GAMES FOR HEALTH JOURNAL: Research, Development, and Clinical Applications
Volume 8, Number 2, 2019

DOI: 10.1089/g4h.2018.0011

Reviews

Role of Digital Games in Self-Management of Cardiovascular Diseases: A Scoping Review

Kavita Radhakrishnan, PhD, RN, MSEE,[1] Thomas Baranowski, PhD,[2]
Christine Julien, PhD,[3] Edison Thomaz, PhD,[4] and Miyong Kim, PhD, RN, FAAN[5]

Abstract

Objective: Examine research on the use of digital games to improve self-management (SM) behaviors in patients diagnosed with cardiovascular diagnoses of hypertension, coronary artery disease, heart failure, or myocardial infarction.
Materials and Methods: For this scoping review, the CINAHL, PubMed, and Web of Science databases were searched for studies published from January 1, 2008 to December 20, 2017 using terms relevant to digital games and cardiovascular diseases (CVDs).
Results: Eight articles met the inclusion/exclusion criteria, seven of which presented studies with participants 50 years or older. Five of the eight studies assessed physical activity. Only two studies included a control group. Digital games significantly improved exercise capacity and energy expenditure but did not affect quality of life, self-efficacy, anxiety, or depression. Digital games were found enjoyable by 79%–93% of participants, including those with lower education or age; however, barriers to game use included being tired or bored, lack of interest in digital games, poor perception of fitness through games, sensor limitations, conflicts with daily life routine, and preferences for group exercise. Average adherence ranged from 70% to 100% over 2 weeks to 6 months of study duration, with higher adherence rates in studies that included human contact through supervision or social support.
Conclusion: Paucity of studies about digital games for CVD SM behaviors precludes the need to undertake a full systematic review. Future studies examining digital games should include larger sample sizes, longer durations, game-design guided by behavioral change theoretical frameworks, and CVD SM behaviors in addition to physical activity behaviors.

Keywords: Cardiovascular, Self-management, Digital games

Introduction

Despite advances in the prevention of cardiovascular disease (CVD) and delivery of cardiovascular healthcare, CVD remains the number one cause of death globally and in the United States.[1] The American Heart Association estimates that 92.1 million US adults have at least one type of CVD and that 44% of US adults will be diagnosed with some form of CVD by 2030.[2] To reduce hospitalizations, clinical complications, and mortality associated with CVD, clinical guidelines advocate effective CVD self-management (SM).[3,4] Moreover, as hospital stays and ambulatory visits have become shorter and less frequent, the onus for CVD SM has increasingly fallen upon patients and their families.[5]

In addition to self-awareness obtained through symptom monitoring, CVD SM requires lifestyle behavioral changes that include regular physical activity, eating a healthy diet specifically reducing dietary sodium intake, stopping smoking, reducing harmful alcohol intake, and taking prescribed medications.[6] SM interventions targeting lifestyle behavioral

[1]School of Nursing, The University of Texas–Austin, Austin, Texas.
[2]Department of Pediatrics-Nutrition, Baylor College of Medicine, Houston, Texas.
[3]Mobile and Pervasive Computing Laboratory, Department of Electrical and Computer Engineering, The University of Texas–Austin, Austin, Texas.
[4]Department of Electrical and Computer Engineering, School of Information, The University of Texas–Austin, Austin, Texas.
[5]School of Nursing, The University of Texas–Austin, Austin, Texas.

changes for CVDs have improved health outcomes, readmission rates, or mortality outcomes.[6–11] For example, in meta-analyses, including 23 trials and involving 11,085 randomized patients with coronary heart disease,[10] and individual patient data from 20 studies involving 5624 patients with heart failure,[11] SM interventions reduced cardiac mortality and hospitalizations and risk of time to all-cause death.

