GAMES FOR HEALTH JOURNAL: Research, Development, and Clinical Applications
Volume 2, Number 3, 2013

DOI: 10.1089/g4h.2013.0025

Reviews

A Systematic Review of Health Videogames on Childhood Obesity Prevention and Intervention

Amy Shirong Lu, PhD,[1] Hadi Kharrazi, MD, PhD,[2] Fardad Gharghabi,[3] and Debbe Thompson, PhD[4]

Abstract

Childhood obesity is a global epidemic. Health videogames are an emerging intervention strategy to combat childhood obesity. This systematic review examined published research on the effect of health videogames on childhood obesity. Fourteen articles examining 28 health videogames published between 2005 and 2013 in English were selected from 2433 articles identified through five major search engines. Results indicated that academic interest in using health videogames for childhood obesity prevention has increased during this time. Most games were commercially available. Most studies were of short duration. Diverse player and game play patterns have been identified. Most studies involved players of both genders with slightly more boys. The majority of players were non-white. Most studies had the players play the games at home, whereas some extended the play setting to school and sports/recreational facilities. Most of the games were commercially available. Positive outcomes related to obesity were observed in about 40 percent of the studies, all of which targeted overweight or obese participants.

Introduction

Childhood obesity is a worldwide problem,[1] which increases the risk of various cancers,[2] shortens lifespan,[3] impedes functional ability,[3] diminishes quality of life,[3] and increases the likelihood for adult morbidity.[4] Dietary and physical activity (PA) behaviors,[5,6] including moderate to vigorous PA,[7] fruit and vegetable[8] and water intake,[9] consumption of family meals,[10] sugar-sweetened beverages,[11] whole grain foods,[12] and fast food,[13] have been related to childhood obesity. Many obesity prevention programs have not produced the desired effect.[14] Videogames offer an innovative alternative that have induced positive health behavior changes among children,[15] such as increased fruit and vegetable intake[16] and PA.[17] Because the definitive obesogenic behaviors have not been clearly identified,[18] it would be valuable to show whether health videogames change behaviors thought to be obesity-related. Once the obesogenic behaviors have been identified, health videogames could be used to promote obesity prevention behaviors in fun and effective ways.

Previous reviews of health videogame research focused on different health outcomes[15,19–21]; none focused on obesity-related outcomes among children. This article systematically reviews research on health videogames' influence on childhood obesity and related behaviors.

Materials and Methods

Data sources

We started this process by generating a definition of "health videogames," progressing to an analysis of individual articles and data extraction. A health videogame was defined as an interactive digital program or application designed for promoting health and wellbeing as part of its goals. To ensure a comprehensive scope of inclusion, two search cycles were performed between 2010 and 2013. The first cycle was conducted as part of a larger systematic review that examined general health videogame research published before 2011,[21] whereas the second cycle identified additional works published between 2011 and March 2013.

For the first review cycle, four independent reviewers with different academic backgrounds participated in article selection and data extraction to ensure a fair and comprehensive coverage of health videogame research; inter-rater reliability was assessed. Five search engines—PubMed, EBSCO, IEEE/ACM, Google Scholar, and Health Game Research Database[22]—were searched between October 2010 and April 2011 with key words ((Health OR Rehab*) OR (Exer* OR Acti*) OR Edu* OR Behav* OR Serious OR (Virtual AND Reality)) AND ((Interactive OR Computer OR Video OR Multimedia OR Internet OR Online) AND Gam*) with the intention of

[1]Department of Communication Studies, School of Communication, Northwestern University, Evanston, Illinois.
[2]Department of Health Policy and Management, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland.
[3]School of Informatics, Indiana University, Indianapolis, Indiana.
[4]USDA/ARS Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas.

capturing most or all of the research articles written in English on health videogames published in peer-reviewed journals and conference proceedings up to 2011. Each reviewer generated an independent list of articles.

The inclusion criteria[21] were as follows: (1) The primary purpose of the study was improving or maintaining health; (2) one or more health videogames were used as the primary intervention; (3) the study incorporated quantitative measures of outcomes; (4) the study was designed for the healthcare-receiver population (e.g., overweight elementary school students) instead of healthcare providers (e.g., orthopedic surgeons[23]); and (5) the publication was an original study, not a review of other studies.

For the first review cycle, 2024 articles were identified by reviewers from the five search engines. The articles were reduced to 396 articles to avoid duplication. The abstracts of the 396 articles were retrieved and screened using the inclusion criteria. If an abstract did not provide adequate information, the reviewers read the article in full. Consensus on coding results was reached through in-depth discussion. Manual searches were also performed on all of the selected articles' reference lists to ensure inclusion of all eligible articles. In total, 149 articles on health videogame research were retained. A scoping overview was published elsewhere.[21] The authors then re-examined the full text of the 149 articles and identified 9 health videogame research articles. To qualify for this systematic review, a health videogame research article had (1) to target participants 18 years or younger and (2) to include one or more of the following obesity-related measures as part of the outcome measures,[11] such as body mass index (BMI), BMI *z*-score/percentile/standard deviation (SD) score, triceps skinfold thickness, waist circumference, waist-to-hip/height ratio, or bioelectrical impedance analysis.

To ensure that the articles included recent health videogame research, a second review cycle was conducted in March 2013 by two of the four independent reviewers following a new protocol: the same five search engines were searched with the same key word string plus "Or Obesity" related publications published between 2011 and March 2013. After duplicates were eliminated, in total, 409 additional articles on health videogame or obesity research were identified. The 409 articles' abstracts were examined, and 16 publications on health videogame research that specifically targeted obesity prevention were identified. The inclusionary criteria for this systematic review were then applied. Eight health videogame studies for childhood obesity prevention and intervention were identified. All of the identified articles included obesity-related outcome as part of their measures. Not all of them, however, explicitly intended to change these outcomes.

