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Effectiveness of multimedia games in promoting nutrition and health awareness and practices among young children: A systematic review

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Abstract
Background: Multimedia games are popular among children and provide challenging and exciting opportunities to play. Therefore, such games offer an enjoyable and engaging means for communication of health messages. This review explored the effectiveness of multimedia games in promotion of health and nutrition awareness and/or practices among young children.
Methods: Potentially eligible original research articles were identified through a systematic search of four databases (PubMed, Cochrane Library, ERIC and WHO Virtual Health Library) and hand searching from 1985 and 2016.
Results: A total of 686 articles were identified through initial search, of which 31 were included in qualitative synthesis. Majority of the multimedia games (26 out of 29) led to positive changes in nutrition/ health-related knowledge and/ or practices post gaming sessions. Improvements were observed in knowledge of nutrition and health (oral health, general hygiene, asthma and diabetes management) and practices such as dietary intake, physical activity, asthma management and diabetes self-care behaviours. Measures such as BMI, body fat, vascular function, asthma symptoms and hyperglycemia among diabetics showed significant improvement. Exergames led to improved physical activity behaviours due to their game design. Most effective games were based on theories of learning or behaviour change and included attractive features like stories, rewarding mechanisms (scores, levels and scales), game characters, behaviour change processes (goal setting, problem solving, decision making) and motivational applause. Multimedia games were observed to be more effective than conventional teaching methods for nutrition and health promotion. Play-way learning offered by multimedia games was liked by children and considered entertaining.

Keywords: multimedia games, nutrition, health, nutrition education, knowledge, children, games

1. Introduction

Enjoyment and fun in the learning process can encourage learning [1]. Games are not just fun but are very central to children's life and hence have the potential to captivate their attention for long periods. In this modern era of technology, multimedia games are a popular leisure activity among children [2, 3]. Use of multimedia games in educational interventions has potential advantages over traditional teaching methods [4]. They offer a unique platform for delivering health promotion messages to children and adolescents. Health professionals and educationists have designed several multimedia games [5, 6] grounded on theories of behaviour change for health promotion [7]. Multimedia games have appealing characters, provide simulated situations that require making decisions for health and lead to realistic health consequences. Games challenge players, they must engage themselves in learning the information or rules provided and applying them to solve problems or reach the goal in order to win [8, 9]. The unlimited repetition and reinforcement that these games offer can engage children in desirable health seeking behaviours [10]. The fun aspect of games is believed to provide intrinsic motivation among players thereby encouraging behaviour change [7].
This paper emphasizes on the effectiveness of multimedia games in promoting knowledge and behaviour related to good nutrition and health.

2. Methods

For the purpose of this review, *young children* were defined as children aged 6-10 years; *multimedia games* comprised a combination of different media including text, audio, graphics, animation, video and interactivity and played on a video game console/ computer/ mobile phone/ tablet.
The study search and selection process was conducted in accordance with the Preferred Reported Items for Systematic Reviews and Meta-analyses guidelines [11]. The review question was framed as per the PICOS (population, interventions, comparison, outcomes and study designs) framework depicted in Figure 1.

Population: Young children aged 6-10 years without mental health or learning disabilities

Intervention: Multimedia games, as defined by authors, aimed at promoting health and nutrition awareness and/ or practices

Control/ Comparison: Other games or communication methods or material[a]

Outcome: Health and/ or nutrition knowledge and/ or practices

Study design: Intervention studies, pre and post studies, randomised control trials (RCTs)

[a] *Of the 31 studies reviewed, 7 did not have a separate control or comparison group and were single group studies*

Fig 1: PICOS framework

2.1 Search Strategy

Articles for this review were searched from four online databases- PubMed, Cochrane Library, ERIC and WHO Virtual Health Library and hand searching between April and December, 2016.

A search strategy was developed based on Boolean logic using a combination of the following terms: *multimedia game**, *nutrition, health, education, awareness, knowledge, behaviour, child**, *game**, *video game**. Age of child from 6 to 10 years and publication dates between 1985 and December 2016 were included as search limiters wherever possible. Search results from all databases and the manual search were imported into reference manager.

2.2 Inclusion and Exclusion Criteria

All the relevant studies were scanned as per the following inclusion criteria: (1) Population: young children aged 6-10 years without mental health or learning disabilities; (2) Intervention: multimedia games aimed at promoting health and nutrition awareness and/ or practices; (3) Outcomes: reported evaluation of intervention in changing knowledge and/ or practices; (4) Study design: intervention studies, pre and post studies, randomised control trials (RCTs); (5) Original research articles published in peer-reviewed journals that provide sufficient results (excluding research posters, conference proceedings, studies reporting only qualitative data); (6) Year of publication between 1985 and 2016; (7) Publication available in English language.

2.3 Study Selection

After importing all search results to reference manager, duplicates were removed, titles and abstracts were screened and a list of potentially relevant studies were identified. Full-text of selected research articles were individually reviewed based on the pre-defined inclusion criteria. Inclusion or exclusion of eligible research articles was approved by both the authors and reasons for exclusion of ineligible articles were noted.

2.4 Data Extraction and Analysis

Data extracted from selected studies included name (s) of author (s), year of publication, study design, study setting, sample size, participant characteristics (age, gender, health status), country, game characteristics (name (s), platform, key features, behaviour change theories), intervention details, outcome measures and results. When further information was required, corresponding authors were contacted via E-mail. Extracted data were tabulated in Microsoft (Redmond, WA) Excel spreadsheet for further analysis. A qualitative synthesis was conducted to explore important themes and summarize characteristics of included studies, game characteristics, effectiveness of games and retention over time.

