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Literature Review

Increasing fruit and vegetables consumption among children: a systematic review of animated nutrition interventions

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Background

Low consumption of fruits and vegetables among children can lead to deprivation of micronutrients necessary for growth and development and predispose them to NCDs later in life. Low consumption of these nutrient-rich foods is related to high consumption of nutrient-poor, high-energy foods, which leads to childhood overweight and obesity. Many children do not consume enough fruits and vegetables to meet recommendations. This review aims to assess the effectiveness of animated interventions in increasing children's fruit and vegetable consumption.

Methods

Articles on animated interventions for increasing fruit and vegetable consumption among children were systematically reviewed from Web of Science, PubMed, and Google Scholar. For the literature searches, inclusion and exclusion criteria were established, and the methodology followed the PRISMA recommendations. Extracted data were synthesized to show the effectiveness of interventions.

Results

Thirteen studies (2003-2017) of animated interventions targeting children (3-12 years) designed to increase their consumption of fruits and vegetables met the criteria for inclusion in the systematic review. Most of the studies (69.2%) were in the United States, with no studies in LMICs identified. The animation interventions used games (46.2%), characters (23.1%), adventures (23.1%), and comic books (7.7 %). 11 of the analysed studies revealed positive or neutral effects of interventions on fruit and vegetable consumption. Parental participation, goal setting, and rewards were identified as facilitators of success. Identified interventions were effective in the short term (follow-up <12months). The games and adventure interventions had the greatest effect, with multi-component interventions most effective in increasing fruit and vegetable intake.

Conclusion

There is a need for more research to determine the effectiveness of such interventions over extended periods. Multi-component interventions especially including parental involvement, goal setting, and rewards should be leveraged in designing similar interventions in LMICs since there was a conspicuous absence of such studies found in the literature.

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INTRODUCTION

Fruits and vegetables are essential components of a healthy diet, as they contain high quantities of micronutrients, phytochemicals, and fibre (Nebeling 2002; Septembre-Malaterre, Remize, and Poucheret 2018). The World Health Organisation (WHO) recommends the daily consumption of 400g (5 servings) of fruit and vegetables per person (WHO 2005). The consumption of a diverse diet including a variety of fruits and vegetables promotes better health, growth, and intellectual development throughout a person's lifetime and reduces the risks and incidence of ill health and death from non-communicable diseases (NCDs) (Samuel, Otitoju, and Okekunle 2020; WHO 2005; Afshin et al. 2019). Low consumption of fruit and vegetables among children can lead to deprivation of micronutrients necessary for growth, development, and body functions and predispose them to NCDs later in life (Lopes et al. 2018). Low consumption of these nutrient-rich foods is linked to high consumption of nutrient-poor, high-energy foods, which is linked to childhood overweight and obesity. Overweight and obesity rates among children and adolescents have more than doubled over the last 50 years (WHO 2020; Micha et al. 2020), and in 2020, 39 million children under 5 years of age were overweight or obese (WHO 2020) with many regions of the world affected.

Many children, especially in low- and middle-income countries (LMICs), do not meet dietary recommendations for fruit and vegetable consumption (Hall et al. 2009; WHO 2005; Spence et al. 2018; Padget and Briley 2005). For example, only 5.4% of adolescents in Lagos, Nigeria consumed the recommended 5 daily servings of fruits and vegetables (Silva, Ayankogbe, and Odugbemi 2017). A study from Ghana found that only 2% of surveyed kindergarten children consumed fruit, while 34% consumed vegetables during school mealtime (Lopes et al. 2018). In many high-income countries, children's consumption of fruit and vegetables is also below recommendations. In the United States, for example, 32% and 19% of children below 6 years of age were found to consume fruit and vegetables respectively less than once daily (Grimm et al. 2014). Children's consumption of fruit and vegetables continued to fall between 2015 and 2020, according to America's State of the Plate (PBH Foundation 2020).

Food choices and dietary behaviours are influenced by a variety of interrelated factors, including (a) psychosocial factors such as attitudes, beliefs, and preferences; (b) components of the food environment; and (c) promotional material such as advertising and product labelling (Davison et al. 2020; Downs et al. 2020; Michels et al. 2018; Vilaro et al. 2018). Consequently, nutrition education and knowledge form an integral part of voluntary nutritional modification and dietary choices (Melesse and van den Berg 2020).

Since established eating habits often persist into adulthood and are then even more challenging to change, studies have found that childhood is more effective for changing eating-related practices (Craigie et al. 2011; Movassagh et al. 2017). Numerous interventions, such as nutrition education, (Ransley et al. 2010), garden-based interventions (McAleese and Rankin 2007), and school-based interventions (Perry et al. 2004; Stables et al. 2005) have been used to encourage children to eat healthily. Learning has become more technologically dependent, and simulation technology, including animation, is increasingly being used in education (Abdalla 2019; Darshan Singh et al. 2018). Animation helps children learn in two ways. First, it facilitates the creation of mental representations of ideas, events, and procedures. Second, it can replace more time-consuming cognitive processes (e.g. abstraction and imagination) (Abdalla 2019). Additionally, studies have demonstrated that animation improves learning outcomes by cultivating a positive attitude in students (Arumugam and Nirmala 2018). Children can acquire concepts and knowledge more effectively by being engaged in animation and visual learning, as part of nutrition education interventions (Kittidachanupap et al. 2012; Xiao 2013; Islam et al. 2014). There is evidence that low-nutritional commercial foods have been successfully promoted through the use of animated commercials (Batada and Wootan 2007; Batada et al. 2008). The same could be applied for promoting healthier food choices. Animation has been found to be effective in improving learning outcomes among children, however, there is a lack of synthesis on its effectiveness in improving their consumption of fruit and vegetables. Hence, this study aimed to examine the existing scientific literature to assess whether animation is effective in increasing fruit and vegetable consumption among children or not. A better understanding of these interventions and their effectiveness can help in the design of appropriate policies and programs to address dietary behaviour among children.

METHODS

PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) (Moher et al. 2009) recommendations were followed for this review, done between September and December 2020 to ensure uniform and open documentation (Moher et al. 2007; Liberati et al. 2009).