The unit of analysis for this systematic review was the intervention or project. If an intervention's findings were reported in more than one publication, only one publication was included in this review. Among the 17 articles collected from both search cycles (9 from the first and 8 from the second), another 3 articles were dropped from the systematic review because they reported the same trial or project that had already been covered by other articles. In total, 14 articles representing 14 interventions or projects were included in this review.

The quality of the included publications was then measured against a combined version of CONSORT[24] and STROBE[25] critical analysis frameworks. These frameworks were combined to accommodate the heterogeneity of the selected articles, which included both randomized and non-randomized intervention. Duplicate criteria were merged, and the combined version was eventually simplified to facilitate the application process. All publications were determined to have acceptable quality scores matching average 16.7 out of 20 quality criteria of the combined framework. None was excluded because of quality score.

Figure 1 provides a flowchart of the selection process depicting both review cycles.

Data extraction and synthesis

To ensure inter-rater reliability and to authenticate the data extraction and interpretation quality, four independent reviewers participated in a pilot training session by coding 10 percent of the health videogame research articles on behaviors other than dietary intake. Differences were resolved by internal in-depth discussion. Following this, each coder reviewed and extracted data from the 14 articles separately. Data extracted from the selected articles included the following: (1) Publication statistics (publication year); (2) sample characteristics (size, age, gender, race/ethnicity, weight status); (3) research design (location, existence of control group, game play setting, project duration, intervention episode duration, intervention episode, total intervention duration); (4) game characteristics (commercial/noncommercial, platform, online, story, game duration); (5) key intervention goals; (6) psychological and behavioral change theories; (7) targeted health behaviors; (8) obesity-related outcome; and (9) whether the intervention changed the obesity-related outcome. Extracted results were tabulated in a compiled Microsoft® (Redmond, WA) Excel spreadsheet for further analysis. Additional e-mail inquiries seeking additional information were sent to authors when their articles did not provide enough details about the studies.

Research questions

Two research questions guided the systematic review: (1) What were the characteristics of the health videogame studies on childhood obesity prevention? (2) What aspects of games led to what outcomes?

Results

High inter-rater consistency was obtained with over 85 percent agreement across variables.

First research question

Table 1 provides a summary of study characteristics.

Year of publication. The number of studies increased across the years. Most studies were published after 2011 ($n = 11$), with only three published between 2005 and 2007.

Sample size. Half of the studies had a sample of 50 or fewer ($n = 7$). Around 40 percent included between 100 and 500 participants ($n = 6$).

Age group. Over 70 percent included participants > 10 years old ($n = 10$).

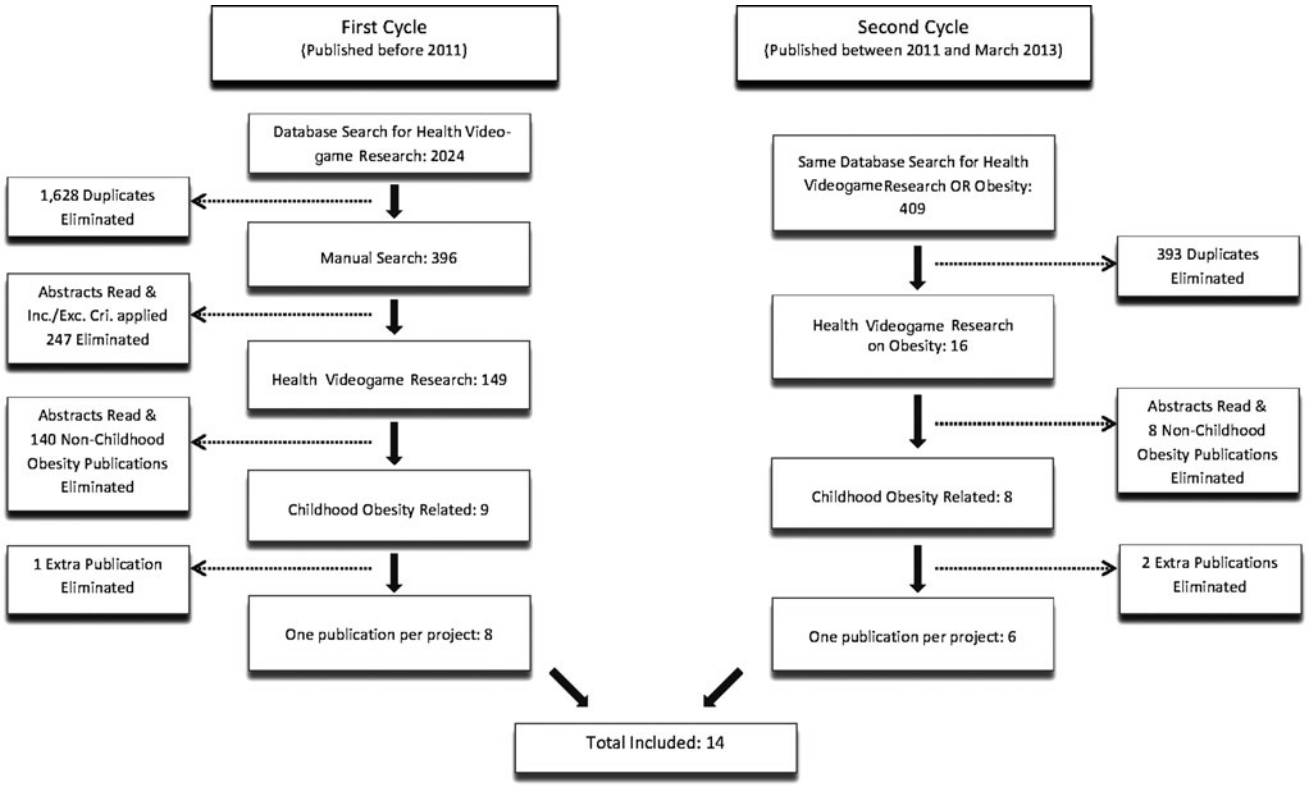

FIG. 1. Article identification process.

