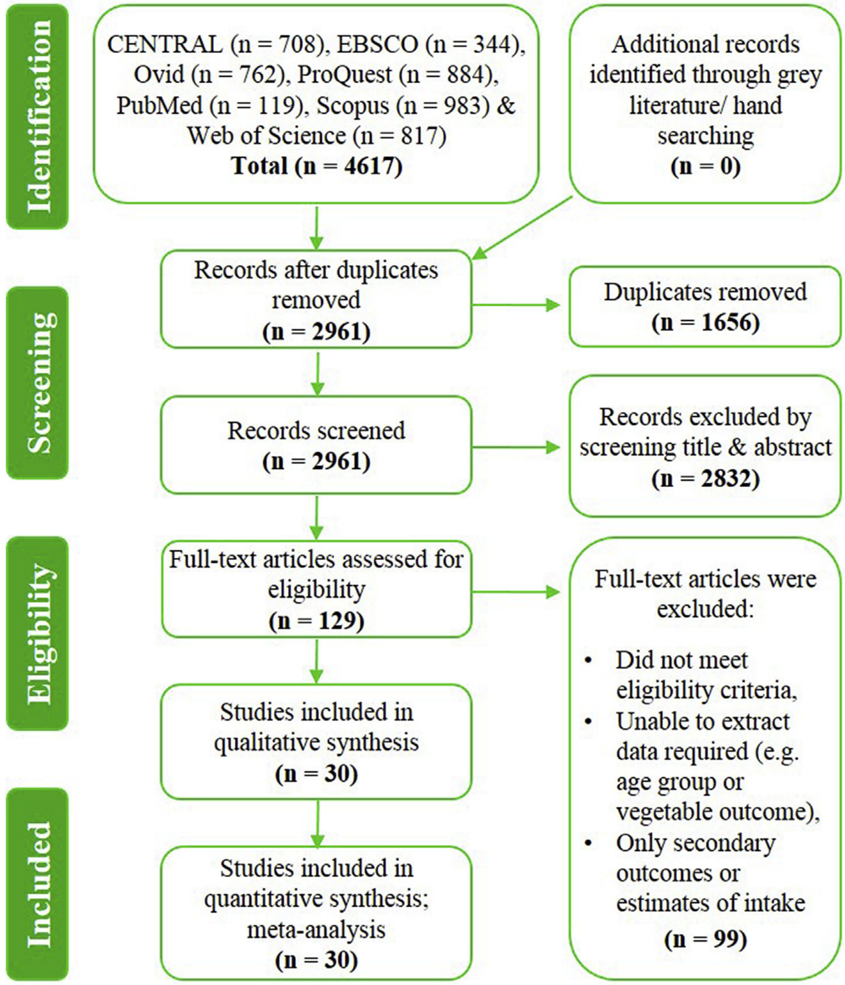

Fig. 1. PRISMA diagram of the study screening process and article selection.

inclusion. Articles were included if vegetables were the only target food group or were part of a health intervention (e.g. promoting healthy eating or/and physical activity). Studies in which vegetable intake data could not be extracted were excluded; for example studies measuring fruit and vegetables combined or secondary outcomes such as liking, willingness to try or proxy measures of intake such as vegetables observed in lunch boxes. Likewise to focus on findings from the age group which was most likely to experience food fussiness, studies were also excluded where data on children of the desired age range (2–5 years) could not be extracted. Only full articles were included. No restrictions were applied for study designs (e.g. randomized controlled trial; RCT, experiment or pre-post format), type of interventions, settings or comparison groups. A total of 30 studies were identified for inclusion, see Fig. 1 for PRISMA flow diagram of the study selection process.

2.3. Data extraction

The details of each study were extracted by the author CN and were verified by a second reviewer (MH or PB). An extended summary table of each study including: the type of intervention, aim, design, participant age, study setting, details of intervention, comparison and main outcomes for vegetable intake is presented in Table 2. The vegetable intake data extracted was based on direct measurements, observations or from parental self-reported questionnaires. For the meta-analysis vegetable outcome data immediately post-intervention were used (not the follow-ups) and if necessary the study authors were contacted for further information.

2.4. Quality assessment

The quality of each study was assessed by at least two authors independently, using the Effective Public Health Practice Project (EPHPP) quality assessment tool for quantitative studies (EPHPP, 1998; Thomas, Ciliska, Dobbins, & Micucci, 2004). Any disagreement in scores were resolved by discussion between two authors (CN & MH). Five components were scored (selection bias, study design, confounders, blinding, data collection methods and withdraw and drop-out); from which overall global quality ratings were calculated. As the effect size did not vary by the quality of the studies, no studies were excluded from the analysis based on these ratings. See Fig. 2 for summary of the quality ratings.

2.5. Statistical analysis

Comprehensive Meta-Analysis (CMA, Biostat, Englewood, NJ, USA) software was used to conduct the meta-analyses. Means, standard deviation (sometimes calculated from the reported standard error) and the sample size (adjusted to the lower value if pre and post n varied) were generally extracted from appropriate time-points (pre and post intervention). If raw data were not reported then *t*-test values, F-ratio and statistically significant p values were sought. If the significant value was statistically significant but not precisely reported then these were round to the significant value (e.g. < 0.05 entered as 0.05 and < 0.01 entered as 0.01). To calculate effect size for paired group studies, pre-post correlation is required. However none of the studies have reported

Table 2
Summary of studies included in the review that assesses vegetable intake in preschool aged children.

Study/intervention	Aim	Design	Sample[a],setting, location	Intervention	Control/comparison	Vegetable related conclusions for primary and secondary outcome
Bell et al. (2015) - Educational - Food-service	Assess the impact of "Start Right – Eat Right" nutrition award scheme (SRER) on food and nutrient intakes.	Pre-post	2-4 years n = 216–221 Day-care centers (Adelaide, South Australia)	Center directors and cooks received 9 h of nutrition training (including improving provision of fruit and vegetable). SRER dietitians supported the staff and reviewed the progress of the program.	Pre-intervention measures.	Post intervention (2–6 months later) intakes of all core food groups increased except for vegetable intake (estimated using observed plate wastage method). Future research to investigate nutrition strategy to reduce food wastage, i.e. change intake, in particular vegetables to maximize cost effectiveness of food-service interventions.
Bouhlal et al. (2014) - Taste exposure - Pairing	Compare effect of repeated-exposure and flavor-flavor learning on acceptance of a non-familiar vegetable (salsify puree).	Between-subjects	24-36 (27.13 ± 7.37) months n = 151 Nurseries (Dijon, France)	8 exposures to salsify (weeks 2–5) 1) repeated exposure (RE) - salsify in standard form 2) flavor-flavor learning (FFL salt - salsify with added salt 3) FFL spice - salsify with added nutmeg spice.	Pre-intervention measures (week 1) Control vegetable: carrot intake measured at pre and post intervention, no exposure.	Increase in the amount consumed (g) of the unfamiliar vegetable at post-intervention (week 6) and at follow-up week 10, 19 and 32. No group effects on liking or intake however, greater change in RE compared to both FFL groups. RE is an effective and simplest method to increase vegetable intake in the short and long term.
Brouwer and Neelon (2013) - Educational	Assess the feasibility of "Watch Me Grow"; a gardening intervention to promote fruit and vegetable intake.	Cluster RCT	3-5 years n = 12 Childcare centers (North Carolina, USA)	The 4 month intervention included a fruit and vegetable garden, monthly "crop-a-month" curriculum, gardening support, and technical assistance from health educator.	Pre-intervention measures (not same individuals observed at baseline and post intervention). Control centers	Vegetable intake (servings) was greater for intervention children compared to control children. Four centers were involved, but intake of only 3 children was randomly observed from each center.
Caton et al. (2013) - Taste exposure - Pairing	Compare effectiveness of FFL and FNL with RE on increasing intake of a novel vegetable (artichoke puree).	Randomly assigned between-subjects	24-38 (31.05 ± 3.50) months (full study sample 9–38; 23.6 ± 5.09 months) n = 32 (data extracted from n = 72) Nurseries (West and South Yorkshire, England, UK)	10 exposures to artichoke puree (over 3 weeks) 1) RE: basic form 2) FFL: paired with sucrose 3) FNL: paired with sunflower oil	Pre-intervention measures Control vegetable: carrot intake measured at pre and post intervention, no exposure	Intake (g) of both vegetables increased over time however, changes in artichoke intake was greater than carrots. Artichoke intake increased to the same extent in all conditions and effect was persistent up to 5 weeks post-intervention. Therefore regardless of the familiar taste or energy density, repetition is imperative for increasing intake. Five exposures were sufficient to increase vegetable intake.
Correia, O'Connell, Irwin, and Henderson (2014) - Pairing - Visual exposure	Investigate pairing of a vegetable (broccoli) with a familiar, well-liked food and enhancing the visual appearance of a vegetable (cucumber) on increasing vegetable intake.	Cluster randomized crossover	4-5 (4.4 ± 0.6) years n = 43 (Lunch) n = 42 (Snack) Child-care center (New Haven Connecticut, USA)	Lunch (paired with a familiar food): steamed broccoli served on top of cheese pizza. Snack (visually appealing): raw cucumber served with chive and olive arranged in a shape of a caterpillar.	Comparison lunch: steamed broccoli was served on the side of cheese pizza. Comparison snack: raw cucumber was served as semicircles with chive and olive garnish.	No increases in vegetable (g) consumption. Pairing increased willingness to try (consumption of 3 g or more) the vegetable. Greater consumption at snack time indicated that snack times in preschools are opportune moments for increasing vegetable intake.
Cravener et al. (2015) - Reward	Effects of pairing positive stimuli (stickers and cartoon packaging) with vegetables and presenting them as a default snack in "low-vegetable consumers" at risk of obesity.	RCT	3-5 (3.9 ± 0.8) years n = 24 Home-based (State College, Pennsylvania, USA)	4 weeks parent-led intervention. Week 1 (baseline) and week 4 (follow-up): generic packaged raw vegetables (celery, broccoli, carrots, red peppers, cauliflower, and sweet snap peas) offered as a free choice with an alternative snack (granola bar). Weeks 2 and 3: vegetables packaged in containers with favorite cartoon characters and stickers inside, presented as the default choice (children were allowed to opt out and request the granola bar after a 5-minute wait).	Pre-intervention measures Week 1–4: control group received generic packaged vegetables, presented as a free choice with an alternative snack (granola bar).	Treatment group increased vegetable intake (g per day) from baseline to week 2, however the effects were not sustained by week 4 when the treatment was removed. Parents were able to administer the intervention in home settings therefore future studies to test long-term sustainability of these practices.