3. Results

3.1 Study Identification and Selection

The systematic review search and selection process of the studies is illustrated in the flowchart (Figure 2). The initial search yielded 686 articles (WHO Virtual Health Library=257, PubMed=220, Cochrane Library=153, ERIC=48, Hand searching=8), of which 276 were within-database duplicates and 40 were between-database duplicates. On the basis of title screening, 107 articles were considered as potentially relevant to the theme of this review. Of these 107 articles, abstract screening led to exclusion of 59 articles. Thus, full-text of 43 articles was assessed for eligibility as the remaining 5 articles were not free to access. Out of these 43 full-text articles, 12 were excluded for not matching the inclusion criteria.

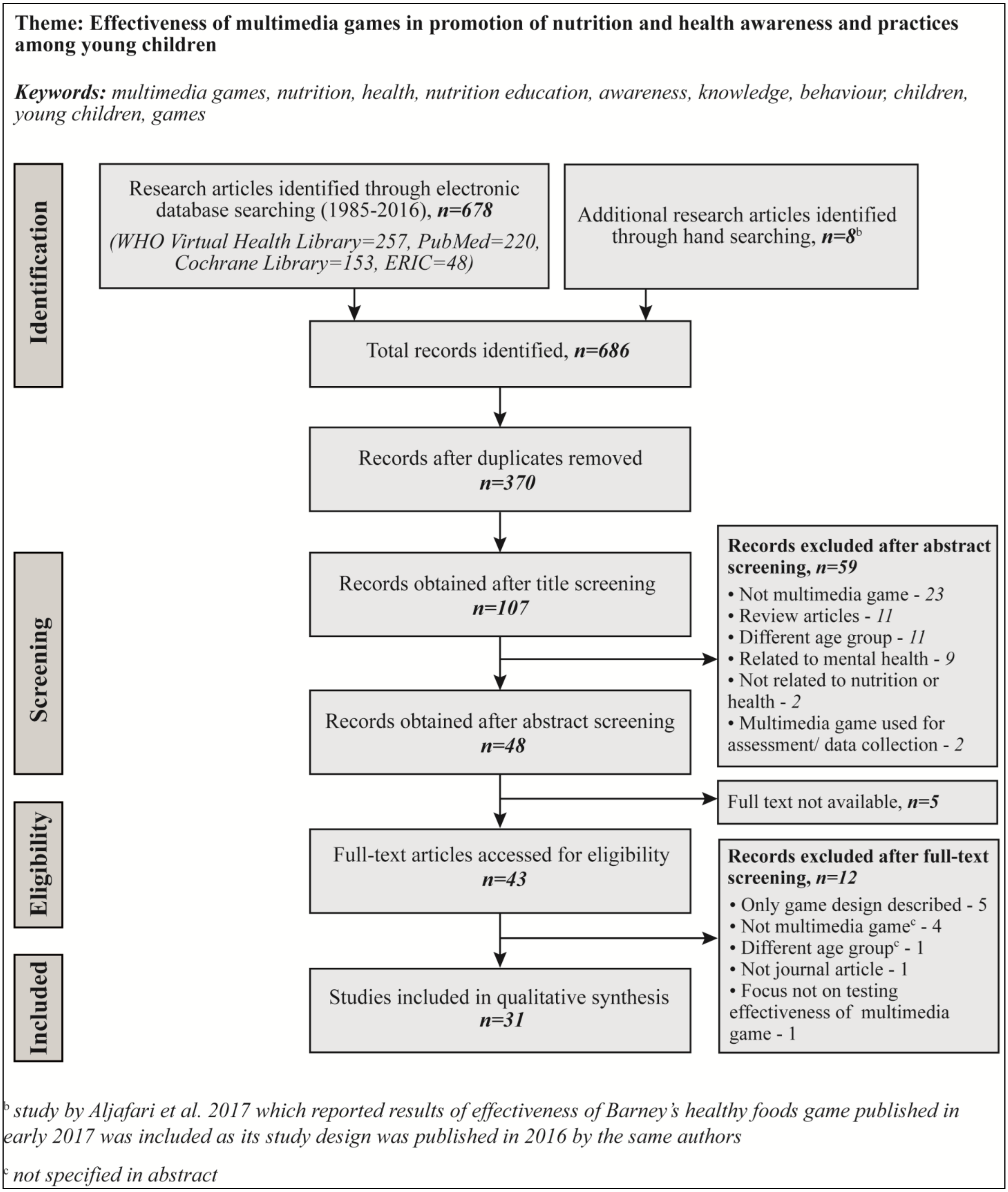

Fig 2: Flowchart depicting research article search and selection process undertaken as a part of the systematic review

3.2 Characteristics of Included Studies

The thirty-one included studies, published between 1985 and 2016, were on evaluation of twenty-nine multimedia games that aimed at promotion of health and/ or nutrition awareness and/ or practices among children. Table 1 provides a summary of study characteristics.

Table 1: General Characteristics of Included Studies (n=31).

