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Review

Nutrition Education and Dietary Behavior Change Games: A Scoping Review

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Abstract

Games provide an attractive venue for engaging participants and increasing nutrition-related knowledge and dietary behavior change, but no review has appeared devoted to this literature. A scoping review of nutrition education and dietary behavior change videogames or interactive games was conducted. A systematic search was made of PubMed, Agricola, and Google Scholar. Information was abstracted from 22 publications. To be included, the publication had to include a videogame or interactive experience involving games (a videogame alone, minigames inserted into a larger multimedia experience, or game as part of a human-delivered intervention); game's design objective was to influence dietary behavior, a psychosocial determinant of a dietary behavior, or nutrition knowledge (hereinafter referred to as diet-related); must have been reported in English and must have appeared in a professional publication, including some report of outcomes or results (thereby passing some peer review). This review was restricted to the diet-related information in the selected games. Diversity in targeted dietary knowledge and intake behaviors, targeted populations/audiences, game mechanics, behavioral theories, research designs, and findings was revealed. The diversity and quality of the research in general was poor, precluding a meta-analysis or systematic review. All but one of the studies reported some positive outcome from playing the game(s). One reported that a web-based education program resulted in more change than the game-based intervention. Studies of games may have been missed; a number of dietary/nutrition games are known for which no evaluation is known; and the data presented on the games and research were limited and inconsistent. Conclusions and Implications: A firmer research base is needed to establish the efficacy and effectiveness of nutrition education and dietary behavior change games.

Keywords: Games, Nutrition education, Dietary behavior change, Scoping

Introduction

Dietary intake has been related to heart disease, diabetes, several cancers, stroke, and perhaps adiposity.[1] Dietary behavior change programs have been shown to change diet, but the mediating variables are not clear.[2,3] Nutrition knowledge change programs (usually called nutrition education) by themselves have been shown to be inadequate to change behavior,[4] but some knowledge is a likely precondition of effective behavior change.[5] Dietary behavior change programs are needed that appeal to large numbers and diverse types of people who could benefit from the educational/behavior change procedures. Innovative approaches to dietary change are needed to engage participants in enjoyable experiences to reach the largest number of participants.

Electronic media are an increasingly popular channel for health promotion, meeting the needs and interests of modern populations.[6–8] At least six types of electronic media for health promotion have been identified: web-based

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educational/therapeutic programs; tailored motivational messaging systems; data collection and feedback systems; active videogames (also called exergames); diverse interactive multimedia; and diverse games.[7] This review concerns games or interactive media incorporating games. A recent review of school nutrition education resources identified 14 of 32 curricula as incorporating games of one type or another to enhance learning, but provided no identification or analysis of the games.[9] This suggests that games are increasingly recognized as an important learning tool, but the role and effectiveness of the games need to be analyzed. There has been recent interest in the use of ''gamification,'' which incorporates aspects of games into the design of media interventions.[10] Gamification most often has employed rewards,[10] thereby not including some of the most interesting aspects of games, for example, repeated losing under the rules of the game to learn a new principle without real-world consequences, and are most appropriately reviewed when considering those behavior change procedures,[11,12] not when reviewing the effects of games.

No consistent, commonly accepted concept exists for what constitutes a game. Games generally have rules that govern actions within the game with the possibility of winning and, importantly, losing based on the rules; feedback on play within the game (often points assigned); and a story or narrative (or an associated back story), among many other possible game elements.[13] Games can provide attractive learning and behavior change media since they can be designed to provide fun, enjoyment, or engagement (thereby providing intrinsic motivation to play)[14]; a multisensory experience to facilitate different learning styles[15]; safe opportunities for drill and practice with feedback; training for higher-order skills, such as critical thinking, problem solving, team work, strategic thinking, and planning[16]; role playing for constructivist learning[17]; experimentation with new identities; development of social skills[18]; modeling of behaviors[19]; training in self-regulation[19]; and/or immersion of players in a storyline into which behavior change procedures can be built.[20]

While several systematic reviews and/or meta-analyses have appeared on games for health,[6,21–24] and even included a few nutrition education games as a subcomponent, no review has appeared devoted to the consideration of games for nutrition education or dietary behavior change alone. Some reviews have indicated that research on few nutrition games have appeared[25]; one found only four games[26]; a review of digital interventions included only one nutrition education game,[27] and another included only six.[28] This scoping review of the diet-related video or interactive games literature attempts to describe the current state of the art in a substantial number of studies involving nutrition education games and identify limitations in the research, which need to be remedied to advance this important intervention medium.

Methods

A protocol for this analysis was not preregistered due to the long idea-incubation period and a lack of clarity about what we might find in our literature search. The structure and sequence of this review follows the PRISMA guidelines, as possible.[29]

Eligibility criteria

To be included in this review, the publication had to include a videogame or interactive experience involving games (i.e., the intervention was a videogame alone, minigames were inserted into a larger multimedia experience, or a game was part of a human-delivered intervention); the game's design objective was to influence dietary behavior, a psychosocial variable believed to be a determinant of a dietary behavior, or some aspect of nutrition knowledge (hereinafter referred to as diet-related); must have been reported in English and must have appeared in a professional publication, including some report of outcomes or results (thereby passing some peer review). No additional exclusionary criteria were employed. This review was restricted to the diet-related information in the selected games.

Information sources

Following the guidelines for a scoping review,[30] this review included two search cycles. Both searches of the literature were conducted using PubMed, Agricola (the agricultural database, since the U.S. Department of Agriculture appeared to fund much of the early work on nutrition games), and Google Scholar, using the search terms (Nutrition AND Games) and (Diet AND Games).

Search

One author conducted the initial systematic search of the databases through December 31, 2016, while the first author culled the articles for whether a game was involved in the identified articles. A second cycle was performed during September 2017, including only the articles produced from January 1, 2017 to September 30, 2017.

Study selection

Since the method of game delivery varied by time, there was an initial interest in the historical development of games for nutrition education. An intensive effort was made to identify any article that concerned a game involving nutrition or diet. This preliminary, broad, exploratory search revealed articles on a substantial variety of games involving nutrition education, including card, board, video, and other delivery channels. One hundred eighty-five abstracts of articles were analyzed; duplicates were removed. Since many of these articles were not research-based (i.e., no evaluation of effects), the investigators narrowed the focus to include articles meeting the eligibility criteria uncovered through the initial ad hoc search. Two coders reviewed the abstracts of these articles; duplicate entries were removed; and selected articles were retrieved and abstracted. In the search process, a number of intervention articles were identified that used one or more multimedia formats, but did not include games,[31–39] and thereby were not included in this review.