Gender. Over 90 percent recruited both genders ($n=13$). Most of the participants were boys (993 of 1663, or 59.7 percent).

Race/ethnicity. Over 70 percent of studies reported the participants' race and ethnicity. Studies conducted in Italy[26] and The Netherlands[12] were assumed to feature all-white participants and were included in the "Reported category." All of the non-Hispanic American participants in another study[13] were coded as white. Although white participants would be overestimated in these studies, more non-white ($n=592$) than white ($n=409$) participants were included. Of the non-white participants, more Hispanic American ($n=416$) than African American ($n=64$) participants were included.

Weight/body composition status. Eight studies (57 percent) did not recruit child participants based on their weight/body composition status. For example, one study[12] used the 20-m shuttle run test and included those with scores below the median for their age and gender group. The remaining six studies (43 percent) used BMI percentiles as part of recruitment screening criteria, with one including normal and overweight children,[27] three including overweight and obese children,[10,28,29] and two including obese children only.[26,30]

Location. The United States was the main venue for the research (70 percent, $n=10$), compared with two studies in Europe and two studies in New Zealand.

Design. Over 70 percent of the studies included control conditions ($n=10$), compared with the other studies (29 percent) that had a treatment group only.

Game play setting. Home was the most popular performance venue (60 percent, $n=8$). The second most popular venue was schools ($n=3$), followed by sport/recreational facilities ($n=2$). Only one study[26] included multiple venues.

Project duration. Durations of the obesity-related health videogame research projects were short. Except for one[31] that lasted a year, all were under 30 weeks or less, with 57 percent taking place in less than 20 weeks ($n=8$).

Intervention episode duration. Most (86 percent) of the intervention episodes were under 60 minutes per session ($n=12$), with only two studies having longer sessions.

Intervention episodes. The number of intervention episodes had a wide range (6–168; mean, 69; SD, 56). Around 40 percent of the intervention had 30 episodes or less.

Total intervention duration. The majority (79 percent) of the obesity intervention durations were between 11 and 60 hours throughout the intervention projects ($n=11$). Overall, the interventions were delivered for between 4 and 144 hours (mean, 36.6 hours; SD, 38.9 hours).

Health behaviors. Two types of health behaviors were identified in the studies: Nutrition and PA. Most studies focused on one of the two, with over 70 percent focusing on PA ($n=10$). Only two focused on both of the behaviors.[27,28]

Obesity-related outcome. All studies but one used a variety of BMI as part of the outcome. Waist circumference was the second most popular outcome measure (four

Table 1. Characteristic of Studies

Characteristic	*References*[a]	*Count*	*%*
Year of publication		14	100
2005–2007	**6, 8, 13**	3	21
2008–2010	**9–12, 14**	5	36
2011–March 2013	**1–5, 7**	6	43
Sample size			
0–50	**2–4, 8, 11–13**	7	50
51–100	**9**	1	7
101–200	**1, 6, 10**	3	21
≥201	**5, 7, 14**	3	21
Age (mean) (years)			
≤10	**2, 6, 9, 10**	4	28
>10	**1, 3–5, 7, 8, 11–14**	10	72
Gender			
Both female and male	**1–13**	13	93
Male only	**14**	1	7
Race/ethnicity			
Reported/assumed	**1–9, 13**	10	72
Did not report	**10–14**	4	28
Weight/body composition status			
No distinction or BMI % applied	**2, 5, 6, 9, 10, 12–14**	8	57
Normal weight + overweight	**1**	1	7
Overweight + obese	**4, 7, 11**	3	21
Obese	**3, 8**	2	14
Location			
Italy	**3**	1	7
The Netherlands	**13**	1	7
New Zealand	**7, 12**	2	14
United States	**1, 2, 4–6, 8–11, 14**	10	72
Design			
Treatment/control/crossover	**1, 5–7, 9–14**	10	72
Treatment only	**2, 3, 4, 8**	4	28
Game play setting			
Field study: Home	**1, 2, 7–9, 11, 12, 14**	8	58
Field study: School	**5, 6, 10**	3	21
Field study: Sports/recreational facility	**3, 4**	2	14
Field study: Combination	**13**	1	7
Project duration			
≤10 weeks	**1, 4, 6, 14**	4	28
11–20 weeks	**3, 11, 12, 13**	4	28
21–30 weeks	**2, 7, 8, 9, 10**	5	36
≥31 weeks	**5**	1	7
Intervention episode duration (minutes)			
≤60	**1, 2, 5–14**	12	86
61–90	**3**	1	7
≥91	**4**	1	7
Intervention episodes			
≤30	**1, 3, 4, 6, 10, 14**	6	42
31–100	**2, 11–13**	4	28
≥101	**5, 7–9**	4	28
Total intervention duration (hours)			
≤10	**10, 14**	2	14
11–30	**1, 4, 6, 9, 11, 13**	6	42
31–60	**2, 3, 5, 8, 12**	5	36
≥61	**7**	1	7
Health behaviors			
Nutrition	**10, 14**	2	14
Physical activity	**2, 3, 5–9, 11–13**	10	72
Nutrition + physical activity	**1, 4**	2	14

(*continued*)

Table 1. (Continued)

Characteristic	*References*[a]	*Count*	*%*
Obesity-related outcome[b]			
BMI (BMI %/z-score/SDS)	**1–12, 14**	13	—
Waist circumference	**1, 3, 7, 12**	4	—
Skinfolds	**1, 13, 14**	3	—
Bioelectrical impedance	**2, 6, 7**	3	—
Waist to height ratio	**3**	1	—
Change in obesity-related outcome			
Non-significant	**1, 2, 8–10, 12–14**	8	58
Partially significant	**5, 6**	2	14
Significant	**3, 4, 7, 11**	4	28

[a]Reference numbers: **1,** Baranowski et al.[27]; **2,** Bethea et al.[55]; **3,** Calcaterra et al.[26]; **4,** Christison and Khan[28]; **5,** Gao et al.[31]; **6,** Goran and Reynolds[13]; **7,** Maddison et al.[29]; **8,** Madsen et al.[30]; **9,** Maloney et al.[33]; **10,** Moore et al.[56]; **11,** Murphy et al.[10]; **12,** Ni Mhurchu et al.[32]; **13,** Paw et al.[12]; and **14,** Thompson et al.[57]

[b]Frequency count: The percentage on the right column is not calculated because of overlapping uses.