Characteristics	References	Count	%
Year of publication			
Before 1996	[12]	1	3
1996-2006	[5, 13, 20]	9	29
2006-2016	[6, 21, 40]	21	69
Sample size			
≤50	[19, 21, 24, 31, 32, 36, 38]	7	23
51-100	[12, 13, 16, 22, 28, 29, 39]	7	23
101-200	[14, 15, 18, 23, 25, 40]	6	19
201-300	[30, 35]	2	6
301-400	[6, 20, 27, 33, 37]	5	16
≥1300	[5, 17, 26, 34]	4	13
Location			
Australia	[32]	1	3
England or/ & Scotland	[26, 40]	2	7
France	[30]	1	3
Italy	[34]	1	3
New Zealand	[27, 38]	2	7
Singapore	[33]	1	3
Spain	[17]	1	3
United States	[5, 6, 12, 16, 18, 25, 28, 29, 31, 35, 37, 39]	22	71
Design			
Treatment and control/ comparison group	[5, 6, 12, 20, 22, 25, 27, 28, 30, 32, 33, 36, 37, 39, 40]	24	77
Treatment group only	[21, 26, 29, 31, 34, 35, 38]	7	23
Participant recruitment setting			
School	[5, 16, 17, 19, 20, 23, 26, 29, 31, 33, 36, 39]	17	55
Hospital/ Health Centre/ Clinic	[12, 15, 18, 21]	6	19
Home	[22, 27, 40]	3	10
No specific setting	[6, 28, 32, 37, 38]	5	16
Themes			
Nutrition	[5, 17, 20, 23, 25, 29, 31, 36, 37]	11	35
Asthma	[12, 14, 16, 18]	5	16
Physical Activity	[22, 24, 27, 28, 33, 39]	6	19
Diabetes	[13, 19, 38]	3	10
Oral Health	[34, 40]	2	6
Stroke or Vascular Function	[32, 35]	2	6
General Hygiene	[26]	1	3
Sickle Cell Disease	[21]	1	3

3.3 Game characteristics

Detailed description of intervention studies involving multimedia games is presented in Tables 2 and 3.

Initial attempts (before the year 2000) of using multimedia games for health among children were targeted at those having diseases like asthma [12, 14, 16] and diabetes [13]. The scope of multimedia games was later (after 2001) expanded to include promotion of a healthy lifestyle and prevention of diseases. There was substantial variability across included studies with respect to game characteristics and assessment of their effectiveness. Multimedia games in the reviewed studies focussed mainly on awareness and/ or practices for promotion of nutrition [5, 6, 17, 20, 23, 25, 29, 31, 36, 37] (n=11), physical activity [22, 24, 27, 28, 33, 39] (n=6), oral health [34, 40] (n=2), hygiene [26] (n=1) and management of asthma [12, 14, 16, 18] (n=5), diabetes [13, 19, 38] (n=3), stroke or vascular function [32, 35] (n=2) and sickle cell disease [21] (n=1). Game platforms were computer (n=18) [5, 6, 12, 14, 18, 20, 21, 23, 25, 26, 29, 30, 34, 37], console (n=9) [13, 22, 24, 27, 28, 32, 33, 39], mobile (n=2) [19, 38], mixed-reality platform (n=1) [31] and tablet (n=1) [40].

Multimedia games designed for health promotion were frequently based on behaviour change theories. Majority were grounded on social cognitive theory (SCT) [5, 6, 14, 20, 25, 35, 37], while the rest were based on learning theories [18, 31], Orem's Self-Care Deficit Nursing theory [23], and theory of planned behaviour and protection motivation theory [33]. *Watch, Discover, Think and Act (WDTA)* [14], *Quest to Lava Mountain (QTLM)* [36] and *Diab and Nano* [25] along with SCT also focussed on self-regulatory & diffusion theory, reasoned action and self-determination & persuasion theories respectively. Situational problem solving or goal setting was

Table 2: Detailed description of intervention studies involving multimedia games for promotion of preventive lifestyle behaviours.

Author, Year	Game title, Platform	Content	Key game features	Theory [d]	Study Design	Sample [e]	Groups [e]	Measures	Effectiveness [f]
Promotion of Healthy Food Choices									
Turnin *et al.*, 2001[17]	Alimentary my dear Joe, PC	Food groups, nutrient content of foods, food composition, balanced diet, choosing breakfast and snacks	Scoring, calculator	-	RCT	1876 (IG-1003, CG-873) children aged 7-12 years	IG: Alimentary my dear Joe (hours/ week for 5 weeks) CG: Conventional nutrition teaching	- Nutrition knowledge - Dietary intake and habits	E
Baranowski *et al.*, 2003[5]	Squire's Quest!, PC	Fruit, juice, vegetable serving/day, buying-storing fruits and vegetables, buying canned and frozen foods, substitution of vegetables, choosing vegetables and fruits, fruit and vegetables to consume in parties, recipe preparation	Story, Cooking fruit, juice, vegetable recipes (in virtual kitchen), Wizard who mentored player through challenges, goal setting, Dragon scale points	SCT	RCT	1578 (IG-785, CG-793) fourth grade children	IG: Squire's Quest! (25 minutes/ session for 10 sessions) CG: usual classroom education	- Fruit servings 100% juice and vegetable consumption - Dietary intake	E
Cullen *et al.*, 2005[20]	Squire's Quest!, PC	Same as Baranowski *et al.*, 2003[5]	Goal setting in addition to features of Squire's Quest![5]	SCT	RCT	1578 (IG-785, CG-793) fourth grade children	IG: Squire's Quest! CG: usual classroom education	- Fruit, juice, vegetable servings consumed meal-wise - Fruit servings	E
Moore *et al.*, 2009[23]	Blast-Off game, PC	General nutrition, variety and moderation, portion size, PA, food pyramid, food pyramid	Animation, nutrient and PA meter	SDNT	Two group, pre-post, quasiexperimental	126 fourth and fifth grade children	IG: Color my Pyramid + Blast off game + more didactic presentations CG: Color my Pyramid	- Nutrition knowledge and behaviour - PA - Anthropometric measures	E (not in knowledge)
Baranowski *et al.*, 2011[25]	Diab and Nano, PC	Healthy eating, fruit, vegetable & water intake, food portions and PA	Story, animation, goal setting, problem solving, motivational statements, energy balance games, video segments	-	RCT	153 (IG-103, CG-50) children aged 10-12 years	IG: Diab and Nano CG: diet and PA knowledge-based games on popular websites	- Fruit, vegetable and water servings - Minutes of moderate to vigorous PA - Anthropometric measures	E (only in fruit and vegetable consumption)
Schneider *et al.*, 2012[29]	Fitter Critters, PC	Choosing healthy food without surpassing the fat, sugar, and caloric allotment	Quests, meters (health and diet), Cooking, Sports games (shot put, foot race), work, sick days, decorations	-	Single group pre-post	97 fifth grade students	Fitter Critters (5 consecutive days)	- Nutrition and PA knowledge, attitudes and self-efficacy - Game acceptability	E (not in knowledge)
Baños *et al.*,	Super	Nutritional terms,	Story, healthy plate,	-	RCT	228 (IG-73,	IG:	- Nutrition	E