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Table 2 (*continued*)

Study/intervention	Aim	Design	Sample[a],setting, location	Intervention	Control/comparison	Vegetable related conclusions for primary and secondary outcome
de Wild et al. (2013) - Taste exposure - Pairing	Investigate FNL as a strategy to increase acceptance of novel vegetable (endive).	Crossover	24-48 (35.0 ± 8.3) months n = 28 Day-care centers (Wageningen, Netherlands)	7 weeks crossover intervention. Vegetable soups (endive and spinach) were offered twice per week (7 exposures to each vegetable). FNL: vegetable soup paired with high energy (endive or spinach) 1) High energy variant of one soup (endive) and low energy variant of the other (spinach) 2) Low energy variant (RE) of one soup (endive) and high energy variant of the other (spinach)	Pre-intervention measures RE: no flavor-nutrient paring: low energy version of each vegetable soups (maltodextrin and sunflower oil was not added)	There was an increase in intake (g) for both variant of vegetable soups irrespective of the energy content, this indicated effect of mere exposure on intake, but not FNL. Results showed a significant liking for the vegetable soup paired with high energy and this supports FNL. Effects were significant at 2 and 6 months follow-up.
de Wild, de Graaf, Boshuizen, and Jager (2015) - Taste exposure - Choice	Investigate if choice-offering is an effective strategy to increase children's vegetable intake in home situation.	Randomly assigned between-subjects	2-5 (3.7 ± 1.0) years n = 70 Home-based (Wageningen, Netherlands)	Exposed 12 times (12 days) to six familiar target vegetables (broccoli, carrots, peas, cauliflower, French beans, and string beans) at home during dinner. Choice group were offered two selected vegetables each time (4 exposures to each vegetables over the 12 days).	Comparison: no-choice group only received one of six target vegetables on each day (2 exposures to each vegetable over the 12 days)	Results suggested that choice-offering has some, but not robust effect on increasing vegetable intake (g) in children. Age and liking of the vegetables mediated the effect of offering a choice.
Fildes et al. (2014) - Taste exposure - Reward	Test the efficacy and acceptability of mailed materials giving parents instructions on taste exposure as a means of increasing vegetables (disliked) acceptance.	RCT	3-4 (3.9 ± 0.3) years n = 442 Home-based (Gemini cohort, 2011–2012, England and Wales, UK)	Parent-administered intervention. Parents were mailed instructions to provide taste exposures. The intervention involved offering each child 14 daily tastes of a disliked (target) vegetable with a small reward (a sticker) if the child complied.	Pre-intervention measures Control group: no treatment	Increased intake (number of pieces eaten) of an initially disliked vegetable. Study highlighted value of parent-administered exposure and how such strategy can be implemented without direct contact with a health professional.
Fisher et al. (2012) - Taste exposure - Pairing	Determine if repeated exposure to a moderately-liked raw vegetable with a familiar dip influenced liking and intake among bitter-sensitive and bitter-insensitive children.	Between –subjects	3-5 (4.0 ± 1.0) years n = 147 Head Start centers (Houston, Texas, USA)	Intake of six vegetables including the moderately liked target vegetable (broccoli) was measured at baseline and post intervention. Broccoli was offered in four conditions twice a week for 7 weeks (13 exposure trials). 1) with regular salad dressing as a dip, 2) with a light (reduced energy/fat) version of the dressing as a dip, 3) mixed with the regular dressing as a sauce	Pre-intervention measures Control group: broccoli without dressing	Providing a dip in any form (regular, light, or as a sauce) increased intake of raw broccoli (g) among bitter-sensitive preschoolers (70% in current study but not those who were not bitter-sensitive). Light-dip decreased intake in children who were not sensitive to bitter taste. Liking increased following exposure but did not vary by bitter sensitivity or dip-condition.
Gripshover and Markman (2013) - Educational	Assess the impact of teaching young children a new theory; 'food as a source of nutrition'.	Cluster RCT	4-5 (experiment 1: 4.9 ± 0.35, experiment 2: 4.7 ± 0.28) years n = 59 (experiment 1) n = 103(experiment 2) Preschool (Stanford University) (Stanford, California USA)	10-12 week intervention: conceptual framework for understanding nutrition included food-body relationship, food as a source of nutrition and diverse nutrients were presented in five child-friendly storybooks (included language, color photographs of food and people and interactive questions). The intervention group read 0-2 books each week.	Pre-intervention measures Experiment 1: control group: no treatment, children's un-tutored nutrition knowledge was recorded for comparison. Experiment 2: alternative condition, 5 child-friendly story books (e.g. enjoyment of healthy eating, exercise etc.)	Learning led children to eat more pieces of vegetables at snack time in both experiments, although the children were not instructed to eat more vegetables as part of the intervention. Young children can benefit from an intervention that teaches theories about nutrition.
Harnack et al. (2012) - Food-service	Evaluate the effects of two meal service strategies on intake of fruits and vegetables (serving fruits and vegetable first and serving meals portioned by providers).	Randomized crossover	2-5 years n = 53 Head Start center (Minneapolis, Minnesota, USA)	Crossover trial over 6 week period during usual lunch time. 1) Provider portioned condition (week 1 & 6) - portioning a specific quantity of all menu items on plate rather than allowing the child to self-serve food items. 2) Fruits and vegetables first condition (week 3 & 5) - minor adjustment to traditional family style meal where fruits and vegetables served first before other meal items.	Control condition: (week 2 & 4) usual traditional family style meal service	The observed intake of fruit but not vegetable servings increased during serving fruits and vegetables first condition. Intake of both fruits and vegetables was lower for provider portioned condition. Results supports the current recommendations for traditional family style meal service.

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Table 2 (*continued*)