The lead author carried out a literature search in PubMed, Web of Science, and Google Scholar for studies that conducted animated nutrition education interventions on children's dietary behaviours. For this review, we refer to animation as a type of moving image in which the movement is either fictional or actual. To find more pertinent papers that might not have surfaced in the computerized searches, review articles' reference lists were also checked. The search terms separated using Boolean operators 'OR' and 'AND' included: 1) participant (Child*, kid* school age* pre-school*); 2) nutrition education intervention (Animat*, puppet* photocard*, photo*, "food photo*", cartoon* "cartoon character*" character*, "video game*", play*, computer*); 3) outcome (Fruit*, vegetable*, "fruit* and vegetable*") (Conducted by IB).

The outcome taken into consideration involved a record of fruit and/or vegetable consumption using any of several techniques of measurement, including dietary recall, food records, food frequency questionnaires, food diaries with

Table 1. Study selection criteria

	Criteria
Inclusion	• Animated interventions targeting consumption of fruits and/or vegetables. • Participants who fall within the specified age range of 4-12 years (pre-school and school-age children), with or without parents or caregivers. • Animated interventions including cartoons, games, comic books, puppet/puppet shows, and adventures. • Studies that measure the consumption of fruits and/or vegetables at two or more time points where one measurement is a baseline measure. • Studies with any length of intervention duration, any setting or location • Fruit and/or vegetable consumption is a primary outcome. Fruits can be either whole or 100% fruit juice
Exclusion	• Review studies, and grey literature. • Self-declared consumption. • Interventions that do not include an animated component. • Studies on the consumption of fruits and vegetables without intervention. • Papers published in a language other than the English language.

short (three days)- or long-term (3-7 days) periods, and plate waste.

SELECTION CRITERIA

The author team jointly decided on the inclusion and exclusion criteria based on the objective of the review (Table 1). A total of 193 original studies published in English were reviewed in stages. We exported references to excel for the title and abstract screening against the inclusion/exclusion criteria (conducted by IB). Where there was uncertainty on the inclusion/exclusion of a study, a co-author (AK), double reviewed and both authors agreed on a decision.

QUALITY ASSESSMENT AND DATA EXTRACTION

We assessed the quality of the included studies using NHLBI Study Quality Assessment Tools (conducted by IB) (NHLBI 2021). Quality was assessed based on the evaluation of potential flaws in study design or execution, including biased sources (such as participant selection and attrition), potential confounding factors, study power, the degree of causality in the relationship between interventions and outcomes, and other factors. Studies were rated as good (10–14), fair (6–9 scores), and poor (1-5). Six were fair, while seven were of good quality.

IB extracted and tabulated data from included full-text articles. A data extraction spreadsheet was developed and piloted at the start of the review.

RESULTS

OVERVIEW OF STUDIES

The results presented are based on 13 studies that met the inclusion/exclusion criteria (Figure 1). Of the 78 papers that underwent full-text screening, 64 were excluded based on eligibility standards, leaving 13 studies for in-depth review and analysis (See supplementary data, Annex 1).

STUDY CHARACTERISTICS

The studies spanned the period between 2003 and 2017. A majority of the studies (69%) were conducted in the United States and had an intervention lasting between 3 months and 2 years. Sample sizes ranged from 76 to 2,433 participants with follow-up attrition 15% or less. Seven studies collected pre- and post-intervention data while six studies collected only post-intervention data (Table 2).

Four distinct animation intervention strategies (games, adventures, animated characters, and comics) encouraging children's consumption of fruits and vegetables were identified in the literature (Table 3). Six of the studies involved playing games (Baranowski et al. 2003, 2011; Jones, Madden, and Wengreen 2014; Jones et al. 2014; Thompson et al. 2015; Cullen, Liu, and Thompson 2016), three animated characters(Hoffman et al. 2010; Van Offelen et al. 2011; Rosi et al. 2015), three adventures (Horne et al. 2004; Lowe et al. 2004; Upton, Taylor, and Upton 2015), and one comic (comic book) (Joyner et al. 2017) (Table 2). Some of these interventions had other accompanying interventions incorporated alongside the animation itself. These include rewards (Horne et al. 2004; Lowe et al. 2004; Upton, Taylor, and Upton 2015), "behavioural inoculation" such as motivational messages (Baranowski et al. 2011), and physical activity (Baranowski et al. 2011). Some studies assessed other health and dietary outcomes including Body Mass Index (BMI), and increased physical activity.

None of the interventions recorded a reduction in fruit or vegetable consumption. However, one reported that the increases in fruit and vegetable consumption at 12 months of follow-up were not maintained and consumption declined overall (Upton, Taylor, and Upton 2015). Another recorded increased consumption of fruit but no increase in vegetable consumption at the end of year 2 (Hoffman et al. 2010), while others had an increase in consumption, although for a shorter follow-up duration (Baranowski et al. 2003; Horne et al. 2004; Lowe et al. 2004; Baranowski et al. 2011; Van Offelen et al. 2011; Jones, Madden, and Wengreen 2014; Jones et al. 2014; Rosi et al. 2015; Thompson et al. 2015; Cullen, Liu, and Thompson 2016; Joyner et al. 2017).