Author, Year	Game title, Platform	Content	Key game features	Theory [d]	Study Design	Sample [e]	Groups [e]	Measures	Effectiveness [f]
2013[30]	ETIOBE, PC	dietary recommendations, food pyramid, nutrient content of foods, food choices, diet disease association	memory game, scoring			CG-155) fourth to sixth grade children	SuperETIOBE CG: Pamphlet	knowledge - Game acceptability	
Johnson-Glenberg & Hekler, 2013[31]	Alien Health Game, Mixed-reality platform	Nutrient content of foods, USDA MyPlate	Story, levels, exergame using Kinect sensor	Learning theory	Single group pre-post	19 fourth grade students	Alien Health Game (45 minutes)	- Nutrition knowledge	E
Sharma *et al.*, 2015[36]	Quest to Lava Mountain, PC	Food, nutrients, healthy food, moderation, sustainable food practices of eco-friendly farming, composting, recycling, use of irrigation water, PA	Quests, game strategies (mazzes, interactive activities and simulations), avtars, traverse virtual environments, color-coading to categorize foods w.r.t. nutrient density and calorie content, coin rewards, recipes, foods in game from ethnically diverse backgrounds	SCT, TRA	Group-RCT	94 (IG-44, CoG-50) fourth and fifth grade children	IG: Quest to Lava Mountain computer game (90 minutes/week for 6 weeks) CoG: continued with usual programs	- Dietary intake Diet, PA, psychosocial factors (self-reported by child)	E (in terms of sugar consumption and nutrition/ PA attitudes)
Thompson *et al.*, 2015[37]	Squire's Quest! II: Saving the Kingdom of Fivealot, PC	Healthy eating	Goal setting	SCT	RCT	400 fourth and fifth grade children and their parent	Squire's Quest! II: Saving the Kingdom of Fivealot 4 groups (none, action, coping, and action plus coping)	- Fruit and vegetable intake	E (for action intentions)
Cullen *et al.*, 2016[6]	Squire's Quest! II: Saving the Kingdom of Fivealot, PC	Healthy eating	Story, animation, goal setting	SCT	RCT	400 fourth and fifth grade children and their parents	Squire's Quest! II: Saving the Kingdom of Fivealot 4 groups (none, action, coping, and action plus coping)	- Dietary intake	E
Physical Activity Promotion									
Maloney *et al.*, 2008[22]	Dance Dance Revolution, Console	Dance using exergame	Exergaming	-	RCT	60 (IG-40, wait-list-20) children (7.5 ± 0.5 years)	IG: Dance Dance Revolution Wait-list CG (10-week delay)	- PA - sedentary screen time - acceptability	E
Fogel *et al.*,	Exergaming,	Dance, stair stepper,	Exergaming	-	Alternating	4 (2 boys, 2	Treatment 1:	- Total minutes	NT