Study/intervention	Aim	Design	Sample[a],setting, location	Intervention	Control/comparison	Vegetable related conclusions for primary and secondary outcome
Hausner et al. (2012) - Taste exposure - Pairing	Investigate mere exposure, FFL and FNL strategies to increase a novel vegetable (artichoke).	Between-subjects	22-38 (28.7 ± 3.71) n = 104 Nurseries (Copenhagen, Denmark)	10 exposure to respective artichoke puree (over 4 weeks) 1) RE: mere exposure 2) FFL: sweetened puree 3) FNL: energy dense puree with added oil.	Pre-intervention measures Control vegetable; carrot intake measured at pre and post intervention	The mere exposure and FFL strategies increased acceptance of vegetable intake (g). Five to six exposures were sufficient to increase intake of the novel vegetable. Repeated exposure is a simple and effective technique that can be used in home and day care settings.
(Holley et al., 2015) - Taste exposure - Reward - Modelling	Evaluate effectiveness of home-based intervention of rewards, modelling and repeated exposure to increase children's liking and consumption of a previously disliked vegetable.	Between-subjects	25-55 (38.0 ± 7.75) months n = 115 Home-based (East Midlands, England, UK)	Parents were instructed to offer small piece of the target disliked vegetable (selection from baby corn, celery, red pepper, cherry tomato, cucumber, and sugar snap peas) for 14 consecutive days. Four experimental conditions: 1) Repeated exposure 2) Modelling (parent) and repeated exposure 3) Rewards (sticker and praise) and repeated exposure or 4) Modelling, rewards and repeated exposure.	Pre-intervention measures Control centers: no treatment	In comparison to the control group increases in liking and consumption (g) were seen in the rewards and repeated exposure and the modeling, rewards and repeated exposure condition. Parent-led, home-based intervention incorporating rewards and modelling are cost efficient strategies to increase children's vegetable intake.
Horne et al. (2011) - Taste exposure - Reward - Modelling	Determine whether modelling (animated character) and rewards intervention produce large and lasting increases in fruit and vegetable consumption.	Within-subjects	24-52 (34.0) months n = 20 Nursery (Bangor University) (Bangor, Wales, UK)	Children were exposed to 8 fruit and 8 vegetables (presented as 4 different food sets, each comprising 2 fruit and 2 vegetables). Taste exposure: during baselines 1–4, children received different food set daily (snack time and again at lunch time). Intake was not rewarded during 4 baselines and during lunch. At least 24 exposures of the target vegetables offered. Reward: 3 types of rewards were offered during the target fruit/vegetable intervention phases based on how many pieces consumed (sticker; lead to group prize, badge or brick from construction toy). Modelling: animated TV characters modelled eating the target foods and urged children to eat 'to be big & strong'.	Baseline measures at different points (for four different food sets)	The interventions produced significant increases in percentage of fruits and target vegetables (baby sweetcorn, courgette, yam and mange-tout) pieces eaten. Effects were maintained 6 months after removal of rewards. Intake at lunchtime, in absence of rewards indicated that once liking is established in one context, the behavior extended to other meal times.
Martinez-Andrade et al. (2014) - Educational	Evaluate feasibility and impact of "Creciendo Sanos" - a clinic-based pilot intervention to prevent obesity.	Cluster RCT	24-60 (40.6 ± 10.0) months n = 201 Primary care clinics Home-based Mexico City, Mexico)	6 weekly educational sessions promoted healthy nutrition and physical activity (included counselling, motivational enhancement, obesity awareness and prevention). Parents and children engaged in activities (e.g. playing active games, cooking healthy snacks and creating shopping list). Counselling involved improving self-efficacy and enhancing motivation for change.	Pre-intervention measures Control: usual care – no intervention	Intervention effects were found for vegetable servings (FFQ) at 3 months but no other behaviors. At 6 months, no effect of intervention was detected. Parents reported high satisfaction but barriers for participation and retention included transportation cost and time. Future interventions need to investigate how to improve participation and adherence.

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Table 2 (*continued*)

Study/intervention	Aim	Design	Sample[a],setting, location	Intervention	Control/comparison	Vegetable related conclusions for primary and secondary outcome
Reinaerts, Nooijer, Candel, and Vries (2007) - Educational - Food service	Measure the effects of two school-based interventions on children's intake of fruits and vegetables.	Cluster matched and randomized	4-5 years (4–12 years full study sample) n = 122–183 (data extracted from n = 939) Primary schools, Home-based (Limburg, Netherlands)	Interventions components matched for age group (over 8 months). 1) Distribution condition - free fruit & vegetable supply at school and a daily routine integrating a periodic moment for children to eat the distributed fruit & vegetable together (peer modelling). 2) multicomponent condition - classroom curriculum and parental involvement (children provided with lunchbox, to bring fruit and vegetables to school, homework, newsletters and poster reminders at local supermarkets)	Pre-intervention measures Control group received program after the study period (no intervention during the study).	Interventions were effective in increasing fruit and vegetable intake (FFQ) for the overall study population (4–12 years). However, for the age group I (4–5 years) both interventions did not indicate a significant positive result. The study did not comment on the result of different age groups. However the differences in findings for different age group indicated the importance of age appropriate intervention.
Remington et al. (2012) - Taste exposure - Reward	Evaluate whether parental delivery of an established intervention consisting of exposure to "tiny tastes of an initially disliked vegetable, combined with reward, would be effective in the home setting.	RCT	3-4 (3.95 ± 0.5) years n = 140 Home-based (North London, UK)	12 days Intervention: parents asked to offer target disliked vegetable (selection from carrot, cucumber, white cabbage, red pepper, celery, or sugar snap peas) every day for 12 weekdays. 1) Parent-administered taste exposure sessions with tangible rewards (stickers) 2) Parent-administered taste exposure sessions with social rewards (praise)	Pre-intervention measures Control group: no treatment	Parental use of tangible rewards with repeated taste exposures improved children's liking and intake (g) of initially disliked vegetables. Differences were maintained at 1 and 3 month follow-up. Findings for social reward condition was not significantly different from the control condition.
Roe, Meengs, Birch, and Rolls (2013) - Variety	Determine whether providing a variety of familiar vegetables or fruit as a snack would lead to increased selection and intake.	Crossover	3-5 (4.4 ± 0.1) years n = 58–60 Family center (The Pennsylvania State University) (State College, Pennsylvania, USA)	8 afternoon snack times (4 for fruits; apple peach and pineapple and 4 for vegetables; cucumber, sweet pepper and tomato). Children were offered variety of all 3 vegetables together. Similar offerings were also made for fruits.	Comparison: children were offered 3 different vegetables as a single type (one at a time).	Providing a variety increased intake of fruits and vegetables (pieces eaten).
Savage, Fisher, Marini, and Birch (2012) - Food servuce	Assess the effect of serving a range of entree portions on children's ad libitum intake and energy density consumed at the meal.	Within-subjects	3-5 (4.3 ± 0.5) years n = 17 Childcare center (The Pennsylvania State University) (State College, Pennsylvania, USA)	Participants received different size entrée portion (i.e. 100 g, 160 g, 220 g, 340 g and 400 g) to measure the effect of varying size portion entrée on ad libitum energy intake of macaroni and cheese, and fixed portions of unsweetened applesauce, green beans, and whole-wheat roll.	No pre-intervention measures or control comparison	Increasing portion size of the entrée, reduced the energy intake (kcal) of foods served with the entrée, including fruit (unsweetened applesauce) and vegetable (green beans). Serving smaller age-appropriate entree portions may help to improve children's nutritional intake including the intake of fruit and vegetables served with the entrée while decreasing plate waste.
Savage et al. (2013) - Pairing	Compare the effects of offering dips (with and without familiar herb and spice) with vegetables and vegetable alone (without dip) on children's willingness to taste, liking, and intake of vegetables.	Within-subjects	3-5 years n = 34 (experiment 1) n = 26–27 (experiment 2) Childcare center (Central Pennsylvania, USA)	Experiment 1 was conducted to determine which vegetable was familiar, disliked or refused and which flavor dip the children preferred. Experiment 2: children rated liking of celery and yellow squash with and without their favorite reduced-fat dip and intake was also measured.	Comparison: intake of vegetable without dip	Herb dip was preferred (pizza or ranch) compared to plain dip. Children were more likely to reject vegetable alone than when served with herb dips. Offering vegetables with reduced-fat dips (familiar herb and spice flavors) can increase tasting and thereby promote liking and intake of vegetables (g), including those which were previously rejected or disliked (celery and yellow squash).

(*continued on next page*)

Table 2 (*continued*)

Study/intervention	Aim	Design	Sample[a],setting, location	Intervention	Control/comparison	Vegetable related conclusions for primary and secondary outcome
Sharma, Chuang, and Hedberg (2011) - Educational	Pilot test CATCH (Coordinated Approach to Child Health) Early Childhood program at promoting healthy nutrition and increasing physical activity.	Pre-post	3-5 years n = 61 Head Start centers (Harris County Texas, USA)	The intervention program was delivered by trained teachers over a 6 week period. The program included nutrition education, physical activity and a family component. Nutrition-based lessons in classrooms aimed at promoting healthy eating habits such as increasing fruits and vegetables intake. Parent were sent education tip-sheets which were designed to modify the home nutrition.	Pre-intervention measures	Children's observed vegetable servings did not increase significantly. Results indicated good feasibility and acceptability of the program.
Sirikulchayanonta, Iedsee, Shuaytong, and Srisorrachatr (2010) - Educational	Evaluate the use of food experience, multimedia and role models for promoting fruit and vegetable consumption.	Pre-post	4-5 years n = 26 Kindergarten (Bangkok, Thailand)	The 8 week intervention consisted of eleven 30–40 min interactive activities (e.g. games, cartoon, gardening and cooking). Classroom curriculum: introduced health benefits of fruit and vegetables to improve familiarity and acceptance. Letter were sent to parents to guide them to motivate and encourage their children to eat variety and quantity of fruit and vegetables. While eating together teachers, peers, and parents were used as role models.	Pre-intervention measures	The intervention was effective in increasing fruit and vegetable consumption (g). Study recommend nutrition education in the course curriculum in combination with social support from the teachers and the family can improve and sustain fruit and vegetable intake.
Spill et al. (2010) - Food service	Investigate whether increasing the portion size of vegetables served at the start of a meal leads to increased vegetable consumption and decreased meal energy intake.	Crossover	3-5 (4.4 ± 0.71) years n = 51 Day-care center (The Pennsylvania State University) (State College, Pennsylvania, USA)	Test lunch served once a week for 4 weeks. In 3 experimental meals, a first course of raw carrots was served varying in portion sizes (30 g, 60 g and 90 g).	Control comparison: no first course served in control meal	Increasing the portion size of a vegetable (carrot) served as a first course was found to be an effective strategy for increasing vegetable intake (g).
Spill, Birch, Roe, and Rolls (2011a) - Food service - Stealth	Investigate whether incorporating pureed vegetables (hiding) into entrees to reduce the energy density affected vegetable and energy intake.	Crossover	3-5 (4.7 ± 0.62) years n = 39 Day-care center (The Pennsylvania State University) (State College, Pennsylvania, USA)	1 day a week for 3 weeks Breakfast, lunch and dinner entrée energy density was manipulated by increasing the proportion of pureed vegetables. Entrees were served with un-manipulated side dishes and snacks. 1) 85% ED (tripled vegetable content), 2) 75% ED (quadrupled vegetable content).	Control comparison: standard 100% energy density entrée.	The incorporation of considerable amounts of pureed vegetables to reduce the energy density of meal (breakfast; zucchini, lunch; broccoli, cauliflower and tomato and dinner; cauliflower and squash) was effective to increase the daily vegetable intake (g) and decrease the overall energy intake. The consumption of more vegetables in entrees did not affect the intake of the vegetable side dishes i.e. at lunch (broccoli) or at dinner (green beans).
Spill, Birch, Roe, and Rolls (2011b) - Food service	Determine the effects of serving varying portion sizes of a low energy dense, vegetable soup on children's energy and vegetable intake within a meal and over the next eating episode.	Crossover	3-5 (4.7 ± 0.85) years n = 72 Day-care centers (The Pennsylvania State University) (State College, Pennsylvania, USA)	Intervention took place 1 day a week for 4 weeks. 3 varying the portion size of tomato soup served as a lunch first course (150 g, 225 g and 300 g) Standard breakfast, lunch, and afternoon snacks were provided during the test days.	Control comparison: no first course was provided.	Serving a low energy dense, vegetable soup (tomato) as a first course is an effective strategy to reduce children's intake of an energy dense main entree and increase vegetable consumption (g) at the meal. Total vegetable consumption across lunch (broccoli) and afternoon snack (cucumber, cherry tomatoes and carrot) increased as size of the soup portion increased.