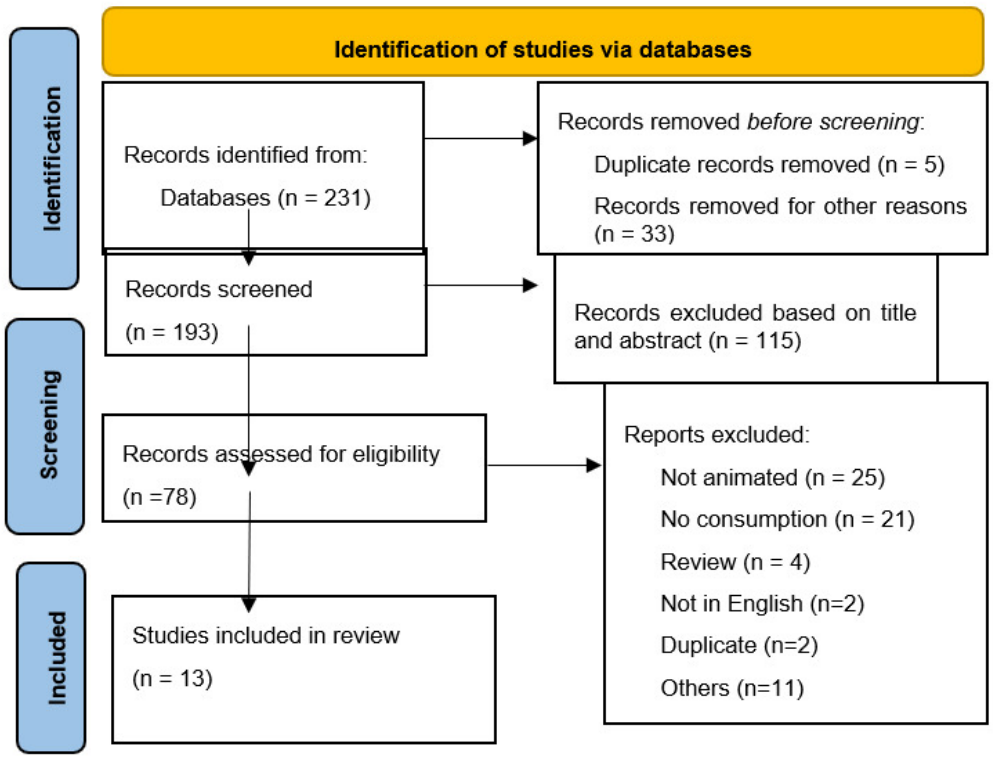

Figure 1. Selection of papers using PRISMA protocol

TYPES OF ANIMATED INTERVENTIONS

GAMES

Six of the reviewed 13 studies involved the use of games (Baranowski et al. 2003, 2011; Cullen, Liu, and Thompson 2016; Jones, Madden, and Wengreen 2014; Jones et al. 2014; Thompson et al. 2015), four of which were randomised controlled trials (RCTs) (Baranowski et al. 2003, 2011; Cullen, Liu, and Thompson 2016; Thompson et al. 2015), while two did not use any comparison group (Jones, Madden, and Wengreen 2014; Jones et al. 2014). All six of these studies were carried out in the United States. The games included computer installed video games (Baranowski et al. 2011; Thompson et al. 2015), interactive video games (Baranowski et al. 2003), online video games (Cullen, Liu, and Thompson 2016), and gamification (Jones, Madden, and Wengreen 2014; Jones et al. 2014) which involved the children assisting the protagonist to overcome the antagonist in the game design.

One of the video game interventions used was *"Saving the Kingdom of Fivealot"* (Squire's Quest 2) (Baranowski et al. 2003; Cullen, Liu, and Thompson 2016; Thompson et al. 2015), where the child becomes a Squire (i.e., a Knight in training). The child's mission is to learn the sacred knowledge and skills (i.e., behavioral components designed to increase fruit and vegetable intake) required to become a Knight. The Knight is to help King Brockwell and Queen Nutritia save the Kingdom from invaders (i.e., snakes and moles) attempting to overthrow the Kingdom by destroying its bountiful fruit and vegetable crops. Squires (players) are assisted in their effort by a "Knight in training" toolkit (i.e., measuring cups and spoons, an apron with the intervention logo shipped to them before initiating gameplay) and the behavioral components led by game protagonists (i.e., characters). Baranowski et al. (2003) found that children (8-12yrs) participating in Squire's Quest increased their fruit, 100% fruit juice, and vegetable consumption by 1.0 servings (p=0.0007) more than the control.

Thompson et al. (2015) included a parental component in their intervention, making electronic newsletters and a website with parents-only access available to one parent in each family. The newsletters included information on the lesson plans for each game episode, along with a list of new terms the child would learn in that episode. It also offered advice on how to overcome barriers that might prevent the children from achieving their fruit and vegetable goals. The children (9-11 years) were randomly assigned to a group (none, action, coping, both). Those assigned to none were the 'control' group. The action plans described how the goals would be attained while the coping plans identified potential barriers and their corresponding solutions. The study had three data collection periods - baseline, immediate post-intervention (post-intervention 1) and 3 months post-intervention (post-intervention 2). At baseline, children consumed an average of 1.8 daily servings of fruit and vegetables 0.5 servings of which was fruit. At post-intervention 1, the action ($p<0.001$), and coping ($p<0.001$) groups had significant increases in fruit and vegetable intake. However, at post-intervention 2, only the action group maintained these increases ($p<0.0001$). The action group had an almost 50% increase in fruit and vegetable intake at post-intervention 1 (0.72 servings) and maintained this increase at follow-up (0.68 servings) (Thompson et al. 2015).

Table 2. Characteristics of included studies

Characteristics of review articles	N (%)
Countries	
United States	9 (69)
UK	3 (23)
Italy	1 (8)
Study design	
Randomized controlled trials	5 (39)
Non-randomized controlled trials	8 (62)
Animated intervention component	
Comic book[1]	1 (8)
Games[2]	6 (46)
Characters[3]	3 (23)
Adventure[4]	3 (23)
Post-intervention/follow-up	
Immediate post-intervention	7 (54)
Follow-up	6 (46)
Follow-up period	
< 3 months	1 (17)
3-5 months	2 (33)
6-11 months	1 (17)
12-24 months	2 (33)
Outcome measured	
Vegetables only	1 (7.7)
Fruit and vegetables	12 (92.3)

[1] Comics is a 'sequential art' that 'presents a montage of both word and image, requiring the reader to exercise visual and verbal interpretive skills' (Eisner 2008)
[2] Games are "a combination of fun and play, a significant force that enables engagement between games and their player containing rules, goals and objectives, outcomes and feedback, competition or challenge, interaction and a story" (Prensky 2001).
[3] This does not follow a definition, but was categorized based on the description given by the primary authors
[4] Similar to characters, adventures were characterised based on author's description.

The control group's consumption of fruit and vegetables declined at post-intervention 1 (0.35 servings) and follow-up (0.04 servings) from its 1.86 servings baseline consumption.