Author, Year	Game title, Platform	Content	Key game features	Theory [d]	Study Design	Sample [e]	Groups [e]	Measures	Effectiveness [f]
2010[24]	Console	bike, baseball, tennis, boxing, skateboarding, martial arts using exergames			treatments design	girls) fifth grade overweight, inactive children with lowest PA scores, good attendance and behaviour records	regular physical education class Treatment 2: Exergaming on the duration of PA	engaged in PA - Total minutes provided for PA during each condition (physical education and exergaming classes)	
Baranowski *et al.*, 2012[28]	Console	Sports related exergame	Exergaming	-	RCT	84 children aged 9-12 years	IG: active video games CG: inactive video games	- PA - Neighbourhood safety	NE
Maddison *et al.*, 2012[27]	Active video games, Console	Active video games offering a variety of activity options	Exergaming, EyeToy motion camera to capture player's image on screen	-	RCT	322 (IG-160, CG-162) overweight and obese children aged 10-14 years who were current users of sedentary video games	IG: active video games CG: continued routine video game play	- Anthropometric measures - Body fat - PA - Cardiorespiratory fitness - Food snacking	E
Lwin & Malik, 2014[33]	Wii exergames (Dance Dance Revolution, Wii tennis & Wii boxing), Console Wii is a home video game console released by Nintendo	Dance, tennis, boxing using exergames	Exergaming	TPB, PMT	Two group, pre-post, randomized	398 fifth grade children	IG: Physical education lesson with Wii condition played Wii exergames - Dance Dance Revolution, Wii tennis & Wii boxing (45 minute lessons over a consecutive 6-week period) CoG: Regular physical education lesson outlined by each school	- PA attitudes - PA self-efficacy - perceived behavioral control subjective norm, group norm and intention towards - PA	E (not in perceived behavioural control)
Sun & Gao, 2016[39]	Earth, Moon, and Sun (EMS)— an interactive learning experience,	Stepper using exergame	Exergaming	-	Two group, pre-post, randomized	53 third, fourth and fifth grade children	IG: active educational video games (Gamercize® GZ Pro-Sport™) CoG: sedentary	- Science knowledge - PA intensity level - Situational interest	E (not in knowledge)

Author, Year	Game title, Platform	Content	Key game features	Theory [d]	Study Design	Sample [e]	Groups [e]	Measures	Effectiveness [f]
	IG: console, CG: PC						educational video games		
Diabetes Prevention									
Baghaei *et al.*, 2016[38]	Mario Bros, Mobile	Diabetes prevention	Story	-	Single group pre-post	12 (6 boys, 6 girls) children aged 9-13 years (not required to have diabetes mellitus)	Mario Bros (1 week)	- Knowledge related to health and lifestyle	NT
Oral Health Promotion									
Vozza *et al.*, 2014[34]	Multimedia game on Oral Health, PC	Dental anatomy, methods of brushing and proper nutrition	Quiz	-	Single group pre-post	1300 third and fifth grade children	Multimedia game on Oral Health	- Oral health knowledge	E (among: fifth graders, extended school time schedulers and females)
Aljafari *et al.*, 2017[40]	Barney's healthy Foods, Tablet	oral health, advice on fruit juice and fluoride intake	Avatar, selection of healthy food rewarded with progression, incentive, animation and encouragement	-	RCT	109 (IG-55, CG-54) Children aged 4-10-years scheduled for general anaesthesia due to severe dental caries	IG: Oral health education using a computer game CG: one-to-one oral health education	- Parent and child satisfaction with education method - child's dietary knowledge - child's diet and tooth brushing habits	NE
Stroke or Vascular Function									
Mills *et al.*, 2013[32]	Exergaming, Console	HiE and LoE using sports exergames	Exergame	-	Two group, pre-post	15 children (10.1 ± 0.7 years)	Graded exercise test and 2x15 minute exergaming sessions; HiE and LoE	- Heart rate - Energy Expenditure - Flow-mediated dilation - Arterial function	E (HiE, but not LoE)
Williams *et al.*, 2014[35]	Stroke Video Game, PC	Stroke symptoms	Story, correct answers for incorrect responses, hip-hop song, incentive reward	SCT	Single group, pre-post, quasiexperimental	210 children aged 9-10 years	Stroke Video Game	- Actionable stroke knowledge	E (in knowledge of one symptom, not overall)
General Hygiene Promotion									
Farrell *et al.*, 2011[26]	eBug Junior Game, PC	Microbes, hygiene and antibiotics	Story, avatar, levels, learning outcomes expressed through rules of the game instead of story or dialogue	-	Single group, pre-post	1700 children aged 9-12 years	eBug Junior Game	- Knowledge related to hand washing, respiratory hygiene and antibiotic resistance	E

Abbreviations
RCT- Randomized Control Trial; PC- Personal Computer; SCT- Social Cognitive Theory; PA- Physical Activity; HiE- High-Intensity Exergaming; LoE- Low-Intensity Exergaming
Letter Superscript: Abbreviation
[d] Theory - SCT = Social Cognitive Theory; SDNT = Self-care Deficit Nursing Theory; TRA = Theory of Reasoned Action; TPB = Theory of Planned behaviour; PMT = Protection motivation

Author, Year	Game title, Platform	Content	Key game features	Theory [d]	Study Design	Sample [e]	Groups [e]	Measures	Effectiveness [f]
theory; '-' indicates not specified in the research article [e] Sample/ Groups - IG- Intervention Group; CG- Control Group; CoG- Comparison Group [f] Effective - E = Significantly effective; NE = Non-significant; NT = Not Statistically Tested; additional comments have been given in parentheses ()									

Table 3: Detailed description of intervention studies involving multimedia games aiming at management of disease conditions.