BMI, body mass index; SDS, standard deviation score.

publications). Skinfold and bioelectrical impendance measures were the third most popular (three publications each). Only one study used waist to height ratio.[26]

Change in obesity-related outcome. Four studies found statistically significant differences in obesity related outcomes[10,26,28,29]; one found a significant reduction in the first half of the intervention,[31] and another found this among girls only.[13]

Second research question

Table 2 addresses the second research question and summarizes characteristics of the games and the interventions. One study did not specify all of the games used.[32] Twenty-eight games were studied in the 14 publications. On average, each intervention used two games.

Games. Of the 28 games, five were health educational games, whereas the remaining 23 were all active videogames or game stations. (Note that these are also known as exergames, but not all exergames are necessarily health videogames unless they are used for health purposes.) "Dance Dance Revolution" (DDR) (Konami Digital Entertainment, El Segundo, CA) was the most popular game (six studies). Two used a stand-alone station, and four used the TV console/dance mat as the platforms.

Commercial. Around 21 percent of the games ($n=6$) were developed by researchers. The rest were commercially available ($n=22$).

Platform. Half of the games used commercial game consoles ($n=14$), with seven on the Wii™ from Nintendo (Redmond, WA) and another seven on the PlayStation® from Sony (New York, NY). Around 25 percent of the games ($n=7$) used stand-alone stations, such as the Interactive Arena from Makoto (Centennial, CO). The rest (25 percent, $n=7$) were computer-based games.

Online. About four of the health videogames (14%) were online or used the network to transfer research data.

Story. Two games (7 percent) contained stories, whereas the rest ($n=26$) did not.

Key intervention goals. Most of the games ($n=19$) targeted increased moderate to vigorous PA, one game focused on nutrition only, and four focused on both PA and nutrition.

Theory. All of the six games developed by researchers had an underlying theoretical framework, including the Social Cognitive Theory, adopted by five games, and Self Determination Theory, Behavioral Inoculation Theory, Elaboration Likelihood Model, and Self-care Deficit Nursing Theory.

Age. The mean age of the participants/players was 10.9 years (range, 7–18 years; SD = 1.6).

Number. The number of participants who played each game was 120 (range, 20–473; SD = 134).

Total intervention duration. On average, each game was played 18.1 hours (range, 0.7–112 hours; SD, 30.2 hours).

Measurement. All but two studies used both subjective and objective measurement instruments.

Key findings. Although 8 of the 14 studies did not change obesity-related outcomes, all but one found significant change in proximate measures such as the duration of vigorous PA.[33]

Effect size. Of the 14 studies, 3 reported small-to-moderate (Cohen's $d=0.16$–0.5) effect sizes. The rest did not provide effect size statistics ($n=11$).

Discussion

All four studies that significantly changed obesity-related outcomes included children who were overweight or obese. (None of the four, however, reported the effect size statistics.) Obesity-related interventions generally have had effects primarily among the overweight and obese participants.[34–36]

Table 2. Characteristics of Health Videogames for Childhood Obesity Prevention and Intervention

Study (year)	Game(s)	[1]C	Platform	[2]O	[3]S	Key goals	Theory	Age (years)	Number of participants	Total intervention duration	Measurements	Key findings	Effect size
Baranowski et al.[27]	"Escape from Diab" and "Nanoswarm: Invasion from Inner Space"	N	Computer	Y	Y	Increase FV and W intakes, MVPA, and reduce adiposity	SCT[a]/SDT[b]/BIT[c]/ELM[d]	10–12	103 treatment; 50 control; 86 males	40 min/session ×9 sessions ×2 games	Questionnaire; Actigraph accelerometer; PE-AIM statiometer; SECA scale; Lange caliper	Treatment group increased FV consumption by about 0.67 servings/day but not W and MVPA or body composition	$d = 0.18–0.26$
Bethea et al.[55]	DDR Extreme	C	Console	N	N	Increase MVPA among African American and Hispanic American youth	—	9–11	28 treatment; 18 males	30 minutes ×3/week ×30 weeks	Questionnaire; Omron blood pressure monitor; Tanita Accustat stadiometer, Tanita biolelectric impedance scale; CardioCheck PA device; 20mSRT	Physical fitness (VO_{2max}) increased by 4.9 ± 9.9% and was sustained through 30 weeks. Absolute VO_{2max} increased by 2.97 ± 4.99 mL/kg/minute. An average of 1.12 hours/day of increased movement to music was maintained.	—
Calcaterra et al.[26]	"Just Dance 2," "Just Dance 3," "Michael Jackson: the Experience," "Samba de Amigo," "Wii Fit," "Wii Fit Plus"	C	Console	N	N	Evaluate a 12-week controlled recreational training program for sedentary obese children	—	9–16	22 treatment; 13 males	90 minutes ×2/week ×12 weeks (game play consists of 5–10 minutes per 90-minute session)	Questionnaire; Harpenden stadiometer; Tanita biolelectric impedance scale; standard anthropometric tape; mercury sphygmomanometer; Architect chemistry analyzer; Immulite immunochemistry analyzer; treadmill walking Session; FitMate Pro gas exchange analyzer; Citec dynamometer; grip strength test; sit-and-reach test	Significant decrease in BMI, SDS-BMI, WC, WC/height ratio, fat mass, blood glucose, HOMA-IR, triglycerides, and systolic pressure before and after exercise	—
Christison and Khan[28]	DDR station, Exerbike XG, Nintendo "Wii Tennis" and "Wii Boxing," Makoto Interactive Arena, Lightspace Play Floor, Cybex Trazer, Treadwall, and Xavix system for boxing and tennis	C	Station	N	N	Evaluate a weight intervention program for children using exergaming technology	—	8–16	48 treatment; 26 males	120 minutes × 10 weeks	Questionnaire; body composition assessment by stadiometers and weight scales	Average BMI change was −0.48 kg/m^2 (BMI z-score change was −0.072). Average Global Self-Worth score improved, screen time and soda intake were reduced, and exercise hours per week increased.	—
Gao et al.[31]	DDR station	C	Station	N	N	Examine the impact of DDR-based exercise on Latino children's physical fitness and academic achievement	—	10–12	208 crossover design; 121 males	30 minutes × 3/week × 52 weeks	Cardiorespiratory endurance assessment (1-mile run); body composition assessment by stadiometers and weight scales; reading and math scores for the Utah Criterion-Referenced Test	Significant differences between the intervention and comparison groups in differences in 1-mile run and math scores in Year 1 and Year 2. Children's yearly pretest and post-test BMI group changes differed only for the first year of intervention.	—