(*continued on next page*)

Table 2 (*continued*)

Study/intervention	Aim	Design	Sample[a],setting, location	Intervention	Control/comparison	Vegetable related conclusions for primary and secondary outcome
Tabak, Tate, Stevens, Siega-Riz, and Ward (2012) - Educational	Evaluate a home-based intervention targeted to parents to improve vegetable intake in preschool-aged children.	RCT	2-5 (3.6 ± 0.8) years n = 43 Home-based (Chapel Hill, North Carolina, USA)	4 month feasibility study of home-based intervention of: 2 motivational phone calls (parent were asked to choose 1 of the 4 topics for improvement. Options were vegetable availability, picky eating, modelling and, family meals 4 tailored newsletters were sent which covered all 4 topics.	Pre-intervention measures Control group: were sent 4 children's books (not health/nutrition related)	Intervention did not increase intake of vegetables (FFQ). However increase were reported for availability, vegetable types and number of fruits and vegetables offered for snacks. Home-based intervention altering parents' behavior such as feeding practices and improving the home environment may aid to increase vegetable intake in children.
Vereecken et al. (2009) - Educational	Evaluate the impact of the "Beastly Healthy at School" intervention in children's food consumption.	Cluster RCT	3-5 years n = 476 Schools (East Flanders, Belgium)	6 month intervention (2 days training for staff). An educational package, including an educational map for the teachers, an educative story and educational material for the children and newsletters for the parents.	Pre-intervention measures Control group	No significant effect of intervention was evident for parental reported vegetable intake (g; FFQ).
Williams et al. (2014) - Educational	Evaluate the effects of nutrition-education program in child-care centers on children's at-home daily consumption of fruit and vegetable and other at-home dietary behaviors.	Matched settings, Cluster RCT	2-5 (4.4 ± 0.3) years n = 1143–902 Childcare centers/Home-based (New York City, New York, USA)	Registered dietician provided nutrition education to the parents and children separately over a 6–10 week period. Children received nutritional education e.g. eating variety of fruits and vegetables ("Vary your Veggies"). Staff were educated on nutrition and physical activity policy. Parents were sent weekly newsletters (activities and recipes)	Pre-intervention measures Control centers	The program improved children's at-home daily consumption of vegetables (reported by parents using pictures of filled cup measurement), no effect on fruit intake. The study also found a significant increase in the frequency of child-initiated vegetable snacking (which contributed to the significant increase in daily vegetable intake). Future research needs to understand the process by which nutrition-education in childcare setting can translate into changes at home consumption.
Witt and Dunn (2012) - Educational	Determine whether an interactive nutrition and physical activity program "Color me Healthy" increases fruit and vegetable consumption.	Cluster RCT	4-5 years n = 122 Childcare centers (Boise, Idaho, USA)	"Color Me Healthy" program was delivered for 6 weeks. The program used color, music, and exploration of the senses to teach children about healthy eating and physical activity. The intervention was teacher-led and included 12 circle-time lessons (2 each week, focused on fruit and vegetables of different colors) and 6 imaginary trip (1 each week, fun imaginary classroom activity).	Control centers did not receive the curriculum	Significant increase in the percentage of fruit and vegetable snack consumed (g) among the intervention group. Results were also significant at the 3 month follow-up.

G: grams, RE: repeated exposure, FFL: flavour-flavour learning, FNL: flavour-nutrient learning, g: grams, FFQ: Food Frequency Questionnaire.
[a] Age range and mean age (SD) reported where appropriate, sample size at baseline and immediately post intervention (if different to baseline).

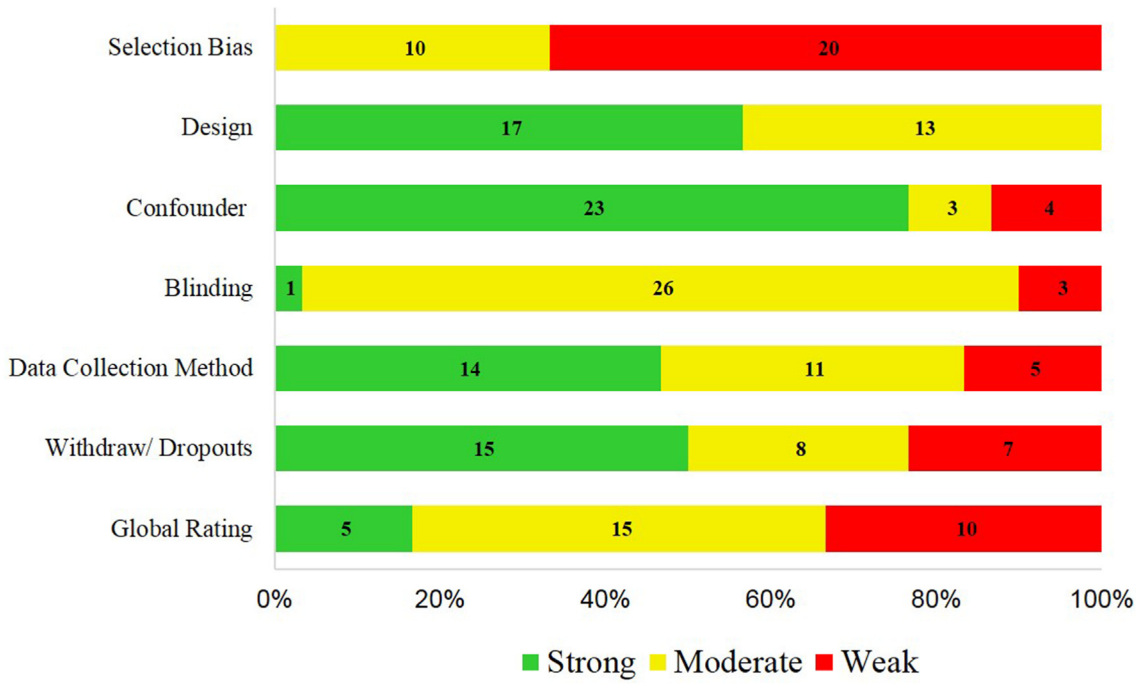


Fig. 2. Summary of study quality assessment using the Effective Public Health Practice Project (EPHPP) quality assessment tool for quantitative studies.

these values in their results. Therefore based on the authors' knowledge and using existing data from a previous early years health intervention project; HabEat (Caton et al., 2013; Hausner, Olsen, & Moller, 2012), we identified and entered a pre-post correlation thought to be reasonable, r = 0.6 (for unfamiliar/disliked) and r = 0.7 (for familiar vegetables, moderately liked and usual vegetable intake). Studies with more than one intervention group were entered separately as intervention arms.