Data collection process

To ensure inter-rater reliability and to authenticate data extraction and interpretation quality, two independent reviewers systematically analyzed the abstracts. Final selection was based on a 92% agreement between reviewers. Data abstraction was started after both reviewers received coding training and

performed a coding of 10% of the articles as a pilot for testing reliability. Differences were resolved by multiple, internal, in-depth discussions. Following training, each coder reviewed and extracted data from the 22 articles separately. The first author provided the final determination for all variables.

Data items

Each row in Tables 1–3 concerns a different study. The studies were summarized in regard to first author, year, country, game name, the key goals and hypotheses, whether a story/narrative was included, game elements or mechanics, behavior change procedures and theories employed, setting, target group, method of delivery, research design, sample size, outcome measures (specifically subjectively reported and objective measures), and diet-related outcomes. Story, often considered a key game element,[6] was coded as present when there were characters other than the player, a logically sequenced set of events (storyline or arc), with the story ending and the outcome depending on game play. Game elements or mechanisms were abstracted as possible from the reports provided.

Risk of bias in individual studies

Quality of study or research bias items from the Cochrane Collaboration Risk of Bias Tool (CCRBT) and the Effective Public Health Practice Project Quality Assessment Tool (EPHPP)[40] were applied to all studies. Table 3 reports on the risk of bias/quality of research characteristics of each study, including whether the method of randomization was reported; randomization was concealed at baseline; prior power calculations were conducted; assessors were blinded; completeness of follow-up reported; selection bias reported; validity or reliability of the measures reported; possible confounding variables were accounted for in the analyses; and the trial protocol was preregistered.

Synthesis of results

Many of the included studies were pilot, feasibility or proof-of-concept studies with small samples, weak designs, and inconsistent and inadequate assessment, thereby precluding a meta-analysis or systematic review. Thus, the major value of this scoping review is to report the breadth of target groups, objectives and game mechanics, and identify specific research enhancements necessary to document the value of the gaming approach to diet-related change.

Results

Study selection

One hundred eighty-five articles were identified in the preliminary search: 61 from Agricola and 124 from PubMed. An additional 50 articles were identified in the second cycle. Twenty-two articles were identified on nutrition education or dietary change video or interactive games, hereinafter referred to as game.

Study characteristics

The first game article identified was published in 2001, with the number per year steadily increasing to eight in 2015–2017.

Risk of bias within studies

The quality or research bias of individual trials was poor, and is summarized in Table 3. Eleven of the 22 articles (50%) were randomized clinical trials (RCTs), and 3 (14%) were group cluster RCTs. Four (18%) were single-group pre-post designs; two (9%) were not randomized control designs, one was a cross-over trial, and one was an A-B–A-B reversal design. The method of randomization, concealment of randomization at baseline, and trial preregistration was reported by none of these trials (Table 3). Five (23%) reported statistical power calculations before the conduct of the trial. While blinding of participants is not possible in behavior change trials, blinding of assessors is possible and was reported in only one trial.

Completeness of follow-up (withdrawals, dropouts) was reported in 12 trials (55%). Selection bias (sample representativeness and participation rates) were reported by five trials (23%). Validity and/or reliability of the measures was reported by 14 trials (64%). Accounting for possible confounders of outcomes was reported by nine trials (41%). Whether the investigators reported analyses of all the prespecified outcomes could not be assessed since none of the research protocols were preregistered.

Results of studies

Only one of the games reported no changes from playing the game on behavior or its determinants,[41] but only 27.6% of the students in that study played the game. All the other studies reported some positive outcomes from game play, but few studies identified a primary outcome, and none identified what percentages of all possible or expected outcomes the games impacted. Another study revealed that a web-based education program was more effective than the game-based education.[42] Most changes were relatively small, but few effect sizes were reported.

Synthesis of results

Thirteen of these games (59%) targeted children at school, three (14%) targeted children at home, three (14%) in a laboratory, one any place, and only two (5%) targeted adults. The sample sizes varied from 1876 to 20. There were 14 (64%) individual or group randomized clinical trials. The games were developed and tested largely in the United States ($n=13$; 59%), Europe ($n=8$; 36%), or Asia ($n=1$).

A story (or narrative) was specifically included in 15 games (68%). The other game elements or game mechanics varied enormously. A number of well-known popular existing game formats/mechanics should have been well known to the target audience (thereby minimizing the need to learn new game rules), for example, the concentration memory game, and adapted these game elements to achieve education purposes or influence behavior.

Five of these games (23%) could be categorized more as primarily targeting some aspect of nutrition knowledge, while nine other games (41%) could be categorized more as targeting dietary behavior change, and eight (36%) as primarily targeting some combination of dietary psychosocial variables and behavior. A diverse variety of educational and/or behavioral change theories with attendant diversity in the corresponding knowledge or behavior change procedures were identified as providing the conceptual foundation and

TABLE 1. AUTHOR, YEAR, COUNTRY, GAME NAME, STUDY GOALS, HYPOTHESES, STORY/NARRATIVE, GAME MECHANICS, BEHAVIOR CHANGE PROCEDURES, THEORIES

ID	*Reference; year, country, name of game*	*Key goals and hypotheses*	*Story/narrative/game mechanics*	*Behavior change procedures*	*Theories named*
1	Turnin[86] 2001, France, *Alimentary My Dear Joe (4): Store, Guess Who, Granny Smith, The Restaurant*	Evaluate primary school children's acquisition of nutritional knowledge and improvement of eating habits from playing four serious games H1: Children who play the four games would increase their nutritional knowledge and eat healthier	• Story: Yes • *Store*: Classify foods into categories • *Guess Who:* Children guess name of food after it being described • *Granny Smith:* Children select breakfast and snack food items by correcting Granny's errors • *The Restaurant:* Catch foods jumping out of fridge and place them to ''balance'' a meal	Nutrition knowledge change	None mentioned
2	Baranowski[67] 2003, USA, *Squire's Quest!*	Test the impact of a nutrition education multimedia program with games on servings of fruit, 100% juice, and vegetables among fourth-grade students H1: Children who play *Squire's Quest!* will increase their intake of fruit, 100% juice, and vegetables	• Story: Player enters training to be Squire and help King fight off Slimes and Mogs • Not specified	• FV knowledge change • Establish meal FV schemas • Progressively more challenging goal setting	Social cognitive theory
3	Serrano[87] 2004, USA, *Super Sorter More or Less*	Test a multimedia package including two games on fourth/fifth-grade students' diet-related knowledge, skills, self-efficacy, attitude and intention H1: Children who play the games as a part of the Food Pyramid Games package will increase their nutrition related knowledge and psychosocial variables	• Story: Yes • *Super Sorter*: Categorize foods that appear into food pyramid categories; progressively faster with each round • *More or Less*: Evaluate meals and menus to include foods from all five groups	Food Good Pyramid, knowledge change	Theory of intrinsically motivating instruction