(continued)

Table 2. (Continued)

Study (year)	Game(s)	[1]C	Platform	[2]O	[3]S	Key goals	Theory	Age (years)	Number of participants	Total intervention duration	Measurements	Key findings	Effect size
Goran and Reynolds[13]	"Interactive Multimedia for Promoting Physical Activity" (IMPACT)	N	Computer	N	N	Develop and examine the efficacy of a computer-based interactive multimedia curriculum for promoting PA in fourth-grade children	SCT	9–11	63 treatment; 59 control; 49 males	45 minutes× 16 lessons	Questionnaire; Tanita TBF 300/A analyzer; Seca mobile height rod; MTI Computer Science and Applications model 7164 activity monitor	There was a significant treatment effect for obesity reduction among girls (BMI z-score and percentage of body fat).	—
Maddison et al.[29]	Sony PlayStation EyeToy games: "Play3," "Kinetic," "Sport," and "Dance Factory"	C	Console	N	N	Evaluate the effect of active videogames over a 6-month period on weight, body composition, PA, and physical fitness	—	10–14	162 treatment; 160 control; 87 males	60 minutes/day× 7/week×24 weeks	Questionnaire; self-reports; Salter scales; standard stadiometer; standard anthropometric tape; ImpediMed DF50 bioimpedance monitor; 20mSRT; Actigraph accelerometer	The treatment effect on BMI (–0.24) favored the intervention group. The change in BMI from baseline increased in the control group (0.34 ± 0.08 kg/m^2) but remained the same in the intervention group (0.09 ± 0.08 kg/m^2). There was also evidence of a reduction in body fat in the intervention group (–0.83%).	—
Madsen et al.[30]	DDR	C	Console	N	N	Explore the feasibility of DDR to promote weight loss among obese youth	—	9–18	30 treatment; 12 males	30 minutes/day×5 days/week×24 weeks	Standard BMI measurement devices; video memory; self-reports	Use of DDR was not associated with change in BMI from baseline at either 3 or 6 months.	—
Maloney et al.[33]	DDR MAX2	C	Console	N	N	Examine the feasibility of DDR in participants' homes to increase PA and to decrease sedentary screen time	—	7–8	40 treatment; 20 control; 30 males	30 minutes/day×4 days/week×28 weeks	Questionnaire; self-reports; ActiGraph accelerometer; Tanika TBF-310 scale; standard stadiometer; Omron HEM-637 wrist sphygmomanometer; open-faced pedometer	The DDR group showed increased vigorous PA and a reduction in light PA; the control group showed no increase in MVPA, although they also had a reduction in light PA. Differences between the groups were not observed.	—
Moore et al.[56]	"Color My Pyramid: Blast Off"	N	Computer	Y	N	Improve nutrition knowledge, self-care practices, PA, and nutrition status (blood pressure and height, weight, and BMI percentiles)	SDNT[e]	9–11	126 treatment; 46 males	6 times over 3 months	Questionnaire; standard BMI measurement devices	Scores for self-care practices, activity, and systolic blood pressure improved significantly but not BMI percentiles.	$d=0.163$
Murphy et al.[10]	DDR	C	Console	N	N	To determine whether DDR is effective in improving EDF and other risk factors in overweight children	—	7–12	23 treatment; 12 control; 18 males	10–30 minutes per session×5/ week×12 weeks	Standard BMI measurement devices; heart rate and ECG monitor; blood pressure cuff; ATL UM-9 HDL ultrasound transducer; SYN-CHRON LX autoanalyzer; ELISA radioimmunoassay assay kits; Life Diagnostics radioimmunoassay; ramped protocol on a cycle ergometer; MedGraphics metabolic cart	Compared with control group, DDR exercise had significant improvements in flow-mediated dilation, exercise time on the graded exercise test, mean arterial pressure, weight, and VO_{2max}. Thirteen exercise subjects achieved normal EDF, but 10 did not.	—

(*continued*)

Table 2. (Continued)