For each meta-analysis/subgroup analysis (e.g. grouping by type of design) the heterogeneity was assessed using I^2 (inconsistency) statistics. Higgins, Thompson, Deeks, and Altman (2003) described I^2 "as the percentage of total variation across the studies that is due to heterogeneity rather than chance"; values < 0.25 were considered low, < 0.50 were considered moderate and > 0.75 were considered high (Higgins et al., 2003). As studies did not use identical or even similar procedures a random-effects model was used for all meta-analyses to pool estimated differences in vegetable intake between intervention and comparison groups. This model is more appropriate as there are various small size studies and the model will give relative weight based on the study population. The random-effects model accounts for within study variance (included in the fixed effect model) and between study variance. Effect sizes are reported using Hedges g (adjusted standardized mean differences), as this measure accounts for differences in measurements of the intake data (e.g. weight in grams, observations, FFQ score). The effect size from each study with confidence intervals and cumulative effect sizes are presented using forest plots. Study was used as the unit for analysis, except for analysis of intervention strategies. For studies with more than one intervention group, the intervention arm (condition) was used as the unit of analysis.

Sensitivity analysis was performed by excluding three studies, one which reported median data (Bell, Hendrie, Hartley, & Golley, 2015), another with various experimental conditions but none were defined as standard or control condition (Spill, Birch, Roe, & Rolls, 2010) and a third study by Harnack et al. (2012) who found non-significant effects for one of their intervention arm but did not report the precise p value (p value of > 0.05 was entered as 0.06). Subgroup analysis was conducted based on study methodology (study design, location, study setting and quality assessment ratings) and intervention factors (intervention strategies, type of vegetable, outcome measurements, delivered by and the intervention recipient). A meta-regression using the random effect model (methods of moments) was performed on the number of taste exposures used in the intervention. Finally, a funnel plot and Egger's regression test were conducted to check for publication bias.

3. Results

3.1. Participants and design

There were 4017 participants included in the review. The sample size varied in each study from 12 to 1154 (902 post intervention) and all studies included boys and girls. The mean age was 3.8 years (based on studies which reported the mean age, n = 19). The children were generally from mid-high socioeconomic status, except for Savage, Peterson, Marini, Bordi, and Birch (2013) and Williams et al. (2014) study which assessed vegetable intake in children of low income parents. The design of the studies included 4 RCT, 8 cluster RCT, 6 crossover, 6 between-subjects, 3 within-subjects, and 3 pre-post format (see Table 2 for individual study design).

3.2. Interventions

The duration of the interventions varied from two single sessions of pairing a vegetable with or without liked food (e.g. broccoli on top of pizza vs broccoli on side of pizza) to an 8 month educational program. They targeted vegetable only (n = 13), fruit and vegetables (n = 6), vegetable as part of healthy nutrition (n = 6), healthy lifestyle (n = 4) or, to prevent obesity (n = 1). To promote vegetable intake in preschool-aged children nine dominant strategies emerged from the included studies. These were educational interventions, repeated taste exposure, pairing, changed food-services, explicit reward, modelling, choice, variety, and visual presentation. Most of the studies included more than one of these approaches; see Table 2 for strategies included in each study and see Table 3 for description of each strategy and the number of studies using them. There were no specific strategies identified for children going through the fussy eating phase or food

Table 3
Description of each intervention strategy and number of studies using them.

Intervention	Brief description	n
Educational	• Teaching about the nutritional value to children, parents or/and staff (e.g. Williams et al., 2014) • Children engage in fun activities such as gardening, games play, cooking classes and tasting (e.g. Sharma et al., 2011; Witt & Dunn, 2012)	10
Taste exposure	• Opportunity to repeatedly taste the same vegetable/s (e.g. Fildes et al., 2014; Hausner et al., 2012); in present studies the number of exposures varied from 2 to 24.	10
Pairing or stealth	• Presenting vegetables with a liked food or flavor for example herb dip (e.g. Fisher et al., 2012) • Providing additional nutrients for example sunflower oil or maltodextrin (e.g. Caton et al., 2013; de Wild et al., 2013) • Vegetables by stealth, such as incorporating pureed vegetable into an entrée (e.g. Spill et al., 2011a)	8
Food services	• Provision of target foods e.g. increasing availability and accessibility (e.g. Bell et al., 2015) • Changed the way food was provided (e.g. served vegetables first e.g. Spill et al. (2010)) • Modification to the portion size (e.g. Savage et al., 2012)	7
Reward interventions	• Social; praise (e.g. Remington et al., 2012) • Tangible non-food rewards e.g. sticker or toy (e.g. Horne et al., 2011)	5
Modelling	• Learning through observation; for example. Holley et al. (2015) required the parents to model vegetable intake to encourage their children to eat the vegetables whereas Horne et al. (2011) used animated video characters to model eating of the target foods.	2
Choice	• Provided vegetables singly or offered children a choice of two vegetables (de Wild et al., 2015)	1
Variety	• Offered vegetables individually or together (Roe et al., 2013).	1
Visual presentation	• Provided vegetables in a visually appealing manner – for example presenting slices of cucumber decorated with olives and chives in the shape of a caterpillar (Correia et al., 2014).	1

neophobia. The comparison groups were reported to receive no treatment (or baseline consumption), usual care or received treatment after the intervention phase.

3.3. Types of vegetables used: familiar/liked and unfamiliar/disliked

The type of vegetables included in the studies were classified as either: familiar/liked or unfamiliar/disliked. The familiar vegetables were usual everyday vegetables, those which were commonly consumed and generally accepted by the study children, for example red pepper, cauliflower, celery, snap peas (mange-tout), broccoli, carrots, tomatoes, cucumbers, green beans and swede. Unfamiliar/disliked vegetables were those which were novel (e.g. salsify, artichoke, endive) or disliked by the study children that is not favored or frequently tasted within that sample in the period leading up to the study. The disliked vegetables were typical everyday vegetables; but were targeted selectively as they were not preferred or consumed by the specific child (e.g. white cabbage, snap peas, baby corn, tomatoes, celery and yellow squash). The reasons why a particular vegetable is disliked, varies between children (for example a child may simply refuse to eat a particular vegetable due to its colour or texture (without prior taste experience) or it could be that the child has tasted or eaten the vegetable before but they no longer like this vegetable. Studies which categorized a vegetable as disliked generally asked parents to identify a target vegetable for their child from a selection of the study vegetables (See, Fildes, van Jaarsveld, Wardle, & Cooke, 2014; Holley, Haycraft, & Farrow, 2015; Remington, Añĥez, Croker, Wardle, & Cooke, 2012). The categorization of the vegetable as familiar/liked or unfamiliar/disliked was mainly based on the study's description or imputed by the authors if missing (for example vegetables which feature within the FFQ measures were considered as familiar vegetables since scores reflected reported intakes).

3.4. Synthesis of results: meta-analysis

With all 30 studies included, overall a small-moderate effect ($g = 0.40$) of intervention was observed (Fig. 3). When 44 intervention arms within studies were used as the unit of analysis, a slightly higher effect size was observed $g = 0.42$, CI: 0.33–0.51, $Z = 8.79$, $p < 0.001$. The sensitivity analyses performed by excluding three studies (Bell et al., 2015; Harnack et al., 2012; Spill et al., 2010) indicated effect size of $g = 0.43$, CI: 0.33–0.53, $Z = 8.27$, $p < 0.001$ and $Tau^2 = 0.04$, $Chi^2 = 85.13$, $df = 26$, $p < 0.001$, $I^2 = 69.54\%$. Considerable heterogeneity was observed for 30 studies ($I^2 = 73\%$), therefore further subgroup analyses were performed to investigate inconsistency between studies.