(*continued*)

Table 1. (Continued)

ID	*Reference; year, country, name of game*	*Key goals and hypotheses*	*Story/narrative/game mechanics*	*Behavior change procedures*	*Theories named*
4	Silk[42] 2008, USA, *The Fantastic Food Challenge (FFC)*	Examine the effectiveness of three modalities for delivery of nutrition education: game, web, or pamphlet, on nutrition knowledge and likeability H1: Participants will report greater liking of the interactive game; H2: Participants will have higher nutrition literacy scores with information media (pamphlet, website) than from game; H3: Participants receiving information media (pamphlet, website) will retain more nutrition knowledge than from videogame	• Story: No • *Fantastic Food Challenge* (4 games): (1) Categorize falling foods (2) Estimate ''cost effectiveness'' based on size, numbers of servings, and cost	Nutrition knowledge change	Media uses and gratification and flow theories
5	Peng[88] 2009, USA, *RightWay Café*	Teach about nutrition and weight management knowledge and increase people's self-efficacy and perceived benefits of healthy eating, as well as their intention to be on a healthy diet H1: Participants who played *RightWay Café* would increase their healthy nutrition, knowledge, self-efficacy, perceived benefits, and intentions	• Story: Yes • Role playing similar to *The Sims* • Game player is star in a TV show ''Star of Healthy Lifestyle'' • Player who manages daily diet to reach optimal weight wins • Create personal avatar • Weekly simulated weight change in avatar based on food selections	• Tailored healthy eating information (kcal, wt, personal food pyramid) • Positive feedback and rewarding points for choosing healthy food • Dialogues set descriptive norms • Information on immediate benefits from a healthy diet • Game presented change goals	Health belief model, theory of reasoned action, and social cognitive theory

(*continued*)

Table 1. (Continued)

ID	*Reference; year, country, name of game*	*Key goals and hypotheses*	*Story/narrative/game mechanics*	*Behavior change procedures*	*Theories named*
6	Dias[43] 2011, Portugal, *Healthy Advergame Less Healthy Advergame*	Test impact of healthy and nonhealthy advergames on children's immediate food choices, liking, and nutritional knowledge H1: Children's spontaneous snack selection will reflect the food content of the advergame they play; H2: Children's food liking will reflect the food content of the advergame they play: (a) The group who played the healthy version will like healthy food more than the other group; (b) the group who played the nonhealthy version will like nonhealthy food more than the other group; H3: Children who played the healthy version will exhibit greater nutritional knowledge, compared with children who played a less healthy version of the same game	• Story: Yes • Child character grabs a snack—if healthy, gains 5 points • Bomb and bullets need to evade • 2 levels: character can fly	Nutrition knowledge change	Food exposure theory (Birch)
7	Baranowski[66] 2011, USA, *Escape from Diab*, and *Nanoswarm: Invasion from Inner Space*	Evaluate the effect of playing two serious videogames on children's diet, physical activity, screen media use, and adiposity H1: Children who play the two serious games will increase their fruit and vegetable and water intake, and physical activity, and decrease their screen time and BMI	• Story: Yes • Action-adventure story/ narrative • Games not specified	• Mastery learning of energy balance for knowledge change • Modeling of behaviors and coping action and coping implementation intentions • Behavioral inoculation • Tailored value-based messaging	Social cognitive and self-determination theories and elaboration likelihood model

(*continued*)

Table 1. (Continued)

ID	*Reference; year, country, name of game*	*Key goals and hypotheses*	*Story/narrative/game mechanics*	*Behavior change procedures*	*Theories named*
8	Baños[89] 2013, Spain, *ETIOBE Mates*	Evaluate the efficacy and acceptability of *ETIOBE Mates* on children's nutritional knowledge compared to a traditional paper–pencil mode of information delivery H1: Children playing *ETIOBE Mates* will improve their nutritional knowledge; and *ETIOBE Mates* will be acceptable and playable (medium to high scores)	• Story: Yes • *The Healthy Plate*: Categorize foods in food pyramid categories • *The Memory Game*: Concentration type game to find pair-wise matches of foods and then answer questions about food—easy, medium, and difficult levels • *Super ETIOBE*: Player helps detective solve cases of children having imbalanced diet and PA	Energy balance knowledge enhancement	None specified
9	Schneider[90] 2012, USA, *Fitter Critters*	Test the acceptability of an online videogame for improving healthy diet and activity in elementary school students H1: Children who play the game will find it highly acceptable and increase their nutrition and activity knowledge, attitudes, and self-efficacy	• Story: No • Players responsible for the health of a Critter • 17 quests • Meters for Critter's health and diet • Food to feed Critter: Should not exceed fat, sugar, calories allotments • Cooking: To feed Critter • Work: Critter can earn money at work; healthier Critter earns more money • Sick days: When Critter is sick, cannot earn money • Decorations: Critter's earnings used to decorate house	None stated	None stated

(*continued*)

Table 1. (Continued)

ID	*Reference; year, country, name of game*	*Key goals and hypotheses*	*Story/narrative/game mechanics*	*Behavior change procedures*	*Theories named*
10	Folkvord[44] 2013, Netherlands, *Advergames*	Examine the effect of advergames that promote energy-dense snacks or fruit on children's ad libitum snack and fruit consumption and examine whether this consumption differed according to brand and product type (energy-dense snacks and fruit) H1: Playing advergames that promote food increases general caloric intake; H2: Playing an advergame that promotes food increases product type–related food intake; H3: Increased food intake after playing an advergame is not specific to a certain brand but will also enhance the intake of a brand promoting products in the same product category	• Story: No • Concentration type memory game attempting to match pair-wise images of foods • The healthy or unhealthy brands appeared on the backsides of the cards to be turned over • Digital timer and time bar to supply urgency • Pleasant sound when child made a matched pair; unpleasant sound for nonmatching pairs	Exposure to brand names	Cue reactivity theory (concentration type memory game)
11	Majumdar[91] 2013, USA, *Creature 101*	Evaluate the efficacy of playing *Creature-101* at promoting energy balance-related behaviors (EBRBs) H1: Adolescents who played *Creature-101* would significantly increase their FV and water intake and PA; and decrease intake of processed snacks (e.g., chips, candy), SB, and recreational screen time	• Story: Yes • Players created own avatars and worlds • Between-player communication of goals and accomplishments • Story/narrative: Murphy in Tween, characters in Tween became addicted to foods and activities brought from Earth • Player learned healthfulness of behaviors when helping creatures change	• Autonomy supportive environment • Learned competence • Diet-related knowledge change • Goal setting for personal behavior change	Social cognitive and self-determination theories

(*continued*)

Table 1. (Continued)