Study (year)	Game(s)	[1]C	Platform	[2]O	[3]S	Key goals	Theory	Age (years)	Number of participants	Total intervention duration	Measurements	Key findings	Effect size
Ni Mhurchu et al.[32]	EyeToy "Knockout" and other active videogames	C	Console	N	N	To evaluate the effect of active games on children's PA	—	10–14	10 treatment; 10 control; 12 males	Around 60 minutes/day for 12 weeks	Questionnaire; self-reports; Actigraph accelerometer; Harpenden stadiometer; Salter scale; standard anthropometric tape	The intervention group spent less mean time playing all videogames compared with the control group (54 versus 98 minutes/day). Average time spent in all PAs was higher in the active videogame intervention group compared with the control group. No significant anthropometric outcome change due to lack of statistical power.	—
Paw et al.[12]	IDSVG	—	Computer	N	N	To evaluate a weekly multiplayer class on the motivation to play an IDSVG at home over 12 weeks	—	9–12	13 treatment; 14 control; 2 males	Daily sessions over 12 weeks	Questionnaire; 20mSRT; standard BMI measurement devices; Harpenden calliper	The multiplayer group played approximately twice as many minutes (901 minutes) as the home group (376 minutes). Dropout was significantly lower in the multiplayer group (15%) than in the home group (64%).	—
Thompson et al.[57]	"Solve It" and "What Moves You?"	N	Computer	Y	N	Enable Boy Scouts to eat 5 or servings of FV and engage in 30+minutes of MVPA/day	SCT	10–14	473 treatment/control; all males	Weekly for 9 weeks×2 games	Questionnaire; MTI accelerometer	Treatment group saw behavioral change in FJ consumption, FJ home availability, and low-fat V, but the improvement was not maintained 6 months later.	$d=0.5$

1: C=Commercial or Non-commercial?
2: O=Online/Network Capacity or Not?
3: S=Story/Narrative Embedded or Not?
Letter Superscript: Abbreviation (Frequency of appearance)
[a]SCT=Social Cognitive Theory (3)
[b]SDT=Self Determination Theory (1)
[c]BIT=Behavioral Inoculation Theory (1)
[d]ELM=Elaboration Likelihood Model (1)
[e]SDNT=Self-care Deficit Nursing Theory (1)

20mSRT, 20-m shuttle run test; BMI, body mass index; DDR, "Dance Dance Revolution"; ECG, electrocardiograph; EDF, endothelial dysfunction; ELISA, enzyme-linked immunosorbent assay; FJ, fruit and juice; FV, fruits and vegetables; HOMA-IR, homeostasis model assessment for insulin resistance; IDSVG, interactive dance simulation videogame; MVPA, moderate to vigorous physical activity; PA, physical activity; SDS, standard deviation score; V, vegetables; VO_{2max}, maximum O_2 uptake volume; W, water; WC, waist circumference.

Both genders were involved in these studies, with an average age of 11.6 years. In terms of research design, two were pre–post design, and the other two were treatment–control. All targeted PAs. One used active games as a small portion of the intervention,[26] but the rest used active games as the main intervention materials.[10,28,29] Two asked the participants to play the games at home, whereas the other two used sports or recreational facilities. All were under 30 weeks in duration. All have used commercial games instead of developing new games for the intervention. Except for one[10] that used a DDR game only, the rest three used multiple games during the intervention: One used four,[29] one used six,[26] and the third used eight games.[28] Part of the reason might be due to the lack of stories in active videogames in general. Stories could serve as a powerful motivating strategy to continuously engage players.[37] When there was no active videogame with involving plots, offering players multiple games could be an alternative way around. Future obesity game developers could incorporate these findings into the design process.[38]

Although the earliest publications on games for health dated back to 1984,[39] those targeting childhood obesity did not start until 2005. Increasing numbers of research articles were published, especially in the United States. This is likely in accordance with the childhood obesity epidemic in the country over the recent decades.[40]

Whereas some may still consider videogames as being primarily created for home entertainment,[41] health videogames for childhood obesity prevention have been used beyond the home setting.[42] Schools and recreational facilities are becoming popular venues to adopt this medium.[43] Computers and game consoles may find their way into the home and school settings compared with stand-alone gaming stations, which may be additions to sports and recreational facilities. None of the studies occurred in laboratories, suggesting that the childhood obesity-related behaviors, nutrition and PA, would be best studied in natural settings with accessible devices.[44] Not many games had networking capacity. In fact, none of the active games had networking capacity. This may have something to do with the goal of these games, the mobile portability requirement of the equipment, and the available measurement devices that could work without network support. A few sedentary educational games and no exergame included stories, which may provide an important motivational aspect with appealing characters and engaging plots.[37]

Most of the studies had a small sample size, which may prevent the detection of significant statistical results. Similarly, the intervention episode/duration was also relatively short. Both the small sample size and short intervention duration could relate to the difficulty of measuring obesity-related outcomes among many participants repeatedly over an extended period. Instead of surveys, many studies involved medical devices and biotesting analyses that posed higher demand for participants' involvement and the cost from the research side. Indeed, among many health videogame publications on dietary intake and PA, only 14 articles included outcome(s) directly related to obesity, and fewer explicitly intended to change these outcome(s).

All participants were above 7–8 years of age. Children this age may have developed sufficient cognitive and motor skills to understand and to play the health videogames by themselves.[45] This may also have something to do with the fact that children of younger ages cannot provide reasonable responses to survey questionnaires.[46] The majority of the participants were male, which may echo the composition of the gamer demographics and the media use among children.[41,47,48] The majority of the participants were of African and Hispanic descent, in contrast with the majority white population. These two populations are more likely to be influenced by childhood obesity compared with whites[49] and are also the groups that play the most games.[47]

Most of the games (75 percent) included in this review were commercially available. These games could continue to be played when the research project was completed. Given game development costs,[50] the adoption of commercially available off-the-shelf games could be a sound economical practice for researchers who are equipped with fewer resources than commercial game developing companies.[51] It is interesting that none of the studies that used commercial games mentioned any psychological or behavioral theory, whereas all of the studies developed by researchers mentioned the use of psychological and behavioral theories. (It is worth noting that there are many studies that used commercial games and mentioned psychological or behavioral theory, but these articles have not been included in this review.) In addition, most of the commercial games were exergames or exergaming stations, whereas all researcher-developed games targeted nutritional behaviors. This could indicate the gaming industry's preference for PA behaviors, which may more easily be integrated with the entertainment and fun factors than nutritional behaviors. Theories help provide the basis for understanding behaviors, for designing interventions, and for new insights into health promotion.[52] If some innovative psychological and behavioral theoretical frames could be developed from commercial games, these theories could help to inform other health videogames' development. Indeed, diverse theories may need to be integrated to provide the strongest foundation for behavior change from health videogames.[53] A closer collaboration between the research and industry may lead to more effective interventions with broader interest and success.[51]