Similarly, Cullen, Liu, and Thompson (2016) randomly grouped participants 9-11yrs based on the type of implementation intentions used within the goal-setting component in each episode (none, action, coping, and both). The objective was to determine whether the intervention affected meal-specific changes six months after baseline. At baseline, children consumed a daily average of 0.63 servings of fruit and 1.13 servings of vegetables, irrespective of their group. At six months post-intervention, the action (P=0.01) and coping (P=0.05) group participants had higher (32% and 18% respectively) vegetable intake at dinner than at baseline.

Baranowski et al. (2011) also used the video games "Escape from Diab" and "Nanoswarm: Invasion from Inner Space" to promote fruit and vegetable consumption among children (10-12yrs). Each game had nine sessions, and each session, a knowledge mini-game which provided practical information relating to modifications of defined goals. The outcomes of the mini-game were compared to those of knowledge-enhancing internet experiences such as a handbook and question-and-answer sessions. Playing the games was found to increase fruit and vegetable consumption among the children by about 0.67 servings per day (p<0.018) compared to the control group.

The gamified interventions that had no comparison groups (Jones, Madden, and Wengreen 2014; Jones et al. 2014) used fictional narrative episodes (the FIT game) with displayed art materials in a setting such as a cafeteria with daily fruit or vegetable targets. "FIT Game" is a low-cost, game-based intervention that incentivizes fruit and vegetable consumption in elementary school children. It provides a narrative in which heroes compete against virtual opponents, and earn virtual currency. All of this are done to capture a band of villains. Events happen daily within the narrative and are dependent upon the school meeting a healthy-eating goal. Daily fruit and vegetable consumption was calculated using a weight-based measure. When target goals were met, the teachers read to the students about how their healthy eating helped the heroes. The students also earned virtual currency. On days when goals were not met, no new episode was read, but the children were encouraged to eat more fruit and/or vegetables to help the heroic characters.

Jones, Madden, and Wengreen (2014) used an alternating-treatments design (where two or more treatments are rapidly alternated) to evaluate the effects of "the FIT Game". A randomly selected fruit or vegetable was targeted for increased consumption daily, and participants were informed of the target food before lunch. They received instructions that their goal was to eat "a little more" than normal. The goals were met when target fruits or vegetables were consumed at or above the 60th percentile of consumption over the last 10 target days. When less was consumed, the target food was repeated until the goal was met. At baseline, respondents consumed an average of 62g of fruits and 42g of vegetables (a serving of fruit but less than a serving of vegetables) daily. When the FIT Game targeted fruit, a 38.7% increase in consumption was recorded (86g, p<0.01), while on fruit non-target days an average of 60g of fruit was consumed. When the FIT Game targeted vegetables, a 33.3% increase in vegetable consumption was recorded (56g, p<0.05), while on vegetable non-target days, 46 g of vegetables was consumed.

Using a similar methodology among children (5-6yrs), Jones et al. (2014) served a total of 5 varieties of fruits and 5 varieties of vegetables throughout the study. At baseline, 0.11 cups (17.71gm) and `phase, fruit consumption increased by 66% to an average of 0.18 cups (32.56gm, an 84% increase) per day (p<0.01) and vegetable consumption increased by 44% to an average of 0.13 cups (14.65gm, a 28% increase) per day (p<0.05).

All games/interventions increased the consumption of fruits and vegetables among the participants at least directly after the intervention. However, the size of the effect varied significantly and longer-term change was not always

Table 3. Summary of characteristics and results of animated nutrition interventions aiming to increase fruit and vegetable intake among children

Reference	Study sample, participants, study setting	Study design, evaluation tools	Outcome measured	Fruit and vegetable data collection method, power to detect outcome, missing data, assessment of bias	Intervention and other approaches and duration, follow-up duration, and participant number at post-intervention	Study quality	Result
Games							
(Thompson et al. 2015) *Creating action plans in a serious video game USA*	400 4th and 5th-grade children (~9-11 years old) and one parent.	RCT; password-protected website hosting questionnaires, 24-hr dietary recall	fruit and vegetable consumption	Three dietitian-assisted unannounced telephone 24-hour dietary recalls at each data collection period; >80% power	A 10-episode online videogame; parental involvement and goal setting. 3 months follow-up; 387 participants. .	Good	A significant group-by-time interaction for fruit and vegetable intake ($p < 0.001$) was found in only the Action group, which had significant increases in fruit and vegetable intake at post 1 ($p< 0.0001$) and post 2 ($p< 0.0001$). No other significant interactions were observed; however, there were significant time effects for fruits ($p < 0.0001$).
(Cullen, Liu, and Thompson 2016) *Squire's Quest! II USA*	400 fourth- and fifth-grade children approximately 9-11 years	RCT; 24hr dietary recall conducted	Fruit and vegetable intake as primary outcome	Three 24-hour recalls at baseline and 6 months later; >80%power	Squire's Quest! II, parent website and weekly mailed newsletter; 6 months post-intervention; 400 participants. Parental involvement and goal setting were additional components.	Good	In the overall models, there were significant increases over time for fruit intake at breakfast (P= 0.009), lunch (P =0.014), and snack (P<0 .001) at 6 months. Higher vegetables intake at 6 months than at baseline was also recorded.
(Baranowski et al. 2003) *Squire's Quest USA*	1578 students aged 8-12 years; all fourth-grade students in participating elementary schools	RCT; Food Intake Recording Software System (FIRSSt), demographic characteristics questionnaire	servings of fruit, 100% juice, and vegetable as primary outcome.	Four days of dietary intake were assessed before and after the intervention. The assessment was made by the FIRSSt, which conducts a multiple pass, 24-hour dietary intake interview directly with the children; fruit, juice and vegetable consumption; 80% power; 89 missing cases;	Squire Quest; delivered over 5 weeks, with each session lasting about 25 minutes; 2 weeks follow-up duration; 1489 participants	Good	Increase in fruits, juice, and vegetables consumption by 1.0 servings (p=0.0007) more than control.