ID	*Reference; year, country, name of game*	*Key goals and hypotheses*	*Story/narrative/game mechanics*	*Behavior change procedures*	*Theories named*
12	Folkvord[92] 2014, Netherlands, various advergames	Examine the moderating role of impulsivity on the effect of advergames that promote energy-dense snacks on children's snack intake H1: Playing advergames promoting energy-dense snacks increases caloric intake; H2a: Stimulating response inhibition by rewarding refraining from eating decreases caloric intake; H2b: Children rewarded for refraining from eating have a lower caloric intake when they play a nonfood advergame than when they play a food advergame; H3: Impulsive children eat more; H4: Rewarding refraining will have less influence on high impulsive children, especially when playing a food advergame	• Story: No • Concentration type memory game attempting to match pair-wise images of foods • The healthy or unhealthy brands appeared on the backsides of the cards to be turned over • Digital timer and time bar to supply urgency • Pleasant sound when child made a matched pair; unpleasant sound for nonmatching pairs	Exposure to brand names	Cue reactivity theory
13	Johnson-Glenberg[93] 2014, USA, *Alien Health*	Assess the feasibility and efficacy of game on nutrition knowledge among an older group of children H1: Playing *Alien Health* will be feasible and result in increased nutrition knowledge	• Story: Yes • Story: Find alien under your bed • Level 1: Student pairs need to discuss and choose between healthy and unhealthy foods within 10 seconds • Kinect sensed child selection and changed to next choice • Children engaged in PA between choices • Level 2: Focused attention on nutrient informational bars to make food selection • Level 3: Drag foods onto MyPlate icon to make a balanced lunch for the Alien	Healthy diet knowledge change	Embodiment theory

(*continued*)

Table 1. (Continued)

ID	*Reference; year, country, name of game*	*Key goals and hypotheses*	*Story/narrative/game mechanics*	*Behavior change procedures*	*Theories named*
14	Jones[94] 2014, USA, *The FIT Game*	Develop an intervention designed to increase FV consumption while minimizing material and labor costs to the school H1: Children who played the game would increase their consumption or targeted FV	• Story: Yes • Story: Help FITs capture the villainous VATs • New script each day read by teacher • Daily goal to eat 60% or higher of yesterday's school fruit or vegetable intake • Competition for best school in 3 elimination rounds • Won game currency for everyday school exceeded goal • Students selected school equipment to purchase with game currency	Reward of goal attainment (set by teachers)	Social and operant learning theories
15	Rosi[95] 2015, Italy, *Menu Composer*, and *Jump Mania*	Evaluate an IT-based intervention on children's fruit and vegetable intake H1: Children who played these games as part of a larger educational program would eat more fruit and vegetables	• Story: No • *Menu Composer*: Choose fruit and vegetables based on correspondence to 5 rules of a healthy diet and drag to a dish with colored spaces • Children with higher *Menu* scores received more time on *Jump Mania* game for which children were expected to match sequence patterns with feet	• Healthy diet knowledge change • Reward with PA	None specified
16	Sharma[96] 2015, USA, *Quest to Lava Mountain*	Evaluate the feasibility, acceptability, and effects of the *Quest to Lava Mountain* computer game on dietary behaviors, physical activity behaviors, and psychosocial factors among ethnically diverse children H1: Children who play *Quest to Lava Mountain* will experience better dietary and physical activity behaviors	• Story: Yes • Action adventure story/ narrative: Not • Make healthy food choices to progress through game and win • Mazes, interactive activities, simulations of nutrition concepts • Increasing challenges across levels of game	• Healthy diet knowledge enhancement • Subjective norms	Social cognitive theory and theory of reasoned action

(*continued*)

TABLE 1. (CONTINUED)

ID	*Reference; year, country, name of game*	*Key goals and hypotheses*	*Story/narrative/game mechanics*	*Behavior change procedures*	*Theories named*
17	Thompson[45] 2015, USA, *Squire's Quest! II*	Test the efficacy of active versus coping implementation intentions on the dietary intake of healthy children H1: One of the forms (unspecified) of implementation intentions will result in greater change in intake of fruit and vegetables at immediate post and 3-month post-assessments	• Story: Yes • Action adventure story/ narrative: King Brocwell and Queen Nutrition are defending the Kingdom of Fivealot from the Mog • Player wants to become knight to help the King and Queen; has to become a Squire • Squire has to face challenges (eat more FV) to build strength • FV knowledge games: Diverse game mechanics (10)	• FV knowledge change • Action and/or coping implementation intentions • Badges awarded for goal attainment • Create personal schema for FV at meals • Behavioral inoculation • FV recipe preparation • Parent engagement through newsletter and website	Social cognitive, self-determination, behavioral inoculation, and maintenance theories and the elaboration likelihood model
18	Spook[41] 2016, Netherlands, *Balance It*	Evaluate the effects of *Balance It* on students' dietary intake, PA, and the psychosocial determinants H1: Students who played *Balance It* would have healthier dietary intake and physical activity	• Story: No • Obtain cards by changing diet • Use cards to build a tower • Want tallest tower, but need to "balance it" • Competition with other players	• Goal setting/action and passive implementation intentions • Barrier identification • Feedback on goal attainment • Peer support from player forum	Intervention mapping, goal setting, self-monitoring, feedback
19	Shiyko[97] 2016, USA, *SpaPlay*	Evaluate game play patterns of *SpaPlay* and its impact on BMI and nutritional knowledge among women H1: Progress in the *SpaPlay* game will lead to increased nutrition knowledge and decreased BMI	• Story: No • Need to develop a spa resort • Healthy eating earns points to build spa • Self-created avatar • Minigames • Quests: Setting and attaining a health behavior goal to attain in coming week • Sparks: Single-time health behavior • Collaborative/cooperative tasks • Chef game: Create healthy dishes	• Goal setting • Self monitoring • Social interaction/ support	Self-determination and stages of change theories

(*continued*)

Table 1. (Continued)