Because of the heterogeneity of the measures and designs, a meta-analysis was not feasible. Only English language articles were included, and the selected articles may also be subject to publication bias for positive findings.[54]

In summary, health videogame research for childhood obesity prevention and intervention is still in its infancy. The increasing publication trend suggests the field's emerging status. Although sample size, research design, and theoretical integration all need improvement, it is helpful to see that health videogame research has found its way into a wider venue, population, and theoretical spectrum.

Closer collaboration between academic researchers and professional game development companies could result in more reusable games that can be applied to a wider audience for a longer duration to achieve more meaningful impact. Therefore, research projects could benefit from more support from the industry, and game production could be enhanced from a more rigorous design.

Acknowledgments

This project was partially funded by the National Cancer Institute (grant 1R21CA158917-01A1; "The Narrative Impact

of Active Video Games on Physical Activity," PI: Amy Shirong Lu, PhD). The authors would like to thank Whitney Coleman of the School of Informatics at Indiana University for her help in retrieving and coding articles.

Author Disclosure Statement

No financial interests were reported from the authors.

References

1. Ogden CL, Carroll MD, Flegal KM. High body mass index for age among US children and adolescents, 2003–2006. JAMA 2008; 299:2401–2405.
2. National Cancer Institute. Obesity and cancer: Questions and answers. 2004. www.cancer.gov/cancertopics/factsheet/Risk/obesity (accessed January 29, 2010).
3. Danaei G, Ding EL, Mozaffarian D, et al. The preventable causes of death in the United States: Comparative risk assessment of dietary, lifestyle, and metabolic risk factors. PLoS Med 2009; 6:e1000058.
4. Freedman DS, Khan LK, Dietz WH, et al. Relationship of childhood obesity to coronary heart disease risk factors in adulthood: The Bogalusa Heart Study. Pediatrics 2001; 108: 712–718.
5. Estabrooks PA, Fisher EB, Hayman LL. What is needed to reverse the trends in childhood obesity? A call to action. Ann Behav Med 2008; 36:209–216.
6. Ludwig DS, Peterson KE, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: A prospective, observational analysis. Lancet 2001; 357:505–508.
7. Trost SG, Kerr LM, Ward DS, Pate RR. Physical activity and determinants of physical activity in obese and non-obese children. Int J Obes Relat Metab Disord 2001; 25:822–829.
8. Rolls BJ, Ello-Martin JA, Tohill BC. What can intervention studies tell us about the relationship between fruit and vegetable consumption and weight management? Nutr Rev 2004; 62:1–17.
9. Kleiner SM. Water: An essential but overlooked nutrient. J Am Diet Assoc 1999; 99:200–206.
10. Murphy EC, Carson L, Neal W, et al. Effects of an exercise intervention using Dance Dance Revolution on endothelial function and other risk factors in overweight children. Int J Pediatr Obes 2009; 4:205–214.
11. Harvard School of Public Health. Measuring obesity. 2013. www.hsph.harvard.edu/obesity-prevention-source/obesity-definition/how-to-measure-body-fatness/ (accessed March 8, 2013).
12. Paw CA, Marijke J, Jacobs WM, et al. The motivation of children to play an active video game. J Sci Med Sport 2008; 11:163–166.
13. Goran MI, Reynolds K. Interactive Multimedia for Promoting Physical Activity (IMPACT) in children. Obes Res 2012; 13:762–771.
14. Summerbell CD, Waters E, Edmunds LD, et al. Interventions for preventing obesity in children. Cochrane Database Syst Rev 2005; (3):CD001871.
15. Baranowski T, Buday R, Thompson D, Baranowski J. Playing for real: Video games and stories for health-related behavior change. Am J Prev Med 2008; 34:74–82.
16. Baranowski T, Baranowski J, Cullen KW, et al. Squire's Quest!: Dietary outcome evaluation of a multimedia game. Am J Prev Med 2003; 24:52–61.
17. Biddiss E, Irwin J. Active video games to promote physical activity in children and youth: A systematic review. Arch Pediatr Adolesc Med 2010; 164:664–672.
18. Anderson PM, Butcher KF. Childhood obesity: Trends and potential causes. Future Child 2006; 16:19–45.
19. Guy S, Ratzki-Leewing A, Gwadry-Sridhar F. Moving beyond the stigma: Systematic review of video games and their potential to combat obesity. Int J Hypertens 2011; 2011:179124.
20. Daley AJ. Can exergaming contribute to improving physical activity levels and health outcomes in children? Pediatrics 2009; 124:763–771.
21. Kharrazi H, Lu AS, Gharghabi F, Coleman W. A scoping review of health game research: Past, present, and future. Games Health J 2012; 1:153–164.
22. Health Game Research. Health game research database. 2012. www.healthgamesresearch.org/db (accessed October 1, 2012).
23. Rosser JC Jr, Lynch PJ, Cuddihy L, Gentile DA, Klonsky J, Merrell R. The impact of video games on training surgeons in the 21st century. Arch Surg 2007; 142:181–186; discusssion 186.
24. Schulz KF, Altman DG, Moher D. CONSORT 2010 statement: Updated guidelines for reporting parallel group randomised trials. BMJ 2010; 340:c332.
25. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: Guidelines for reporting observational studies. Ann Intern Med 2007; 147:573–577.
26. Calcaterra V, Larizza D, Codrons E, et al. Improved metabolic and cardiorespiratory fitness during a recreational training program in obese children. J Pediatr Endocrinol Metab 2012 December 15 [Epub ahead of print]. doi: 10 .1515/jpem-2012-0157.
27. Baranowski T, Baranowski J, Thompson D, et al. Video game play, child diet, and physical activity behavior change: A randomized clinical trial. Am J Prev Med 2011; 40:33–38.
28. Christison A, Khan HA. Exergaming for Health: A community-based pediatric weight management program using active video gaming. Clin Pediatr 2012; 51:382–388.
29. Maddison R, Foley L, Mhurchu CN, et al. Effects of active video games on body composition: A randomized controlled trial. Am J Clin Nutr 2011; 94:156–163.
30. Madsen KA, Yen S, Wlasiuk L, et al. Feasibility of a dance videogame to promote weight loss among overweight children and adolescents. Arch Pediatr Adolesc Med 2007; 161:105–107.
31. Gao Z, Hannan P, Xiang P, et al. Video game–based exercise, Latino children's physical health, and academic achievement. Am J Prev Med 2013; 44:S240–S246.
32. Ni Mhurchu C, Maddison R, Jiang Y, et al. Couch potatoes to jumping beans: A pilot study of the effect of active video games on physical activity in children. Int J Behav Nutr Phys Act 2008; 5:8.
33. Maloney AE, Bethea TC, Kelsey KS, et al. A pilot of a video game (DDR) to promote physical activity and decrease sedentary screen time. Obesity (Silver Spring) 2008; 16:2074–2080.
34. McMurray RG, Bauman MJ, Harrell JS, et al. Effects of improvement in aerobic power on resting insulin and glucose concentrations in children. Eur J Appl Physiol 2000; 81:132–139.
35. Gutin B, Islam S, Treiber F, et al. Fasting insulin concentration is related to cardiovascular reactivity to exercise in children. Pediatrics 1995; 96:1123–1125.
36. Foster GD, Linder B, Baranowski T, et al. A school-based intervention for diabetes risk reduction. N Engl J Med 2010; 363:443–453.