Reference	Study sample, participants, study setting	Study design, evaluation tools	Outcome measured	Fruit and vegetable data collection method, power to detect outcome, missing data, assessment of bias	Intervention and other approaches and duration, follow-up duration, and participant number at post-intervention	Study quality	Result
(Baranowski et al. 2011) *Video Game Play USA*	133 children aged 10–12 years, initially between 50th percentile and 95th percentile BMI.	RCT; 24-hr dietary recall, stadiometer, SECA alpha 822, Gulic tape, Lange caliper for anthropometric measurements, Actigraph AM-7164 accelerometer for physical activity	Servings of fruit, vegetable, and water and minutes of moderate to vigorous physical activity as primary outcomes	At each point of assessment, 3 non-consecutive days of 24-hour dietary recalls were obtained; 80% power; 7.5% missing data;	"Escape from Diab" and "Nanoswarm: Invasion from Inner Space" for treatment group. Control Group played diet and physical activity knowledge-based games on popular websites; each game had nine sessions and a minimum of approximately 40 minutes of game-play per session; within 2 months follow-up duration; 133 participants	Good	Children playing these video games increased fruit and vegetable consumption by about 0.67 servings per day (p<0.02)
(Jones, Madden, and Wengreen 2014) *The FIT Game USA*	251 first-through fifth-grade students in one elementary school	Alternating-treatments design; floor scale to measure fruit and vegetable weights, total fruit and vegetable waste in bins was measured	Fruit and vegetable intake as primary outcome	Plate waste measure, >80% power	The FIT game; 29 days; less than 2 months follow-up duration; 251 participants. Virtual incentives were additional components.	Good	On intervention days, fruit and vegetable consumption increased by 39% and 33%, (p<0.01, p < 0.05; binomial tests), respectively.
(Jones et al. 2014) *Gamification of dietary decision making USA*	180 students in kindergarten (5-6 years old) through 8th-grade enrolled at a charter school in Northern Utah.	Alternating-treatments experimental design; a 317-kg capacity scale for food weights, a smaller scale for portion weights, storage bins as waste receptacles	fruit and vegetable intake as primary outcome	Waste-weight based measure; >80% power	Gamification; 13 days; Less than 2 months Follow-up duration. Virtual incentives were additional components.	Good	Over 13 school days, fruit consumption increased by 66% (p<0.01) and vegetable consumption by 44% (p<0.05) above baseline levels.
Adventures							
Upton, Taylor, and Upton 2015 *Food Dudes UK*	2433 children aged 4–11 years from Fifteen primary	Ecological design; Salter digital scales accurate to 1g was used to measure portion size (80g)	Lunchtime fruit and vegetable consumption as primary	Weighed intake for school-provided lunches, food photography for home-provided lunches	The Food Dudes; 12 months follow-up duration; 1696 participants at 3 months follow-up and 1470 participants at 12month	Fair	A significant increase of 14% P<0.05 in the consumption of fruits and vegetables was found at 3 months for children in the intervention schools eating school-supplied

Reference	Study sample, participants, study setting	Study design, evaluation tools	Outcome measured	Fruit and vegetable data collection method, power to detect outcome, missing data, assessment of bias	Intervention and other approaches and duration, follow-up duration, and participant number at post-intervention	Study quality	Result
	schools in West Midlands, United Kingdom	for school provided lunches, digital photograph of whole lunch and leftover was taken for measurement for home provided lunch	outcome and lunchtime high-fat and high-sugar foods as secondary outcome.		follow-up. The intervention phase lasted for 16 days. Rewards were given when children consumed target fruits or vegetables.		lunches compared to the control group.
(Horne et al. 2004) *Peer-modelling UK*	749 children aged 5–11 y from two inner-city London primary schools	Visual estimation and rating on 5-point scale at lunchtime, scale to weigh fruit before and after consumption at snack-time, parental 24hr dietary recall aided by food diaries	Fruit and vegetable intake as primary outcome.	Visual estimation rating, food waste, and 24hour parental recall	The Food Dudes; 16 days; 4 months follow-up duration; 749 participants. Peer-modeling and rewards were additional components.	Fair	Compared to the control school, lunchtime consumption in the experimental school was substantially higher at intervention and follow-up than baseline (P<0.001), while snack-time consumption was higher at intervention than baseline (P<0.001). There were significant increases in fruit and vegetable consumption at home (P<0.05).
(Lowe et al. 2004) *Peer-modelling UK*	402 children, aged 4 to 11 y from three primary schools in England and Wales	24hr dietary recall, visual estimation and rating on a 5-point scale, weighing food waste	Fruit and vegetable intake as primary outcome and liking for fruits and vegetables as secondary outcome.	Visual estimation rating, food waste, and 24-hour parental recall	The Food Dudes; 16 days; less than 2 months follow-up duration; 402 participants. Peer-modeling and rewards were additional components.	Good	Consumption during the intervention was significantly higher than during baseline at lunchtime and snack-time (P<0.001 in all instances). Consumption outside the school was significantly higher during the intervention on weekdays (P<0.05) but not on weekend days.
Characters							
(Van Offelen et al. 2011) *Go Wild with Fruits and Veggies USA*	140 children in 3rd-5th grade within three urban schools in St. Paul, Minnesota	Quasi-experimental pre-post intervention comparison group design; 24hr dietary recall	Fruit and vegetable intake and physical activity as primary outcomes.	Self-report in the rural setting and 24-hour dietary recall in the urban setting	Go wild with fruits and vegies; two schools served as intervention school while one served as the control (with delayed-intervention); intervention lasted for 7weeks; 7weeks follow-up	Fair	Fruit intake increased in both groups from pre- to post-intervention. Vegetable intake increased in the intervention compared to the control group (p<0.037).