ID	*Reference; year, country, name of game*	*Key goals and hypotheses*	*Story/narrative/game mechanics*	*Behavior change procedures*	*Theories named*
20	Fraticelli[98] 2016, Italy, *Gustavo in Gnam's Planet*	Test the improvement of knowledge about healthy nutrition and enjoyment in adolescents H1: Playing the web game *Gustavo in Gnam's Planet* in comparison with a leisure web game will improve knowledge about healthy nutrition and enjoyment in adolescents	• Story: Yes • Story: Gustavo and his cat escape to unknown planet, cannot return unless live healthy, player needs to help • 3 levels	• Foal feedback • Reward • Punishment • Shaping • Instructions	Transtheoretical model of change, social cognitive theory, self-determination theory, and elaboration likelihood model
21	Joyner[99] 2017, USA, *FIT Game 3*	Test the efficacy of the *FIT Game* to increase vegetable intake H1: Presenting the *FIT Game* materials in comic book format on the school cafeteria wall would significantly increase vegetable consumption	• Story: Yes • Story/narrative: Help FITs capture the villainous VATs • New script each day read by teacher • Daily goal to eat 60% or higher of yesterday's school fruit or vegetable intake • Competition for best school in 3 elimination rounds • Won game currency for every day school exceeded goal • Students selected school equipment to purchase with game currency	Reward of goal attainment (set by teachers)	Not clearly specified
22	Wang[100] 2017, Hong Kong, *Escape from Diab*	Evaluate the effect of playing a health videogame designed for Western children on diet and PA-related psychosocial variables and behaviors among Chinese children H1: Playing *Escape from Diab* will enhance diet and PA psychosocial variables and increased story immersion will result in larger effects	• Story: Yes • Action-adventure story/ narrative • Games not specified	• Mastery learning of energy balance for knowledge change • Modeling of behaviors and coping action and coping implementation intentions • Behavioral inoculation • Tailored value-based messaging	Social cognitive, self-determination, and elaboration likelihood theories

BMI, body mass index; FV, fruit and vegetables; PA, physical activity.

Table 2. Author, Year, Country, Game Name, Settings, Target Groups, Design, Sample Size, Measures, Results and Conclusions

ID	Reference; year, country, name of game	Setting/target group; design/sample size	Measures		Results and conclusions
			Subjective (self-reported)	Objective	
1	Turnin[86] 2001, France, *Alimentary My Dear Joe (4): Store, Guess Who, Granny Smith, The Restaurant*	School/healthy 7–12-year-old children Part of teacher presented intervention GRT, 2 groups, post only/ $n=1876$	Diet record at home, with help from the parents, covering 3 consecutive days including one weekend (variables: kcal, macronutrients, saccharose, calcium, fiber); nutrition knowledge questionnaire (variables: global nutrition knowledge and 8 knowledge subscales), eating habits questionnaire (variables: whether meals and snacks were consumed)	None	Children in the games group had significantly higher knowledge and better balanced diet; more carbohydrate, less fat, less protein, less saccharose, more calcium, and more fiber. The games group had a better snack at 10 a.m., a less copious lunch and less nibbling
2	Baranowski[67] 2003, USA, *Squire's Quest!*	School/4th grade, 8–12 years old Games inserted in multimedia story with behavior change procedures GRT, 2 groups, pre, post/ $n=1578$	Measured fruit and veggie intake using Food Intake Recording Software System (FIRSSt)	None	Children participating in *Squire's Quest!* increased their FJV consumption by 1.0 serving per day more than the children not receiving the program
3	Serrano[87] 2004, USA, *Super Sorter More or Less*	School/Latino 4th–5th graders, 10–13 years old Games part of larger multimedia program RCT, 2 groups, E: pre, post, C: post only/ $n=115$	Measured nutrition knowledge, skills, self-efficacy, attitude, intention	None	Children playing these games significantly increased nutrition knowledge and skills, but not self-efficacy, attitude or intention
4	Silk[42] 2008, USA, *The Fantastic Food Challenge (FFC)*	State extension office, other agencies, home/low-income mothers Games alone RCT, 3 groups, post1, post2/ $n=155$	Measured nutrition literacy, liking of, attention to the game, understanding the message, and intention to use the game in the future	None	Website participants had consistently highest knowledge/ literacy, attention, ease of understanding, and intention to use in the future
5	Peng[88] 2009, USA, *RightWay Café*	Research lab/young adults Game alone RCT, 2 groups, pre, post1, post2/ $n=40$	Measured in regard to eating a healthy diet: self-efficacy, perceived benefits and barriers, intention; EFNEP knowledge questionnaire and game likeability	None	Short-term effects of *RightWay Café* included increased nutrition knowledge, self-efficacy and perceived benefits of healthy eating; 1-month follow-up showed maintenance of effect only for self-efficacy

(*continued*)

TABLE 2. (CONTINUED)

ID	Reference; year, country, name of game	Setting/target group; design/sample size	Measures		Results and conclusions
			Subjective (self-reported)	Objective	
6	Dias[43] 2011, Portugal, *Healthy Advergame, Less Healthy Advergame*	School/Piaget's concrete operational stage, 7–8 years old Game alone RCT, 2 groups, post only/ $n=231$	Measured: healthy versus not food selection task, liking of each food presented, knowledge of healthy foods	None	Children who played the *Healthy Advergame* chose more healthy snacks immediately after game play while those playing the *Less Healthy Advergame* chose less healthy snacks; children who played the *Less Healthy Advergame* liked the less healthy snacks more that those playing the *Healthy Advergame*, but those playing the *Healthy Advergame* did not like the healthier snacks more
7	Baranowski[66] 2011, USA, *Escape from Diab*, and *Nanoswarm: Invasion from Inner Space*	Home/10–12 years old Games within a story-driven multimedia production RCT, 2 groups, pre, mid, post1, post2/ $n=153$	Measured three 24-hour dietary recalls at each assessment point for fruit, vegetables, water, and total energy; Social Desirability of Response scale	BMI, waist circumference, triceps skinfold	Playing *Diab* and *Nano* increased fruit and vegetable consumption by about 0.67 servings per day, but not water intake nor body composition
8	Baños[89] 2012, Spain, *ETIOBE Mates*	Home/3rd–6th grades, 7–11 years old Game as part of a larger clinical intervention RCT, 2 groups, pre, post/ $n=228$	Nutritional Knowledge Questionnaire, Game Acceptability–Playability Questionnaire, Game Playing Habits Questionnaire	Calibrated electronic stadiometer (height and weight for BMI)	Playing *ETIOBE Mates* significantly increased nutrition knowledge; $\sim$50% of participants liked the game
9	Schneider[90] 2012, USA, *Fitter Critters*	School/5th grade, 8–12 years old Game alone 1 group, pre, post/ $n=97$	Nutrition and physical activity knowledge, healthy eating attitude, diet self-efficacy, and videogame acceptability	None	Playing *Fitter Critters* significantly increased diet self-efficacy and positive attitudes toward healthy foods; but no change in diet knowledge
10	Folkvord[44] 2013, Netherlands, *Advergames*	Lab/3rd–4th grades, $\bar{x}=8.9$ years Game alone RCT, 4 groups, post only/ $n=270$	Hunger before and at end; recognition of brand and product in game	Weighed food intake at snack over 5 minutes, BMI	Playing an advergame containing food cues increased general energy intake, regardless of the advertised brand or product type (energy-dense snacks or fruit); this activity particularly increased the intake of energy-dense snack foods; playing the fruit version of the advergame did not significantly increase fruit intake
11	Majumdar[91] 2013, USA, *Creature 101*	School/6th–7th grades, 11–13 years old Game alone GRT, 2 groups, pre, post/ $n=341$	Measure of frequency and amount of beverage and snack items	None	Students who played *Creature 101* reported significant decreases in frequency and amount of sweet beverages and frequency and amount of processed snack intake