37. Lu AS, Baranowski T, Thompson D, Buday R. Story immersion of videogames for youth health promotion: A review of literature. Games Health J 2012; 1:199–204.
38. Lu AS, Thompson D, Baranowski J, et al. Story immersion in a health videogame for childhood obesity prevention. Games Health J 2012; 1:37–44.
39. Seyrek S, Corah N, Pace L. Comparison of three distraction techniques in reducing stress in dental patients. J Am Dent Assoc 1984; 108:327–329.
40. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity in the United States, 2009–2010. NCHS Data Brief 2012; (82):1–8.
41. Phillips CA, Rolls S, Rouse A, Griffiths MD. Home video game playing in schoolchildren: A study of incidence and patterns of play. J Adolescence 1995; 18:687–691.
42. Raessens J, Goldstein J. *Handbook of Computer Game Studies*. The MIT Press, Cambridge, MA; 2011.
43. Turnin MC, Tauber MT, Couvaras O, et al. Evaluation of microcomputer nutritional teaching games in 1,876 children at school. Diabetes Metab 2001; 27:459–464.
44. Meiselman HL. Methodology and theory in human eating research. Appetite 1992; 19:49–55.
45. Fischer KW. A theory of cognitive development: The control and construction of hierarchies of skills. Psychol Rev 1980; 87:477–531.
46. Borgers N, de Leeuw E, Hox J. Children as respondents in survey research: Cognitive development and response quality 1. Bull Method Sociol 2000; 66:60–75.
47. Kaiser Family Foundation. Generation M2: Media in the lives of 8- to 18-year-olds. 2010. www.kff.org/entmedia/upload/8010.pdf (accessed May 18, 2010).
48. Wright JC, Huston AC, Vandewater EA, et al. American children's use of electronic media in 1997: A national survey. J Appl Dev Psychol 2001; 22:31–47.
49. U.S. Department of Health & Human Services Office of Minority Health. Obesity data/statistics. 2012. http://minorityhealth.hhs.gov/templates/browse.aspx?lvl=3&lvlid=537 (accessed March 9, 2013).
50. Rogers E. The rise of costs, the fall of gaming. 2012. www.notenoughshaders.com/2012/07/02/the-rise-of-costs-the-fall-of-gaming/ (accessed November 30, 2012).
51. Buday R, Baranowski T, Thompson D. Fun and games and boredom. Games Health J 2012; 1:257–261.
52. Baranowski T, Cullen KW, Nicklas T, et al. Are current health behavioral change models helpful in guiding prevention of weight gain efforts? Obes Res 2012; 11(Suppl 10):23S–43S.
53. Baranowski T, Baranowski J, Thompson D, Buday R. Behavioral science in video games for children's diet and physical activity change: Key research needs. J Diabetes Sci Technol 2011; 5:229–233.
54. Easterbrook PJ, Gopalan R, Berlin J, Matthews DR. Publication bias in clinical research. Lancet 1991; 337: 867–872.
55. Bethea TC, Berry D, Maloney AE, Sikich L. Pilot study of an active screen time game correlates with improved physical fitness in minority elementary school youth. Games Health J 2012; 1:29–36.
56. Moore JB, Pawloski LR, Goldberg P, et al. Childhood obesity study: A pilot study of the effect of the nutrition education program Color My Pyramid. J Sch Nurs 2009; 25:230–239.
57. Thompson D, Baranowski T, Baranowski J, et al. Boy Scout 5-a-Day Badge: Outcome results of a troop and Internet intervention. Prev Med 2009; 49:518–526.

Address correspondence to:
Amy Shirong Lu, PhD
Department of Communication Studies
School of Communication
Northwestern University
2240 Campus Drive
Evanston, IL 60208

E-mail: amylu@northwestern.edu