Reference	Study sample, participants, study setting	Study design, evaluation tools	Outcome measured	Fruit and vegetable data collection method, power to detect outcome, missing data, assessment of bias	Intervention and other approaches and duration, follow-up duration, and participant number at post-intervention	Study quality	Result
					duration; 140 participants		
(Hoffman et al. 2010) *Longitudinal Behavioral Effects* *USA*	297 children with a mean age of 6.2 years for both experimental and control groups in an urban school district in the north-eastern part of the US.	RCT; open and closed-ended child questionnaire, fruit and vegetable preference, structured questionnaire for caregiver, food scale accurate to 1g, SECA digital electronic scale and a portable stadiometer for anthropometric measurements	Fruit and vegetable intake as primary outcome.	Weighted plate waste	5-A-Day; 2 years Follow-up duration; 213 participants. Role modeling was an additional component.	Fair	Children in the experimental group consumed more (0.21 servings/ lunch at p<0.0001 and 0.07 servings/lunch at p<0.01) fruit and vegetables respectively at the end of Year 1 compared with children in the control group. At the end of Year 2, children in the experimental group consumed more fruit (0.15 servings/ lunch at p<0.0005), but not more vegetables compared with children in the control group.
(Rosi et al. 2015) *The "5 a day" game* *Italy*	76 children, 8–10 years old in primary schools in Parma and Milan	Single-group education intervention; food diary	Fruit, vegetable, 100% fruit juices and total antioxidant capacity as primary outcomes	Three-day food diary	5 a Day game; 3 months follow-up duration; 76 participants	Fair	The daily total consumption of fruits and vegetables increased from 421.8 to 484.3 g/day (p=0.016).
Comic books							
(Joyner et al. 2017) *FIT Game III* *USA*	572 children (5-11 years) kindergarten through 5th-grade attending two Title 1 elementary schools in Cache County, UT.	A-B-A-B reversal design; a 1g resolution scale to measure individual vegetable portion, Total fruit and vegetable waste in bins was weighed	Vegetable intake as primary outcome	Weighing of plate waste	FIT Game; intervention lasted 14 days in School I and 22 days in school P; less than 2 months follow-up duration	Fair	Vegetable consumption increased significantly from 21.3 g during the two baseline phases to 42.5 g During the FIT Game phases

achieved. This is suggestive that games have the potential to improve the consumption of fruit and vegetables among children but may need to be accompanied by other interventions or re-designed to maintain the effects.

ADVENTURE

Three studies implemented in a school setting used video adventures featuring heroic peers (the Food Dudes) to encourage the consumption of fruit and vegetables among children 4-11years in the UK (Horne et al. 2004; Lowe et al. 2004; Upton, Taylor, and Upton 2015). The heroic peers, in each episode, battle the evil 'Junk Punks' whose aim is to take over the world by depriving the people of their life-giving fruit and vegetables. These Food Dudes eat fruit and vegetables to aid themselves in battle and in doing so urge the children in speech and song to keep their 'life force' strong by consuming a variety of fruit and vegetables. Food Dude customized rewards such as pencils, rulers, stickers, etc. were given when fruit and vegetables were consumed by the children. The participating children's teachers also read letters from the Food Dudes to the children to reinforce the messages from the adventure series. Two of these interventions (Horne et al. 2004; Upton, Taylor, and Upton 2015) had a maintenance phase after intervention where fruit and vegetable consumption was encouraged with less intensity than in the intervention phase. Upton, Taylor, and Upton (2015) measured consumption at baseline, 3- and 12-months post-intervention. They found a significant increase of 14% in fruit and vegetable consumption at 3 months for children eating school-supplied lunches (t =-2.54, P<0.05). In control schools, there was no increase (t=-0.97, p>.05). However, this increase was not maintained at 12 months characterised by a 9% and 16.3% decline in consumption for both intervention and control groups (t=1.40, p<.01and t=2.63, p<0.01 respectively). There were no short-term changes in consumption of home-provided fruits and vegetables in the intervention group. The intervention lasted for 16 days.

Horne et al. (2014) used a peer-modelling and rewards-based intervention (using the Food Dudes video adventure) to increase fruit and vegetable consumption among children (5-11yrs) measured at lunchtime and snack time. This intervention also included 'home packs' to encourage consumption at home and to include parental participation. At school, compared to the control group, lunch-time consumption in the experimental school significantly increased for fruit (from 36% to 79%) and vegetables (from 44% to 66%) during the intervention and follow-up period (p<0.001). Snack-time consumption of fruit (from 75% to 87%) was also significantly higher after the intervention and follow-up period than at baseline (p<0.001). There were also significant increases in the consumption of fruits and vegetables at home in the experimental school. On weekdays, fruit consumption increased from 0.8 portions at baseline to 1.5 portions at intervention while vegetable consumption declined from 1.5 at baseline to 1.1 portions at intervention (p<0.05). On weekends, fruit consumption increased from 1.3 portions at baseline to 1.4 portions at intervention while vegetable consumption increased from 1.2 at baseline to 1.7 portions at intervention (p<0.05). The control group had no increase in fruit or vegetable consumption at home.

Lowe et al. (2004) also used a peer-modelling and rewards-based intervention (the Food Dudes video adventure) to increase fruit and vegetable consumption among children (4-11yrs). They measured consumption at lunchtime and snack time and gave 'home packs' in three primary schools in England and Wales. At lunchtime, the mean percentage who consumed fruit increased from 39% at baseline to 78% after intervention while for vegetables there was an increase from 17% at baseline to 57% after intervention. At snack time, the mean percentage consumption of fruits increased from 48% at baseline to 71% after intervention. Consumption of vegetables increased from 38% at baseline to 68% at intervention (p<0.001 in all instances). Significantly higher consumption was recorded during intervention on weekdays (P< 0.05) but not on weekends when children were outside of school.

All 3 studies also used rewards and promoted parental participation. Fruit and vegetable consumption increased by an average of about 30%. However, 2 of these studies recorded an average decline of 27% in weekday vegetable consumption (Horne et al. 2004), and an average of 9% and 16.3% for intervention and control group consumption at follow-up respectively (Upton, Taylor, and Upton 2015).

CHARACTERS

Cartoon characters, animal characters, and multimedia characters with a game-like structure have been used in studies conducted in Italy (Rosi et al. 2015) and the United States (Hoffman et al. 2010; Van Offelen et al. 2011). Van Offelen et al. (2011) used animal characters to engage children's interest in learning about fruits and vegetables. In this game, the children listed their favorite animal character because they liked the fruits and vegetables associated with the character during the program. The authors conducted a pre-and post- 24-hour dietary recall and found increased fruit intake in both intervention (21.4%) and control (30%) groups post-intervention while vegetable intake significantly increased only in the intervention group (23.5%).