(*continued*)

Table 2. (Continued)

ID	Reference; year, country, name of game	Setting/target group; design/sample size	Measures		Results and conclusions
			Subjective (self-reported)	Objective	
12	Folkvord[92] 2014, Netherlands, various advergames	Lab/3rd–4th grades Game alone RCT, 4 groups, post only/ $n=261$	Pre-experimental hunger and fullness; attitude toward brands and foods shown in game; and impulsivity: door opening task	Weighed snack calorie intake, BMI	Playing an advergame with food cues increased caloric intake; rewarding children to refrain from eating calories worked; rewarding children to refrain from eating worked more among low impulsive children, and those who played the nonfood cue game
13	Johnson-Glenberg[93] 2014, USA, *Alien Health*	Research lab/6th–7th grades Game alone, but played in pairs in front of classroom 2 groups, pre, post1, post2/ $n=20$	Nutrition knowledge and food choice test	None	Knowledge increased more in the control group at immediate post, but reversed at post 2 to favor the experimental group
14	Jones[94] 2014, USA, *The FIT Game*	School/1st–5th grades Game in context of school lunchroom and competition with another school 1 group, targeted versus nontargeted FV/ $n=180$	None	Measure food weights consumed at school using weight scales	Playing *The FIT Game* significantly increased fruit and vegetable consumption following baseline; with no significant increase in nontargeted fruit or vegetable consumption
15	Rosi[95] 2015, Italy, *Menu Composer*, and *Jump Mania*	School/3rd–5th grades, 8–11 years old Game as part of curriculum delivered by teachers 1 group, pre, post/ $n=76$	5-a-day food diary to measure fruit and vegetable intake	None	Playing these games increased vegetable intake by 27.8%, but not fruit or juices
16	Sharma[96] 2015, USA, *Quest to Lava Mountain*	School/4th–5th grades Game alone RCT, 2 groups, pre, post/ $n=94$	Two random 24-hour dietary recalls for kcal, macronutrients, fruit, vegetables, fiber, sugars, total fat and calcium; and number of days breakfast	Height and weight for BMI	Playing *Quest to Lava Mountain* significantly decreased sugar intake pre- to post-intervention, and significantly improved Nutrition Attitude Scale
17	Thompson[45] 2015, USA, *Squire's Quest! II*	Home/4th–5th grades, 9–11 years old Games integrated into story-driven multimedia experience RCT, 4 groups, pre, post1, post2/ $n=400$	Three unannounced 24-hour dietary recalls at each data collection period using the Nutrient Data System for Research (NDSR-2009) conducted directly with the child; two weekday and one weekend day recalls; fruit and vegetable preference questionnaire	None	Playing *Squire's Quest! II* significantly increased fruit and vegetable intake only in the Action Implementation Intentions group at both post1 and post2

(*continued*)

TABLE 2. (CONTINUED)

ID	*Reference; year, country, name of game*	*Setting/target group; design/sample size*	*Measures*		*Results and conclusions*
			Subjective (self-reported)	*Objective*	
18	Spook[41] 2016, Netherlands, *Balance It*	Any place/secondary, vocational students, 16–21 years old Game alone played individually or competitively RCT, 2 groups, pre, post1, post2/$n=231$	Food frequency questionnaire for fruit, vegetable, snack, and soft drink intakes; and attitude, self-efficacy and intention to eat healthy foods	None	Only 27.6% of students used *Balance It*; no significant between-group differences were detected for behavior or determinants
19	Shiyko[97] 2016, USA, *SpaPlay*	Home/women dietary change contemplators Game alone 1 group, pre, post1, post2, post3/$n=47$	Self-reported height and weight for BMI; General Nutrition Knowledge questionnaire for adults; Readiness to Change Questionnaire for nutrition and sweetened beverages	Telemetry time-stamped game play actions	Participation varied substantially; self-reported BMI was lower and nutrition knowledge was higher among those who spent more time playing *SpaPlay*
20	Fraticelli[98] 2016, Italy, *Gustavo in Gnam's Planet*	School/17–21 years old Game alone Cross-over, pre, post1, post2/$n=65$	Healthy food knowledge questionnaire and game level of fun	None	Mean diet knowledge increased significantly after playing *Gustavo in Gnam's Planet*, with no difference in the "fun" of playing *Gustavo* versus a commercial game
21	Joyner[99] 2017, USA, *FIT Game 3*	School/K–5th grades Game in context of a school classroom and competing with another school A-B–A-B reversal/$n=572$	None	Plate waste method using weight scales measured: vegetables served, waste, and unserved, leaving intake	During phase B1, vegetable consumption increased by an average of 15.1 g per child per day (69%); during phase B2, vegetable intake increased by 37 g per child per day (18%); fruit consumption, not targeted for improvement, did not significantly increase; maintenance of effect beyond the game is problematic
22	Wang[100] 2017, Hong Kong, *Escape from Diab*	School/8–12 years old Game alone 2 groups, pre, post1, post2/$n=179$	Game immersion; in regard to fruit, vegetable and water intake: intrinsic motivation, self-efficacy, and preferences; and social desirability of response	None	At post1, playing *Escape from Diab* significantly increased intrinsic motivation for fruit and for water; change in immersion was not significantly related to changes of other diet measures; a game designed for children in western audiences can be used with English-speaking students

GRT, general randomized trial; RCT, randomized clinical trial.

Table 3. Risk of Bias, Quality of Research Indicators for Each Study

ID	Reference; year, country, name of game	Method of randomizing reported (Y/N)	Randomization at baseline (Y/N)	Prior power calculations (Y/N)	Blinding of assessors (Y/N)	Completeness of follow-up (Y/N)	Selection bias reported (Y/N)	Validity/reliability of measure reported (Y/N)	Accounting for possible confounders reported (Y/N)	Preregistered trial (Y/N)
1	Turnin[86] 2001, France, *Alimentary My Dear Joe (4): Store, Guess Who, Granny Smith, The Restaurant*	N	N	N	N	Y	N	N	N	N
2	Baranowski[67] 2003, USA, *Squire's Quest!*	N	N	Y	N	Y	N	Y	Y	N
3	Serrano[87] 2004, USA, *Super Sorter More or Less*	N	N	N	N	Y	N	Y	N	N
4	Silk[42] 2008, USA, *The Fantastic Food Challenge (FFC)*	N	N	N	N	Y	N	Y	Y	N
5	Peng[88] 2009, USA, *RightWay Café*	N	N	N	N	Y	N	Y	N	N
6	Dias[43] 2011, Portugal, *Healthy Advergame, Less Healthy Advergame*	N	N	N	N	Y	N	N	N	N
7	Baranowski[66] 2011, USA, *Escape from Diab*, and *Nanoswarm: Invasion from Inner Space*	N	N	Y	N	N	N	Y	Y	N
8	Baños[89] 2013, Spain, *ETIOBE Mates*	N	N	N	N	N	Y	Y	N	N
9	Schneider[90] 2012, USA, *Fitter Critters*	NA	NA	N	N	N	N	Y	N	N
10	Folkvord[44] 2013, Netherlands, *Advergames*	N	N	N	N	NA	N	Y	Y	N