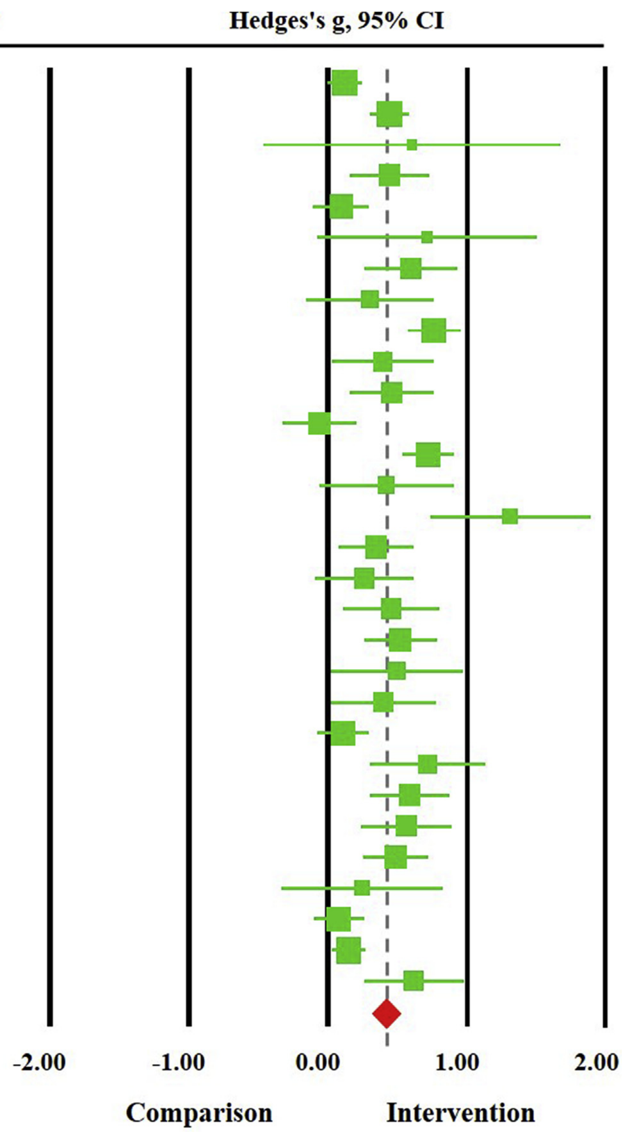
3.5. Subgroup analyses

The subgroup analyses (grouping studies according to moderators e.g. the study design and intervention strategy) showed a reduction in dispersion, but generally the heterogeneity remained high, see Table 4. The effect size significantly varied by study design, outcome measures, intervention recipient, intervention strategy and the type of vegetable used. Studies which used RCT, within-subjects, between-subjects or crossover design had better outcome than studies which used cluster RCT or pre-post designs. This may be because some of the studies within these design categories did not always include the same participants at baseline and post-intervention. The effect size also varied by how vegetable intake was measured, for example the pooled effect was higher when the pieces eaten were counted than when intake was measured in grams or by FFQ. Also when children were the only recipient the effect size was higher than when parents or teachers were involved. However, it should be noted that the number of studies in each category were uneven, this makes comparison less precise. There were no other significant overall group differences identified. Some interesting findings were observed when pairwise comparisons were performed for the category of “who delivered” the intervention and the location of the studies. For example, vegetable intake was higher when the intervention was administered by the parents compared to the research team alone (excluding teachers); $Q = 5.46$, $df = 1$, $p = 0.019$; and for location when comparing UK studies ($n = 5$) to the US studies ($n = 16$), a significantly higher effect size was observed $Q = 4.87$ with $df = 1$, $p = 0.027$ for UK based studies.

3.6. Vegetable familiarity

The pooled effect size varied by the type of vegetable investigated in the studies, see Fig. 4. The analysis indicated that intake of unfamiliar/disliked vegetables improved more than that of familiar/liked vegetables. Of the 9 studies investigating unfamiliar/disliked vegetables 8 used a taste exposure strategy (high multi-collinearity) therefore, it was not possible to assess whether intervention strategy or the type of vegetable was a stronger predictor for the intake. However, 8 of the 10 taste exposures studies using unfamiliar/disliked vegetables had a better combined effect ($g = 0.60$, CI: 0.46–0.74) compared to the 2 studies which used familiar/liked vegetables ($g = 0.35$, CI: −0.00–0.70). Here the pairwise comparison was not statistically significant, possibly due to lack of power.

Study	n	Hedges's g	Lower	Upper
Bell, 2015	216	0.12	-0.02	0.25
Bouhlal, 2014	151	0.44	0.29	0.59
Brouwer, 2013	12	0.60	-0.47	1.67
Caton, 2013	32	0.43	0.14	0.73
Correia, 2014	85	0.09	-0.12	0.30
Cravener, 2015	24	0.71	-0.09	1.51
de Wild, 2013	28	0.59	0.25	0.93
de Wild, 2015	70	0.30	-0.17	0.77
Fildes, 2014	442	0.76	0.56	0.95
Fisher, 2012	147	0.39	0.02	0.76
Gripshover, 2013	162	0.45	0.14	0.76
Harnack, 2012	53	-0.07	-0.34	0.21
Hausner, 2012	104	0.72	0.52	0.91
Holley, 2015	115	0.42	-0.08	0.91
Horne, 2011	20	1.30	0.72	1.89
Martinez-Andrade, 2014	201	0.34	0.06	0.62
Reinaerts, 2007	122	0.26	-0.10	0.62
Remington, 2012	140	0.45	0.10	0.80
Roe, 2013	58	0.52	0.24	0.79
Savage, 2012	17	0.49	0.01	0.97
Savage, 2013	26	0.39	0.01	0.78
Sharma, 2011	61	0.10	-0.09	0.30
Sirikulchaya-nonta, 2010	26	0.71	0.29	1.13
Spill, 2010	51	0.58	0.29	0.88
Spill, 2011	39	0.56	0.23	0.89
Spill, 2011	72	0.48	0.24	0.72
Tabak, 2012	43	0.24	-0.35	0.83
Vereecken, 2009	476	0.07	-0.12	0.26
Williams, 2014	902	0.14	0.01	0.28
Witt, 2012	122	0.61	0.25	0.98
Overall	4017	0.40	0.31	0.50



Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 109.01$, df = 29, p <0.001; $I^2 = 73.40\%$. Test for overall effect: Z = 8.00, p <0.001

Fig. 3. Forest plot of overall intervention effect versus comparison on vegetable intake by study (n = 30).

3.7. Intervention strategies

Many studies used more than one strategy to promote vegetable intake, for primary analysis studies were grouped by the main intervention strategy; education, taste exposure or others. When grouped by main strategy the studies using taste exposure had a significantly higher impact on intake than education or other strategies (Table 4). To explore this further, the intervention arms (n = 44) were clustered by the combinations of strategies used (Fig. 5). Analysis with 14 subgroups showed that the effect size was significantly higher for taste exposure strategy when coupled with reward and modelling. However this subgroup only consisted of two studies, which had very different effect sizes for Horne et al. (2011); hedges g = 1.30, CI 0.72–1.80, p < 0.001 and intervention arm within the study by Holley et al. (2015); hedges g = 0.50, CI: −0.54–1.54, p = 0.35). The study by Horne and colleagues which included 20 children and offered sixteen different fruits and vegetables with a minimum of 24 repeated taste exposures to target food pulled the effect size considerably. When assessing these strategies further, main effect of taste exposure appeared to be most important because repeated taste exposure intervention alone had a higher effect than taste exposure and reward, reward alone or taste exposure and modelling (Fig. 5). Moreover taste exposure to the vegetable on its own (plain form) produced a bigger impact on intake than pairing with other flavors, dips or energy. Some interventions such as offering choice, pairing with dips or making vegetables visually appealing did not improve vegetable intake; this may due to lack of power as only one or two studies were from these categories.

3.8. Number of taste exposures

A meta-regression analysis was performed to examine if the number of exposures offered in the ten repeated taste exposure studies has an effect on vegetable intake (Fig. 6). The analysis indicated that the number of taste exposures was positively associated with effect size (B = 0.035 (SE 0.01, CI 0.00–0.06, p = 0.01). The model was statistically significant (Q = 6.21, df = 1, p = 0.013) and the goodness of fit indicated that the effect size does not vary significantly between these studies when the number of taste exposures are controlled for ($R^2 = 74\%$, $Tau^2 = 0.02$, Q = 10.21, df = 8, p = 0.250, $I^2 = 21.67\%$). For a significant improvement in intake (a moderate effect of g = 0. 5) children would require approximately 8–10 exposures.

Table 4
Subgroup analysis to highlight effect size and heterogeneity by methodology and intervention factors (study as unit of analysis).

Variables	No. of studies	Effect size (95% CI)	I2%	Heterogeneity within (Q/P values)	Heterogeneity between (Q/P values)
Main strategy					**10.52**[a]
Educational	10	0.26 (0.13–0.39)	54	19.39[a]	
Taste Exposure	10	0.57 (0.43–0.70)	52	18.69[a]	
Other	10	0.36 (0.22–0.50)	61	22.53[a]	
Design					**11.84**[a]
Between-subjects	6	0.48 (0.31–0.66)	26	6.77	
Cluster RCT	8	0.25 (0.10–0.40)	44	12.61[a]	
Crossover	6	0.43 (0.26–0.61)	68	15.55[a]	
Pre-post intervention[1]	3	0.22 (0.01–0.44)	72	7.26	
RCT	4	0.59 (0.34–0.84)	30	4.30	
Within-subjects	3	0.64 (0.32–0.97)	71	6.88[a]	
Measurement					**18.83**[a]
Cup serving (image)	1	0.14 (−0.18–0.47)	0	0.00	
FFQ	4	0.38 (0.14–0.62)	0	2.32	
Weight (Grams)	15	0.43 (0.32–0.54)	62	36.97[a]	
Weight (Grams/day)	1	0.71 (−0.14–1.56)	0	0.00	
Energy (Kcal)	1	0.49 (−0.08–1.06)	0	0.00	
Observed	4	0.08 (−0.12–0.28)	0	2.29	
Pieces (count)	4	0.67 (−0.46–0.89)	65	8.48[a]	
Settings					1.01
Early years	22	0.39 (0.28–0.50)	76	88.18[a]	
Home	6	0.51 (0.26–0.75)	27	6.92	
Multi	2	0.30 (−0.07–0.67)	0	0.12	
Location					13.97
Australia	1	0.12 (−0.25–0.48)	0	0.00	
Belgium	1	0.07 (−0.32–0.46)	0	0.00	
Denmark	1	0.72 (0.32–1.12)	0	0.00	
France	1	0.44 (0.07–0.81)	0	0.00	
Mexico	1	0.34 (−0.10–0.78)	0	0.00	
Netherlands	3	0.39 (0.10–0.69)	0	1.98	
Thailand	1	0.71 (0.17–1.25)	0	0.00	
UK	5	0.63 (0.41–0.85)	61	10.22[a]	
USA	16	0.34 (0.22–0.46)	59	36.25[a]	
Quality					0.31
Strong	5	0.42 (0.20–0.65)	84	24.76[a]	
Moderate	15	0.43 (0.28–0.57)	16	16.61	
Weak	10	0.36 (0.18–0.54)	85	60.48[a]	
Delivered by					3.84
Parent	6	0.51 (0.26–0.75)	28	6.92	
Research Team	6	0.24 (0.05–0.43)	67	15.02[a]	
Teacher	8	0.43 (0.23–0.64)	70	23.67[a]	
Teacher, Researcher	10	0.45 (0.29–0.60)	78	41.55[a]	
Recipient					**9.95**[a]
Child	22	0.48 (0.38–0.58)	61	53.22[a]	
Child, Parent	3	0.29 (0.00–0.58)	0	0.17	
Child, Parent, Teacher	4	0.19 (−0.01–0.39)	61	7.71	
Staff	1	0.12 (−0.23–0.47)	0	0.00	

[a] $p < 0.005$; bold font indicates the group differences to be statistically significant; 1 pre-post format studies did not always include the same children.