Hoffman et al. (2010) used engaging cartoon characters and child actors as influential role models. The aim was to capture children's (mean age 6.2yrs) attention and increase the retention of nutrition information on fruit and vegetables. Announcements were made about the fruit and the vegetable of the day to the entire school. In the classroom, cartoon characters were used to deliver the program information to the students. Posters with the cartoon characters from the classroom component were hung in the cafeteria at lunchtime. The study found increased consumption of fruit (0.21 servings/lunch, p<0.0001) and vegetables (0.07 servings/lunch at p<0.01) among an intervention group of children at the end of year 1 of the program. However, at the end of year 2, more fruit (0.15 servings/lunch at p<0.0005) but not more vegetables were consumed in the intervention group than in the control group.

Rosi et al. (2015) employed the use of the multimedia character '*JummmpyFive*" to aid learning among 8-10-year-old Italian children. The intervention, identified as a 5-a-day program, recorded children's meal consumption for two weekdays and one weekend day in a food diary. After recording in the food diary, the teachers conducted classroom activities based on the 5-a-day manual. At the end of the lessons, a special day was organized to give the children the opportunity to apply the knowledge they had gained. On this day, "JummmpyFive" guides the children during the activities. The children are grouped into five teams and are provided a computer with the "5-a day" application. The application is used to create a daily menu which will be scored for the group to move to the next stage. Their score determines how long they will stay in the next stage. The next stage involves jumping around the platform following music and a sequence of arrows. The *JummmpyFive* is responsible for delivering and explaining to the children the activities of the intervention by acting as the intermediary among the lessons, interactive game, food consumption and their eating habits. Compared to baseline, a significant increase (27.8%, p=0.001) was recorded only for vegetable intake but total consumption of fruit and vegetables taken together also significantly increased by 12.7% (p=0.016).

The three studies using characters recorded an average of about a 15% increase in fruit and vegetable consumption among respondents. This intervention included a major involvement of both parents and teachers.

COMIC BOOK

Joyner et al. (2017) used a healthy eating "FIT Game" wherein consumption of vegetables by school children (5-11years) influenced events in a "good versus evil" narrative presented in comic book formatted episodes. New episodes emerged as vegetable consumption goals were met. In School I, there were 14 episodes and in School P, there were 20 episodes. The mode of delivery and number of days for each phase differed for each school. There was no comparison group in this study, an A-B-A-B reversal design was used, with ''A'' referring to the no-intervention baseline phases and ''B'' referring to intervention phases. Baseline 1 lasted for 10 days; intervention phase 1 lasted for 10 days in school I and 16 days in school P. Baseline 2 lasted for 6 days in school I and 4 days in school P, while intervention phase 2 lasted 4 and 6 days in schools I and P respectively. Vegetable intake was based on plate-waste measurement. Before lunch, study personnel weighed all vegetables prepared, and the amount not served. After lunch, children returned their trays to the waste station where the waste was weighed again. During baseline 1, the children consumed an average of 21.7g of vegetables. In Phase I, vegetable consumption was 36.8g, a 69% increase. Vegetable consumption significantly increased in both schools; School P (R=0.61, P=0.05) and School I (R=0.34, P<0.05). During baseline 2, vegetable consumption declined (from 38.6g to 20.5g) from phase 1. However, in Phase II when the game resumed, there was a 181% increase (an average of 57.5g per child per day) of vegetable consumption from baseline 2 (School P: R=0.98, P=0.0001; School I: R=0.81, P=0.03). Overall, there was a 99.9% increase in vegetable consumption among the children in less than 2 months from both baseline phases.

DISCUSSION

SUMMARY OF RESULTS

All of the 13 studies reviewed found that animated nutrition interventions increased the consumption of either fruit or vegetables or both among children. However, these changes were often not sustained in the long term (Upton, Taylor, and Upton 2015). Two studies found that the increases were not maintained after a follow-up period of 12 months (Hoffman et al. 2010; Upton, Taylor, and Upton 2015). A review conducted found the effectiveness of interventions to be dependent (reduced) on follow-up duration (Rose et al. 2017) while Knai et al. (2006) pointed out that length of follow-up (longer periods) is generally associated with successful results.

All of the studies included in this review were carried out in high-income countries. This may be due to low investment in such interventions in lower income countries because of limited access to resources required (e.g., computers for computer-based interventions). There may also be less research focus on promoting more fruit and vegetable consumption because of perceptions of more pressing challenges such as acute malnutrition and food insecurity.

Generally, the animated nutrition interventions moderately increased fruit and vegetable consumption by an average of 33%, mostly driven by an effect on fruit intake. This is similar to the findings by Evans et al. (2012) who found that school-based interventions moderately increased fruit and vegetable intake in children 5-12years with a minimal impact on vegetable intake. Only one of the reviewed studies that had comparison groups (Van Offelen et al. 2011) found an increase in both control or comparison groups from baseline to intervention; thus the intervention had no effect. And 2 studies reported a decline in consumption (Horne et al. 2004; Upton, Taylor, and Upton 2015). The 5 studies without a control recorded increases from baseline to intervention.

While some studies could be grouped based on similar interventions, there was considerable heterogeneity among studies included in the review which varied by duration, follow-up period, target population, and outcome measures. There were also variations in intervention effects. However, the general finding is that animated interventions increased fruit and vegetable consumption among participants in the short term, but that with longer term follow-up, the effect waned.

FEATURES OF EFFECTIVE INTERVENTIONS

There appear to be several components to the animation-based interventions reviewed here that enhanced their effectiveness in increasing children's fruit and vegetable consumption. Parental involvement was associated with significant improvements. Parents were involved through newsletters, parent-only websites, or home packs of inter-

vention components (Horne et al. 2004; Thompson et al. 2015; Lowe et al. 2004). The interventions that included home packs (Horne et al. 2004; Lowe et al. 2004) had increased effectiveness in consumption at home and for home meals. Rose et al. (2017) also found parental involvement to be effective when combined with digital interventions to improve the diet and physical activity behavior of adolescents.