(*continued*)

Table 3. (Continued)

ID	Reference; year, country, name of game	Method of randomizing reported (Y/N)	Randomization at baseline (Y/N)	Prior power calculations (Y/N)	Blinding of assessors (Y/N)	Completeness of follow-up (Y/N)	Selection bias reported (Y/N)	Validity/reliability of measure reported (Y/N)	Accounting for possible confounders reported (Y/N)	Preregistered trial (Y/N)
11	Majumdar[91] 2013, USA, *Creature 101*	N	N	N	N	N	Y	Y	Y	N
12	Folkvord[92] 2014, Netherlands, various advergames	N	N	N	N	NA	N	Y	N	N
13	Johnson-Glenberg[93] 2014, USA, *Alien Health*	NA	NA	N	N	N	N	N	N	N
14	Jones[94] 2014, USA, *The FIT Game*	NA	NA	N	N	NA	N	N	NA	N
15	Rosi[95] 2015, Italy, *Menu Composer*, and *Jump Mania*	NA	NA	N	N	N	N	N	N	N
16	Sharma[96] 2015, USA, *Quest to Lava Mountain*	N	N	N	N	Y	Y	N	Y	N
17	Thompson[45] 2015, USA, *Squire's Quest! II*	N	Y	Y	Y	Y	N	N	Y	N
18	Spook[41] 2016, Netherlands, *Balance It*	N	N	Y	N	Y	N	Y	N	N
19	Shiyko[97] 2016, USA, *SpaPlay*	NA	NA	N	N	Y	N	Y	Y	N
20	Fraticelli[98] 2016, Italy, *Gustavo in Gnam's Planet*	NA	NA	N	N	Y	N	Y	N	N
21	Joyner[99] 2017, USA, *FIT Game 3*	NA	NA	N	N	NA	Y	N	NA	N
22	Wang[100] 2017, Hong Kong, *Escape from Diab*	NA	NA	Y	N	Y	Y	Y	Y	N

N, no, did not meet that indicator; NA, indicator not applicable; Y, yes, met that indicator.

operationalization of the theory constructs for the game. Social cognitive theory appears to have been the most commonly stated theory, and nutrition knowledge change was the most commonly mentioned behavior change procedure.

The measures used to assess outcomes were perhaps even more diverse wherein different measures were often employed to assess the same knowledge or behavior construct across studies. Five studies (23%) reported more objective methods of dietary intake assessment (e.g., weighed plate waste): three of these as part of laboratory-based tests of the effects of diet-related advergames, and two as part of a test of game play in a school lunchroom/cafeteria.

Three articles studied the effects of food advergames[43,44] and showed that exposure to only 5 minutes of game play influenced the child's dietary intake immediately following the game. This suggests the possible strong (at least short-term) behavioral impacts of dietary game play.

One game systematically varied two forms of a behavior change procedure, action and coping implementation intentions, and tested impact on fruit and vegetable intake within a four-group RCT.[45] Since the programming keeps all other aspects of game play comparable, this is an ideal method for conducting tests of behavior change procedures for use in videogames, and perhaps outside of games.

Discussion

Summary of the evidence

While all but one of the articles reported some positive outcomes from playing the game(s), the quality of much (but not all) of the research reported left much to be desired, making it difficult to determine the extent to which games had the intended, and reported, effects. The research on diet-related change games diverged in regard to target populations, dietary behavior targets (e.g., fruit, vegetables, general nutrition information, Mediterranean diet), theories (social-cognitive, persuasion, health belief model, attachment, socio-constructivist, or even none), game elements/mechanics, behavior change procedures, research designs, and measures. As a result, a meaningful meta-analysis or systematic review was not possible across all these studies at this time.

Comparisons to other reviews

A recent review of advergames alone indicated a small effect increasing unhealthy food intake.[46] While that was not the primary focus of the current review, it does indicate that games can influence dietary intake to some extent under some circumstances. The review, including six games for health, noted the generally positive effects on nutrition knowledge, but the diversity in delivery, poor measurement of process variables and engagement, and thereby the inability to draw conclusions about effects.[28] We noted similar patterns, but in a larger number of nutrition education game studies, and provided a more detailed assessment of the limitations in the research methods.

Future directions/needed research

Conceptual frameworks exist to guide the development of sophisticated G4H (Games for Health).[47] Research from three large behavior change trials (not using games) used mediating variable analyses to validate a multi-theoretical model to specify the conceptual framework for the design of health behavior change interventions that are likely to be effective.[48] Several conceptual models have been advanced to account for how games may influence diet-related outcomes.[49–51] Some of these models interrelate game elements and behavior change principles,[50,51] while others emphasize the relevance of food cues and individual predisposing factors (e.g., impulsivity).[49] Little research, however, has tested aspects of these models with games. Much of the effort in diet-related games has been to design, develop, and test a game or interactive experience including game(s) to influence outcomes, rather than test principles of game mechanics or behavior-mediating variables within games. Research is urgently needed that systematically varies aspects of game mechanics or behavior change procedures within games to optimize their effects on game engagement,[52] maintenance of interest, psychosocial mediators of change, and behavior change (shorter or longer terms). Thompson et al. systematically varied four types of goal setting/implementation intentions within *Squire's Quest!* and demonstrated that action implementation intention was the only procedure to maintain changes 3 months after the end of the game.[45] This research provides an important model for making future contributions to an understanding of how game mechanics can influence change in behavior.

No commonly accepted compendium or taxonomy of elements in games exists. The ''game lenses'' identified by Schell[13]; the ''playful experience cards'' of Bjork and Holopainen[53]; and/or Lucero et al.'s playful experiences list[54] preliminarily enumerate items for consideration. Without a commonly accepted compendium, consistencies in game mechanics across games may have been missed since different words may have been used to specify an essentially common underlying mechanic or set of mechanics. Developing and obtaining consensus for such a taxonomic compendium should be a high priority to permit the identification and comparison of game elements in future systematic reviews and meta-analyses and also to identify mechanics that are most engaging. Such taxonomic compendia would also facilitate the conduct of process evaluations,[55] which relate participation in game elements to outcomes.