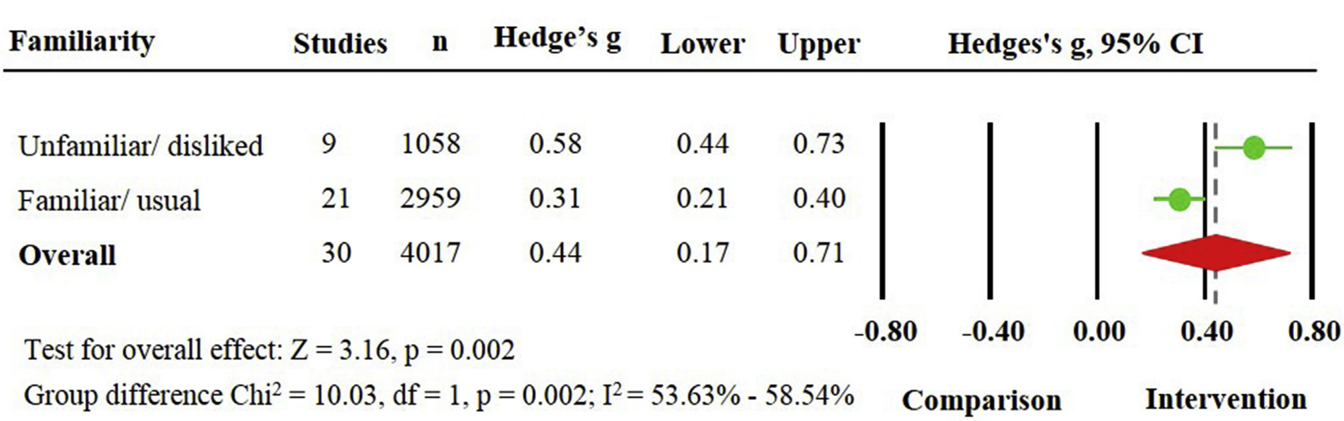
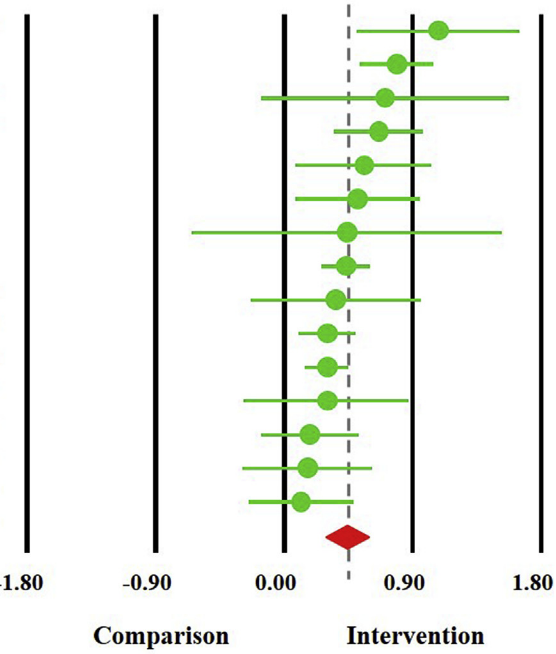


Fig. 4. Forest plot of subgroup analysis by vegetable familiarity/liking on vegetable intake (study as unit of analysis, n = 30).

Intervention strategies	Sub- group	n	Hedges's g	Lower	Upper
Taste Exposure, Reward, Modelling	2	47	1.08	0.50	1.66
Taste Exposure	5	134	0.79	0.53	1.05
Reward	1	24	0.71	-0.16	1.58
Taste Exposure, Tangible Reward	3	541	0.66	0.35	0.98
Food Service and Stealth	1	39	0.56	0.08	1.04
Variety	1	58	0.52	0.08	0.95
Taste Exposure, Modelling	1	28	0.44	-0.65	1.53
Taste Exposure, Pairing	8	358	0.43	0.26	0.61
Taste Exposure, Social Reward	1	71	0.36	-0.24	0.96
Food Service	6	315	0.30	0.10	0.50
Educational	10	2005	0.30	0.15	0.46
Taste Exposure, Choice Exposure	1	70	0.30	-0.28	0.88
Pairing	2	69	0.18	-0.16	0.52
Visual Appeal	1	42	0.16	-0.29	0.62
Educational, Food Service	1	216	0.12	-0.25	0.49
Overall	44	4017	0.44	0.29	0.59



Heterogeneity: $Tau^2 = 0.06$; $Chi^2 = 139.43$, df = 43, p <0.001; $I^2 = 69.07\%$
Test for overall effect: Z = 5.72, p <0.001
Group difference $Chi^2 = 25.42$, df = 14, p = 0.031; $I^2 = 13.43 - 78.31\%$

Fig. 5. Effect by intervention strategies on vegetable intake by intervention arms (n = 44 arranged by the effect size).

3.9. Publication bias

A funnel plot indicated significant asymmetry (Fig. 7), which suggests the presence of publication bias in the present selection of the studies. This is supported by Egger's regression test, indicating that the unpublished studies were likely to have an effect on the overall change in vegetable intake (intercept (B0) is 1.74, 95% CI: 0.17–3.31, df = 28, t = 2.27, p = 0.015). Duval and Tweedie's trim and fill method indicated that under the random effects model, 8 studies are missing and if these studies are added to the analysis then the imputed combined effect is adjusted to g = 0.31 (95% CI, 0.208–0.41) from g = 0.40. The overall effect is slightly reduced, however the effect of the intervention on vegetable intake remained favorable compared to the comparison.

4. Discussion

4.1. Main findings

The present review identified interventions designed to promote vegetable intake in young children that were successful and determined whether some strategies were more effective than others. Overall, evidence from the studies pooled in the meta-analysis indicated that a range of interventions were moderately successful in increasing vegetable intake. The most successful strategies were those which included taste exposures and reward and the less successful, but effective strategies were those which included food services and nutrition education. This was the first systematic review which attempted to investigate

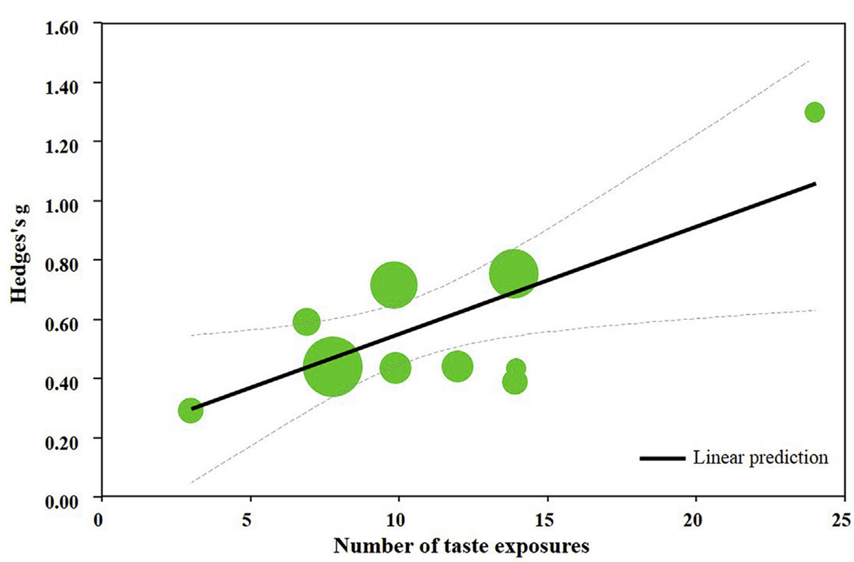


Fig. 6. Meta-regression of effect size (hedges g) according to the number of taste exposures in repeated taste exposure studies (with line of best fit, 95% confidence interval and each study's weight in the meta-analysis, n = 10).