Author, Year	Game title, Platform	Content	Key game features	Theory [d]	Study Design	Sample [e]	Groups [e]	Measures	Effectiveness [f]
Asthma Management									
Rubin *et al.*, 1986[12]	Asthma Command, PC	Manage asthma, medication, allergen identification, use of healthcare	Story, scoring	-	RCT	54 (IG-25, CG-29) moderately severe asthmatic children aged 7-12 years	IG: Asthma Command educational computer game (45 minutes) CG: routine computer game not related to Asthma	- Asthma knowledge and behaviour	E (not in behaviour)
Bartholomew *et al.*, 2000[14]	Watch, Discover, Think and Act, PC	Manage asthma, medication, self-monitoring, allergen identification, skill building	Story, tailored to individual child, choice of game character, match gender/ ethnicity	SCT, SDT and PT	Pre-post, randomized	171 (IG-70, CoG-63) asthmatic children aged 6-17 years and their primary care givers	IG: Watch, Discover, Think and Act CoG: usual care	- Knowledge of asthma management - Knowledge of self-regulatory steps - Symptom - Hospitalization	E (only among milder asthma subjects; not in knowledge)
Homer *et al.*, 2000[15]	Asthma Control, PC	Manage asthma, medication, self-monitoring, allergen identification, use of healthcare	Story, incentives, health level/ asthma condition scale	-	RCT	137 (IG-76, CG-61) asthmatic children aged 3-12 years	IG: Asthma Control (45 to 60 minutes) CG: Printed educational material to families	- Acute health care use (emergency department and outpatient) - Parental and child knowledge - Asthma symptom severity, child functional status and school absences, satisfaction with care	E (not in health care use and health status)
Yawn *et al.*, 2000[16]	Air Academy: TM The Quest for Airtopia, PC	Anatomy of lung, pathophysiology of asthma, allergen identification, therapeutic management	Story	-	RCT	87 third and fourth grade asthmatic children	IG: Air Academy: TM The Quest for Airtopia (20 minutes) CG: usual health and science education programs with no information on asthma	- Asthma knowledge	E

Author, Year	Game title, Platform	Content	Key game features	Theory [d]	Study Design	Sample [e]	Groups [e]	Measures	Effectiveness [f]
Huss *et al.*, 2003[18]	Instructional asthma game, PC	Manage asthma, medication, allergen identification, use of healthcare	Story, health level/ asthma condition scale	Learning theory	RCT	101 (IG-56, CG-45) inner-city asthmatic children aged 7-12 years	IG: Conventional education (written asthma materials, a nonasthma-related computer program) & the computer-based instructional asthma game (60 minutes) CG: only the conventional education	- Asthma symptoms (Juniper's Pediatric Asthma Quality of Life Questionnaire) Lung Function measures	NE
Diabetes Management									
Brown *et al.*, 1997[13]	Packy & Marlon, Console	Diet, exercise	Story, 24 levels, meal plan, food exchange calculator, blood glucose level meter (color-coaded)	-	RCT	59 (IG-31, CG-28) diabetic children aged 8-16 years	IG: Packy & Marlon using Super Nintendo video game system CG: Entertainment video game containing no diabetes related content	- Perceived self-efficacy, social support - Knowledge about diabetes, HbA1c blood test	E (but not in knowledge & glycated haemoglobin)
Kumar *et al.*, 2004[19]	DAILY, Mobile	Diet, self-monitored blood glucose, basic diabetes Knowledge	Blood glucose prediction	-	RCT	40 (IG-19, CG-21) insulin-treated diabetic children and adolescents aged 8-18 years (type 1=39, type 2=1)	IG: Blood Glucose meter, PDA with data management software and DiaBetNet CG: Blood Glucose meter, PDA with data management software	- Blood glucose level - Knowledge related to diabetes	E
Sickle Cell Disease Management									
Yoon *et al.*, 2007[21]	The Sickle Cell Slime-O-Rama Game, PC	Sickle Cell Disease facts, disease management and pain management	Levels, quiz, explanation of correct answer	-	Single group, pre-post	22 children with Sickle Cell Disease aged 6-14 years	The Sickle Cell Slime-O-Rama Game	- Knowledge related to Sickle Cell Disease Confidence level regarding self-management	E

Abbreviations
RCT- Randomized Control Trial; PC- Personal Computer; SCT- Social Cognitive Theory
Letter Superscript: Abbreviation
[d] Theory - SDT = Self Determination Theory; PT = Persuasion Theory; '-' indicates not specified in the research article
[e] Sample/ Groups - IG- Intervention Group; CG- Control Group; CoG- Comparison Group
[f] Effectiveness - E = Significantly Effective; NE = Non-significant; NT = Not Statistically Tested; additional comments have been given in parentheses ()

the most common learning method in majority of the games, moreover creating action plans along with goal setting while playing *Squire's Quest! II: Saving the Kingdom of Fivealot* [6, 37] enabled players to meet their desired diet-related goals. Alternatively, the game *DAILY DiaBetNet* [19] involved real-life assessment of patient's accuracy in predicting his or her blood glucose levels. Two [23, 30] studies were a part of broader e-learning programs, both on obesity prevention.

Stories are usually an important and common component of multimedia games [41, 42]. Most of the games included in this review employed simulated stories addressing behaviour change with the idea that lessons learnt through story would lead to improved knowledge and behaviour [5, 12, 16, 18, 20, 25, 26, 29, 31, 35, 36, 38, 40]. Main game features included: rewarding using scores [5, 6, 15, 17, 20, 30, 36, 37], levels [5, 6, 13, 20, 26, 29, 31, 36, 37] or scales [13, 15, 18, 23, 29]; game character [14, 26, 36, 40]; animation [6, 23, 25, 37, 40]; and motivational applause [25]. Tailoring game situations can be one important component in games that may favour player's interest and involvement [43]. *WDTA* [14], a game designed for asthma management, allowed the patients to tailor the game character's asthma characteristics as that of their own and also permitted them to match their gender and ethnicity. *Air Academy:TM The Quest for Airtopia* [16] and *Alimentary my dear Joe* [17] were designed by a team of health care professionals and game developers; children having asthma along with child psychologists and educationists were also involved in designing of *Air Academy:TM The Quest for Airtopia* [16]. Exergames (or active video games) involved movement of limbs for gameplay and therefore mainly aimed at improving physical activity behaviours [22, 24, 27, 28, 31, 33, 39] or vascular function [32].