A compendium of behavior change procedures has been proposed,[56] although challenges have been reported in classifying procedures into the proposed categories.[57] Such a common taxonomy should also be used in games research to clearly specify what procedures were employed. Of course the same procedure (e.g., goal setting) could be implemented in a variety of ways in the context of a game,[58] with each variant possibly affecting outcome in a different way, indicating specific details of the intervention design need to be presented in the reported outcome or process evaluations.

Fifteen games (68%) incorporated a story or narrative in one form or another. Given the potential for story immersion to influence attention to change procedures (especially behavior change messaging),[20] developing and incorporating stories into nutrition education games may be a way to enhance effectiveness. Alternatively, the incorporation of a story into a game may distract the player from active game play, thereby reducing player game enjoyment.[59] Several stories have been tested and demonstrated to change behavior without a game.[36,60] A study that designs and compares separate story and game elements with their integration

would be an important contribution to our knowledge of nutrition education games (and games in general).

There seems to be an implicit assumption that simply providing a diet-related change program in a game format will automatically make the activity fun, or engaging, and thereby motivate the player to substantially increase the knowledge or change the behavior at substantial levels. Alternatively, one of the studies revealed that a web-based education program was more effective that a game-based program.[42] Unfortunately, the relative quality of these two programs cannot be meaningfully assessed from the published information, and thus it is not clear if primarily the medium (web-based or game-based) or qualities of the programs influenced this outcome. The modest changes in knowledge and behavior that have been reported in these studies suggest the assumption of game dominance is not well supported. The role of ''fun'' in games and game play has not been well specified; the definition and measurement of fun or enjoyment has not been clearly delineated[61]; story or narrative may contribute to the fun of games, but this has not been clearly assessed.[62] If fun in games was better understood, games might be designed to enhance the fun aspects to, in turn, enhance the dietary change.

Many of these games targeted nutrition knowledge, often as the primary or only target. Each set of authors appears to have created their own measure of nutrition knowledge with unknown psychometric properties. While knowledge for academic purposes (e.g., types of dietary fats; how sodium, potassium, and magnesium interact to influence blood pressure) can be valuable, all these games were targeted in one way or another to positively impact health, often through dietary behavior change. The field would benefit from a library of nutrition knowledge items that tapped information that were preconditions for behavior change (e.g., how to make a salad) and could be incorporated into computer adaptive testing[63] to provide brief measures of outcomes comparable across studies.

Developing a diet-related intervention that can be expected to impact body mass index (perhaps the most prevalent nutrition-related health problem) for obesity prevention requires that the game impact the necessary relevant knowledge and psychosocial variable(s) (e.g., knowledge, self-efficacy, intrinsic motivation) to change the targeted behavior(s) (e.g., diet, physical activity, sedentary behavior, and/or sleep) for a long enough time to change body composition.[64] There are few examples of such large games. The time to develop and evaluate them can take years,[65,66] and the cost for their development can be staggering (millions of dollars). It seems unlikely that this level of funding will become generally available for game development anytime soon. Rather than creating a single integrated multimedia experience that incorporates games to address dietary change, it may be appropriate to develop a comprehensive intervention structure (including multimedia and face-to-face components) into which a series of games could be developed and inserted to achieve those outcomes for which games are most effective, for example, knowledge enhancement, simulation of interpersonal interactions, etc. Alternatively, dietary behavior change requires learning some new skills that could be learned through games, for example, food preparation,[67] menu planning, effective food parenting practices,[68] and even taste testing. Games attempting to increase these skills or behaviors could be developed, tested, and incorporated into larger behavior change programs.

There has been substantial concern about the quality of research, also called risk of bias, in general[69–74] and how to incorporate issues of quality into systematic reviews.[75,76] The general quality of the evidence in support of games on nutrition knowledge or behavior change outcomes[77] was low and needs further enhancement. This has been pointed out elsewhere.[78,79] Only five of these nutrition education game studies used objective measures of dietary intake to assess dietary change outcomes. Subjective measures tend to be subject to bias (i.e., low validity or accuracy) and unreliability (or imprecision).[80] Both active and passive methods of more objective dietary intake assessment[81] are being developed and refined for use in uncontrolled community settings and should be considered for future use as measures of outcome of games for nutrition education. G4H researchers need to expend substantially more effort to enhance the quality of this research if for no other reason than self-interest, that is, to increase the likelihood of obtaining funding for future research.[82]

Many of the studies identified a substantial number of behavioral, psychosocial, and/or anthropometric or physiological outcomes, without specifying a primary outcome. This approach to evaluation runs a high risk of type 1 statistical error (i.e., obtaining a statistically significant effect purely by chance).[83,84] Diet-related game research should specify a primary outcome upon which power calculations are conducted, with prespecified hypotheses or models of the way in which game play is expected to influence the outcome.[85] In this way, tests can be made of whether the game influenced the targeted variable(s) as designed. The stronger our knowledge base about how games result in change, the more effective ensuing games can be if designed based on what has been learned.

Limitations

One or more game studies may have been missed. A number of diet-related games have been available for purchase, but about which nothing has been published. (At least one game developer has been overheard saying ''I have all the evaluation I want or need. My games sell.'') A recent systematic review of G4H identified a total of 1743 games produced between 1983 and 2016, of which 99 (6.4%) were about nutrition education and eating disorders.[8] The number of academic publications that evaluated the efficacies of those games is far less than the games produced. This review was based on reports of games in publications that tended to provide minimal details, which could have resulted in mischaracterizing the games or studies. On one hand, we may miss existing games that were effective but never evaluated. On the other hand, actual play of the games might have provided different characterizations and insights, but many of the games no longer function on modern technology.

Conclusion

To the best of our knowledge, this is the first English review devoted to diet-related video or interactive games. Although a variety of diet-related games have been reported, the research base is inadequate to ascertain whether putting nutrition education or diet-related behavior change into a

game format consistently results in the desired outcomes, or what aspects of game elements or behavior change procedures appear to be most effective. Future diet-related game research should use randomized controlled designs; common validated outcome measures (preferably more objective measures); behavior change procedures as specified in recent taxonomic inventories; and be guided by conceptual models that reflect the complexities of game design, user experience, and their interactivity. A taxonomic inventory of game elements needs to be developed to clearly specify game designs, and facilitate game reporting and comparisons of outcomes. Research is needed that systematically varies game elements between different versions of the same game to test what game elements produce the most change. Different concepts of fun in game play need to be comparatively tested. Perhaps we need a leaderboard of game researchers and their numbers of publications weighted by the quality of their contributions to make a game of it.

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