Teacher involvement in the dissemination of intervention components such as instructions and story reading were also found to be an effective component of the interventions reviewed (Horne et al. 2004; Lowe et al. 2004; Upton, Taylor, and Upton 2015). The school environment can be influential in affecting dietary practices. Hence, teachers could be encouraged to develop skills and learn age-appropriate methods to disseminate information on healthy eating.

Rewards (customized animation) and goal setting were found to be effective in increasing consumption in three of the studies (Horne et al. 2004; Lowe et al. 2004; Upton, Taylor, and Upton 2015). Not all studies used such features as incentives. Horne et al. (2004) reported giving rewards to children who may have failed to eat any fruit or vegetables. Cooke et al. (2011) in their review on the effect of reward on food acceptance, found that the effect is dependent on the type of reward (tangible food rewards like sweetened drinks; tangible non-food rewards like stickers; and non-tangible rewards like praise and encouragement) and the outcome measured (consumption or liking of the food). However, they concluded that its judicious use may promote acceptance of healthy foods by encouraging children to try new things (Cooke et al. 2011).

Our review also points towards the strength of multicomponent interventions such as including parental involvement, rewards, teachers' involvement etc. This has also been found in other studies. In a systematic review of school-based interventions to improve daily fruit and vegetable intake among children, Evans et al. (2012) found that compared to single-component interventions, multi-component interventions resulted in a greater increase in fruit and vegetable intake.

STRENGTHS AND LIMITATIONS

To our knowledge, this is the first review of this kind to determine the effectiveness of animated nutrition interventions on fruit and vegetable consumption among children. There were several limitations to our review. We excluded studies that used animated interventions but relied on self-declared consumption; including those studies might have provided useful information, but we were concerned about measurement bias. We also did not include studies that were not published in English and those that were not published in peer-reviewed journals. Thus, we cannot exclude the possibility of publication bias as a result of excluding unpublished articles or of qualitatively different findings from places where English is not the primary language. The presence of non-RCTs in the review such as the single case experimental design may influence the generalizability of the study conclusions. Finally, one study (Van Offelen et al. 2011) relied on a single 24-hr dietary recall and this may therefore not be a representation of overall dietary intake.

CONCLUSIONS AND RECOMMENDATIONS

Animated nutrition education can be an effective intervention in increasing the consumption of fruits and vegetables among preschool and school-age children under 12 years of age. Their effectiveness can be enhanced if accompanied by other components such as parental involvement, goal setting, and rewards. Therefore, multi-component interventions especially including parental involvement, goal setting, and rewards can be leveraged in designing similar interventions in LMICs since there was a conspicuous absence of such studies found in the literature.

This review showed short-term effects are generally positive. Long-term effects were not always measured – but where they were measured, they tended to be insignificant or associated with a decline in consumption. Longer-term interventions and follow up should be included in future research to improve our understanding of the dynamics the interventions can trigger and to ensure sustainable effects beyond short term success. It would also be useful to have comparative studies between animated nutrition education and other forms of nutrition education to ascertain comparative effectiveness.

Fruit and vegetable consumption is essential for optimal health; however, their consumption especially among children is below recommended levels in many parts of the world. This low consumption may contribute to micronutrient deficiencies, overweight, and obesity. It is therefore vital to identify the most promising interventions that can influence healthy eating habits among children early in life.

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CONFLICTS OF INTERESTS

The authors declare that there are no conflicts of interests.

AUTHOR CONTRIBUTIONS

IB: Study conceptualization; study design; analyzed the data; wrote the first draft of the manuscript. AK: Study design; manuscript revision. AI: Study design manuscript revision. SM: Study design; manuscript revision. KM: Study design; manuscript revision.

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Annex 1. Quality assessment of the reviews using NHLBI study quality assessment tools (NHLBI 2021)

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total	Grading
Thompson et al. 2015	1	1	1	1	1	1	1	1	1	1	1	1	1	0	13	Good
Cullen, Liu, and Thompson 2016	1	1	1	1	0	1	1	1	1	0	1	1	0	1	11	Good
Baranowski et al. 2003	1	1	1	0	0	1	1	1	1	1	1	1	0	1	11	Good
Baranowski et al. 2011	1	1	0	0	0	1	1	1	1	1	1	1	1	1	11	Good
Jones, Madden, and Wengreen 2014	1	0	1	1	1	1	1	0	1	1	0	0	1	1	10	Good
Jones et al. 2014	1	0	1	1	1	1	1	0	1	1	0	0	1	1	10	Good
Upton, Taylor, and Upton 2015	0	0	0	0	0	1	1	1	1	1	1	0	0	1	7	Fair
Horne et al. 2004	0	0	0	0	0	1	1	1	1	1	1	0	0	1	7	Fair
Lowe et al. 2004	1	1	1	1	0	1	1	0	1	1	0	0	1	1	10	Good
Van Offelen et al. 2011	0	0	0	0	0	1	1	1	1	1	1	0	0	1	7	Fair
Hoffman et al. 2010	1	1	0	0	0	1	1	1	1	1	1	0	0	1	9	Fair
Rosi et al. 2015	1	0	1	0	0	1	1	0	1	1	1	0	1	1	9	Fair
Joyner et al. 2017	1	1	1	1	0	1	0	0	1	1	0	0	1	1	9	Fair

NHLBI TOOL Key: 1 = Yes, 0 = No/Cannot determine/Not applicable/Not reported. Areas assessed are numbered 1 to 14 on horizontal axis; 1-described as randomized, 2-adequate method of randomization, 3-concealed treatment allocation, 4-participants and providers blinded, 5-people assessing outcome blinded to group assignments, 6-group similarity at baseline, 7-overall drop-out rate 20%loweer than allocated number, 8- differential drop-out rate at 15% or lower, 9- high adherence to protocol, 10- similar background treatments, 11- validity and reliability of outcomes measurements, 12- power calculation, 13- prespecified outcomes, 14- intention-to-treat-analysis