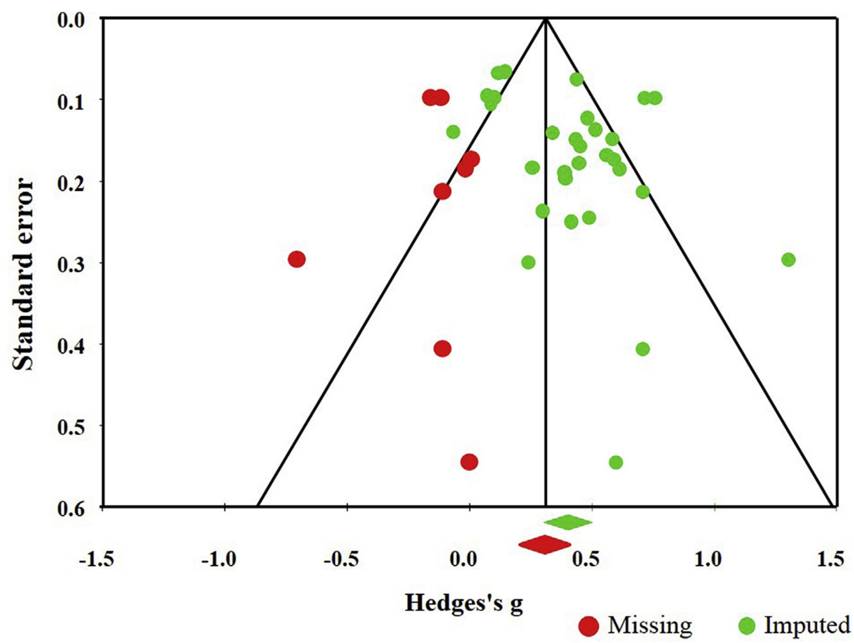


Fig. 7. An asymmetry Funnel plot of standard error by Hedges g of included (n = 30) and missing studies (n = 8).

pooled effects based on vegetable familiarity/liking in order to assess whether the type of vegetable offered to the children influenced outcomes. Evidence showed that the effect size was greater when the vegetable used in the studies were unfamiliar/disliked compared to studies using familiar/liked vegetables. Thus intervention effectiveness may also depend on vegetable familiarity and liking. The magnitude of change for familiar/liked vegetable may be influenced by ceiling effects, however interventions promoting intake of familiar/liked vegetables were also successful.

A previous review by Wolfenden et al. (2012) concluded that the taste exposure strategy was not beneficial in the short-term (at 3 months follow-up), but that using reward with taste exposure was an effective strategy for increasing vegetable consumption. These conclusions should be interpreted with caution as this meta-analysis only included two studies and the findings were mainly driven by one study (Cooke et al., 2011). Cooke et al. (2011) found that the repeated taste exposure strategy was successful immediately after the intervention and at 1 month follow-up but exposure alone had no sustained effects at 3 months, although liking increased as expected. The authors further added that due to a compliance problem (e.g. in home), the children in the exposure alone condition may have received fewer exposures than the children in the tangible reward condition. Although the number of exposures were controlled in their analysis, the present review has identified that the number of taste exposures children received was an important factor for increased intake. Interventions with repeated taste exposures were most effective, therefore, in contrast to Wolfenden et al. (2012) this review stresses the importance of repeated taste exposures, independent of reward. This is further supported by the Horne et al. (2011) study which found that once the liking was established during snack time, the intake generalized to lunch time in the absence of rewards.

A pairwise comparison indicated that the children had improved intake when vegetables were offered at home by a parent compared to when offered by the researcher alone. This may be because parents participating in studies may be highly motived and closeness to the children is likely to yield stronger effects than interventions delivered by unfamiliar others. This is confirmed by finding no differences in intake when teachers delivered the intervention. This review complements and extends the previous review by Holley et al. (2017a) as the present review is based on quantitative synthesis and provided evidence from educational strategies which were missing in the previous reviews. The present meta-analysis included nineteen of the twenty-two studies from the previous review (Holley et al., 2017a). Present findings supported previous suggestions of successful strategies in 2–5 year olds (taste exposure, modelling and non-food reward), however it has further demonstrated the success of these strategies based on effect sizes and more importantly it highlights small effects of educational interventions on vegetable intake.

A previous review by Diep et al. (2014) found that the quality of the study determined the success of the intervention. This was not apparent in the present review. The majority of the studies were scored as weak or moderate and this raises concerns about quality of research in this area. Typically there are problems around lack of representativeness of the sample, the researcher or participants not being blind to the intervention and issues of accuracy when recording intake. However, these are common methodological constraints in this field. Therefore as suggested by Hodder et al. (2018) future research should adopt more rigorous methods to minimize risk of bias and advance the field of research concerning promotion of fruit and vegetable intakes.

Significant heterogeneity was observed in pooling 30 studies, however, additional subgroup analyses indicated that the moderators were possible sources of inconsistency (e.g. the type of vegetable used and intervention strategies). Furthermore, due to the problem of multicollinearity, it was difficult to determine whether taste exposure strategy or the use of an unfamiliar vegetable was more important in predicting intake. This needs to be explored in future research. Meta-analysis is a powerful tool to summarize data from many studies, however there is also the potential to over interpret results, for example small studies tend to report larger treatment benefit than larger studies (Sterne, Gavaghan, & Egger, 2000), affecting the overall effect size. Thus findings should be interpreted with some caution. A major limitation of using standardized effect size (Hedges g) is the clinical interpretation of the findings. To counter this issue to some extent findings from taste exposure only in four studies which provided at least a full portion of the vegetable to the children and measured intake in grams indicated that on average children increased intake by 67 g of the target vegetable (Bouhlal, Issanchou, Chabanet, & Nicklaus, 2014; Caton et al., 2013; de Wild, de Graaf, & Jager, 2013; Hausner et al., 2012). Given that an adult portion of vegetables is 80 g and for a child is 40 g, this increase of 67 g is at least one and a half portions and is therefore important.

Some novel findings have emerged from this review including the effect of vegetable familiarity/liking on intake of vegetables and the most effective intervention strategies in children aged 2–5 years. The findings in relation to vegetable familiarity on intake is novel and interesting but there are some limitations. While the authors of the present paper categorized the type of vegetables based on vegetables used in the primary research and author's descriptions there are potential overlaps between the vegetable categories, for example a vegetable which is familiar can be disliked and unfamiliar foods are not necessarily disliked. Therefore, the outcome from this subgroup analysis should be interpreted with caution. Repeated exposure in early years is perceived to be important in the formation of taste preference (Ventura & Worobey, 2013). According to the meta-regression the more exposure a child receives to a particular vegetable the more likely they are to increase their intake of that vegetable. To achieve an increase in intake at least 8–10 exposures are recommended, especially for unfamiliar/disliked vegetables. Moreover, the evidence suggests that offering vegetables alone is better than pairing with flavors or energy as this can result in a negative contrast effect when subsequently presented alone (Dwyer, 2012).

A comprehensive search for the present review did not retrieve any papers which specifically addressed fussy eaters, but the age range for the search included the peak period for fussy eating. Future studies might investigate what specific strategies are effective in children who score high for neophobia or fussy eating. Also, longer term studies are needed to investigate if taste exposure strategies are sustainable over time (12 + months) and whether they are feasible and cost effective at a large scale. Some strategies may work better with younger than older children. For example, preschool children may be more amenable to these interventions than older children who have established food preferences, therefore early intervention is key. In addition, some strategies may need to be tailored to the needs of particular children, for example those with genetic taste sensitivity to bitter tastes (see Keller, 2014 for a review).

A previous systematic review by Mikkelsen, Husby, Skov, and Perez-Cueto (2014) reported that including an education component to children's vegetable intervention was important. In the present meta-analysis, all educational interventions were successful but the effect sizes were smaller than the taste exposure strategies. A more recent systematic review by Hendrie, Lease, Bowen, Baird, and Cox (2016) investigating child's 'usual intake' rather than specific target vegetable (e.g. disliked) in 2–15 year olds stated that the taste exposure studies were promising for the target vegetables but no evidence was reported beyond this on the habitual intake (Corsini, Slater, Harrison, Cooke, & Cox, 2013). Therefore the authors suggested that future interventions should combine the taste exposure strategies with those which influence the usual intake. To our knowledge repeated taste exposure (usually for target vegetables) in combination with education (generally for improving the usual intake) has not been investigated on the intake of vegetables in children aged 2–5 years. Therefore, these strategies should be combined to assess if intake of both the target vegetable and child's usual vegetable intake can be improved simultaneously.

5. Conclusions

In conclusion repeated taste exposure is a simple technique that could be considered suitable for broader translation to childcare settings and the home. Health policy could specifically target the use of novel and disliked vegetables in addition to the usual vegetables consumed in day care settings with emphasis on offering a minimum of 8–10 exposures. Further research is needed to understand which strategies works best for the food fussy children. Improving liking and encouraging intake of vegetables will lead to long term health benefits only if the intake is sustained. Therefore lasting strategies which encourage vegetable intake in the early years is essential and can influence later health outcomes.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.appet.2018.04.019.

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