3.4 Effectiveness of games

Twenty-two studies assessed primarily whether the game changed knowledge [16, 21, 26, 29, 31, 34, 35, 38] or behaviour [5, 6, 18, 20, 22, 24, 25, 27, 28, 32, 33, 36, 37] with nine assessing both [12, 15, 17, 19, 23, 39, 40]. The primary outcome measures varied from knowledge; to psychosocial variables [15, 36]; specific health promoting behaviours; anthropometric [23, 25, 27], physiological [13, 18, 19, 27, 32] or health-outcome variables [14, 15, 18, 32]. All except three studies [18, 28, 40] reported positive outcomes; majority (26 out of 29) of the studies [5, 6, 12, 14, 17, 20, 23, 25, 27, 29, 31, 33, 35, 37, 39] that tested significance reported significantly effective (P<0.05) improvement in terms of either knowledge or practices post-intervention (two studies [24, 38] did not test significance) while over two-thirds (69%) [15, 19, 21, 26, 30, 31, 34, 35] that tested knowledge change showed statistically significant (P<0.05) advancement in knowledge levels post-intervention.

Majority of the studies [13, 19, 23, 26, 30, 31, 34, 35, 38, 39] (15 out of 17) that tested knowledge change showed knowledge improvement among participants post-intervention. Of these, in three-fourth of these studies [15, 19, 26, 30, 31, 34, 35] (10 out of 15) the improvement was statistically significant (P<0.05) (two studies did not test significance).

All nutrition-related studies which assessed dietary intake [5, 6, 17, 20, 25, 36, 37] indicated some improvement in diet with respect to fruit, vegetable or fruit juice, sugar, fat or fiber intake, however, there was no effect on fruit and vegetable intake of participants after *QTLM* [36] gaming session. Few nutrition-related studies even assessed physical activity minutes [23, 25] or attitude [29, 36], and anthropometric measures [23, 25]. One game [23] led to significant improvement in physical activity time, whereas no change was observed in moderate to vigorous physical activity levels in another study [25]. A trial with *QTLM* game reported that higher exposure to the game and gaming process significantly increased frequency of physical activity (P<0.05). Nutrition/ physical activity attitude (P<0.05) [36] and healthy eating attitude (P<0.001) [29] significantly improved post gaming sessions, however, no significant changes were observed in anthropometric measures [23, 25].

Physical activity was commonly promoted by exergames which involved obligatory muscle movement for gameplay and therefore led to improvement in total physical activity minutes [22, 24, 27, 39], attitudes [33], self-efficacy [33], reduced sedentary screen time [22, 27], reduced BMI [27] and body fat [27], however in naturalistic settings one study [28] observed no significant difference in physical activity levels among children playing exergames versus those playing sedentary video games. Exergaming, in general, resulted in increased heart rate [39] while high intensity exergaming was also observed to be associated with improved vascular function [32]. Compared to sedentary educational video games, exergaming benefitted children more with respect to increase in physical activity and motivation [39].

Asthma-related multimedia game intervention led to fewer hospitalizations [14] (P=0.01), reduction of acute visits due to asthma [12] (P < 0.13), increased functional status [14] (P<0.05) and improved child behaviour for asthma management (P=0.44 [14], P<0.008 [12]). An improvement in asthma symptoms was observed in two studies [14, 15] but results were statistically significant only for patients with milder asthma [14]; on the other hand, no significant changes were observed in another study [18].

Amongst multimedia games for diabetes management, *DiaBetNet* [19] resulted in significantly less hyperglycemia (P<0.001) among participants post gaming session, while *Packy and Marlon* [13] showed no significant difference in glycated haemoglobin (HbA1c) levels (P=0.64) between groups. *Packy and Marlon* [13] resulted in better diabetes-related self-efficacy (p=0.07), communication about diabetes with parents (p=0.025), self-care behaviours (p=0.003), and decrease in unscheduled urgent doctor visits (p=0.08) among intervention group participants. Better knowledge of healthy diet and lifestyle was observed among *Mario Bros* [38] players over a period of 1 week.

3.5 Knowledge retention over time

Only two studies [16, 35] assessed the retention of knowledge gained through multimedia game intervention and found that the improved knowledge could be retained for 4 to 7 weeks.

3.6 Game acceptability

Acceptability among target participants is an important factor influencing effectiveness of an educational tool. Few reviewed studies [14, 16, 22, 28, 30, 40] tested the acceptability and suitability of games as rated by children, teachers or parents. *Alimentary my dear Joe* [17], *Barney's healthy Foods* [40]. *Fitter Critters* [29]. *Super ETIOBE* [30], *Dance Dance Revolution (DDR)* [22] and *WDTA* [14] were liked by children and these were reported to be enjoyable, entertaining, fun and easy to learn by them.

Teachers appreciated the games, *Air Academy:™ The Quest for Airtopia and Alimentary my dear Joe* [16, 17] and were enthusiastic about including *Air Academy* [16] in their school curriculum. Exergaming was liked by children as the physical activity involved could be done indoors, however, some children disliked the difficulty level/ did not understand the character/ had no partner to play [28]. Children liked sedentary video games as they were challenging and motivated them to achieve a high score [28]. Exergames were observed to be more enjoyable than sedentary video games among children [39].

4. Discussion

This systematic review examined published research on the effect of multimedia games on nutrition and health knowledge and practices of young children. Most games were aimed at promotion of healthy lifestyle behaviours related to nutrition, physical activity, oral health and general hygiene. Some aimed at either prevention or treatment and management of disease conditions such as obesity, diabetes, asthma and stroke. Overall, it was observed that most multimedia games led to improvement in health and nutrition knowledge and behaviours.

Utility of multimedia games for nutrition and health promotion: Multimedia games offered promising consequences when used for nutrition or health promotion among young children. Playing most of these games led to desirable outcomes including improvement in knowledge, behaviours and physiological or health-related parameters. Such games were observed to be effective for promoting awareness and desirable behaviours among both healthy and diseased children, either for management of diseases (such as diabetes, asthma, heart disease) or for preventive lifestyle behaviours (e.g. healthy eating, physical activity, hygiene and oral health). Many other researches (not meeting inclusion criteria of this review) have reported use of multimedia games for medical conditions such as cancer, HIV, Parkinson's disease, obesity and psychiatric conditions (e.g., autism spectrum disorder, depression, anxiety) [44]. A meta-analysis of 54 serious digital games showed that games had a statistically significant improvement in healthy behaviours and their determinants, however the effects were small [45]. Exergames resulted in positive outcomes in physical activity time, level, attitude, improvement in BMI and body fat among children. Likewise, another systematic review [46] on exergames for therapeutic purposes demonstrated improved health outcomes when exergaming was used for rehabilitation, management of disease or illness and attaining energy balance. Although multimedia games were typically observed to be effective for health promotion, it is essential to recognise their usefulness in comparison to conventional methods.

Multimedia games vs. conventional methods

Traditional or conventional teaching methods such as classroom education or printed educational material targeted at children had limited effectiveness in improving both knowledge and practices related to nutrition and health when compared with multimedia games [5, 14, 18, 20, 30, 36]. The present review revealed that behaviours including dietary intake, dietary habits, asthma or diabetes self-care behaviours, self-efficacy, symptoms, hospital admissions and unscheduled visits significantly improved using multimedia game intervention as compared to conventional methods. However, a study resulted in knowledge improvement in both groups post intervention, with no significant differences between groups, when health education w.r.t. oral health was delivered on one to one basic by a nurse educator to the control group [40]. Another study [15] targeted at asthmatic children led to improvements in asthma management behaviour in both the groups (where control group families received written education materials) although asthma knowledge was significantly higher in the game group. A meta-analysis [47] of 39 studies declared game-based learning more effective than conventional learning methods for student learning and retention. Thus, providing health messages in a play-way method using multimedia games could be better in capturing children's attention and also be a cheaper alternative to conventional education methods when used in public health campaigns.

Common features of effective games

Success of multimedia games as tools for nutrition and health promotion depend fairly upon game design and features. Such games would perhaps serve their purpose better if designed in an attractive manner while keeping in mind the target group and their preferences. Simulated stories are a prominent feature in video games that possibly builds interest among players and facilitates learning. Stories are directed towards desirable health seeking behaviours in case of health video games and are believed to evoke emotions that may be responsible for influencing health behaviour [42]. However, active video games (or exergames) may be with or without stories and emphasize primarily on physical exercise during game play using motion sensors and cameras. Reinforcement mechanisms such as rewarding, incentivizing, scoring and motivational applause are other important features of effective games. Realistic sound, graphics, winning and losing feature, scoring, character development, ability to customize games and multiplayer features are considered as essential components in video games by gamers [48]. These features perhaps make video gaming a pleasant experience and stimulate curiosity to continue playing.

Overall, multimedia games could be more effective than conventional teaching methods in promoting awareness w.r.t. good nutrition and health by improving knowledge and behaviours as they (a) are appealing, entertaining, challenging and motivating; (b) include stories and behaviour change processes (like goal setting, problem solving, decision making) [41] which encourage players to learn in order to progress in the game and win; (c) provide constant feedback in the form of scoring, reinforcing messages and reaching different game levels; (d) encourage repetition and help children learn by trial and error method; (e) provide ease in message comprehension. The fun element of games could be because of the attractive game characters, animations and interesting sound effects. Games also offer challenging goals and levels, provide motivation in the form of scores, points, incentives and motivational messages. In addition, basing these games on theories of learning and behaviour change facilitates the process of behaviour change. These features of multimedia games make them engaging which could further encourage repetition and reinforcement that could result in better awareness and finally improved behaviours.

5. Limitations

Some limitations to this systematic review need to be noted. First, no attempts were made with respect to segregating data to obtain data exclusively pertaining to 6-10 years old children as sixteen studies [12, 15, 17, 19, 21, 25, 28, 30, 32, 38, 40] reviewed included children beyond the age range of 6-10 years. Second, meta-analysis could not be conducted because of limited access to statistical expertise. Third, articles were searched from only four databases due to time constraint and limited research team members. Fourth, full-text of 5 articles could not be obtained due to limited funding.

6. Conclusion

Multimedia games are an interesting and useful way to improve health and nutrition related knowledge and behaviours among young children. Game design and features including storyline, reinforcement, repetition, sound and graphics appear to influence the effectiveness of multimedia games in health and nutrition promotion. However, further research is needed on the impact of multimedia game design, features and theory-based propositions in promoting health and nutrition.

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