Attaining proficiency in CVD SM is difficult, however, because it requires patients to become adept in a wide range of skills within the context of their daily routines and comorbidities.[12] Moreover, such patients are often fatigued and unable to travel great distances to meet cardiac specialists, attend group education, or participate in exercise sessions at healthcare facilities. To exacerbate this problem, a healthcare provider shortage is anticipated, with severe shortages in specialties such as CVD.[13,14] Together, these factors suggest an urgent need to find effective, portable, and scalable tools that can be delivered in the home to improve patients' SM of CVD.

Digital games, popularized by the widespread availability of personal digital devices such as smartphones and tablets, have emerged as an alternative to traditional patient education and offer a new and exciting avenue to learn about and engage in CVD SM behaviors. Digital games can provide flexible, accessible, and appealing educational environments, within which patients can learn about disease SM of their disease by seeking information, practicing skills, and receiving social support.[15–17] Because prior literature has examined only the genre of exergames for cardiac rehabilitation,[18,19] in this scoping review we investigate recent evidence on diverse digital game genres for a range of CVD-related SM behaviors in patient populations diagnosed with the CVD conditions of coronary artery disease, heart failure, hypertension, and myocardial infarction. These CVD diagnoses were selected because improvement in SM of these diagnosed can potentially prevent unexpected health exacerbations that can result in hospitalizations, readmissions, or other complications.[7–11]

Methods

Because the field of games for CVD SM is still emergent, we selected a scoping review framework to explore the current knowledge base on this topic and to identify gaps and inconsistencies so that we might make recommendations for future research.[20] Arksey and O'Malley's five-stage scoping review framework[20] enabled us to (1) identify our research question; (2) identify relevant studies; (3) select studies; (4) chart the data; and (5) collate, summarize, and report the results.

Search strategy

The CINAHL, PubMed, and Web of Science databases were searched for studies published between January 1, 2008 and December 20, 2017, using the terms (serious game or video game or gaming or digital game or computer game) and (cvd or cardiovascular or ''heart failure'' or cardiac or hypertension or myocardial infarction or coronary artery disease). Articles were exported and managed with the EndNote referencing software program (vX8.1, Clarivate).

Study selection

For this review, based on a classic game definition that included key elements of game playing,[21] a *digital game* was defined as a contest with goals, played according to a framework or rules, that determines players' actions inside a virtual game world. In our initial search, we included articles published in English that presented (1) one or more participants diagnosed with a CVD condition, (2) a videogame, digital game, or exergame with or without sensors as an intervention; (3) CVD-related physiological, psychological, or behavioral outcomes; and (4) participants' adherence with use of the gaming technology for CVD SM. This search yielded 1083 articles, of which 175 were discarded as duplicates. Studies that did not report original results (e.g., commentaries, reviews, study protocols, and letters to the editor) or were reported as poster abstracts or dissertations were also excluded. The remaining abstracts and full texts were then retrieved to confirm that they met our inclusion/exclusion criteria. The reference lists of the retrieved full texts were also perused to identify any additional relevant articles. Two articles that reported use of gaming platforms (Wii™, Xbox®) as a telehealth application but not as a game were excluded.[22,23] Finally, eight articles met our inclusion/exclusion criteria for this scoping review. This included one qualitative study in which participants diagnosed with heart failure were interviewed after participating in a randomized-controlled trial (RCT) of a gaming intervention that is currently in progress.[24] Figure 1 illustrates the search's details.

Data abstraction and analysis

From the final eight articles, the following data were charted: (1) study design; (2) participants' demographic characteristics, including diagnosis; (3) game intervention and timing of use; (4) duration of study period; and (5) measures and outcomes. These data were categorized and organized in Microsoft Excel with use of narrative summaries to report the outcomes from the studies.

Results

A detailed overview of the characteristics of and key outcomes from the eight articles is provided in Tables 1 and 2, respectively. Although the search was restricted to articles published in the last 10 years, all eight were published within the last three. Five (63%) were conducted in continental Europe,[24–28] two in United States,[29,30] and one in Jamaica.[31]

Study design

Because the application of gaming for CVD management is relatively new, 75% of the studies included in this review were feasibility or pilot studies. Only two of the eight (25%) studies reported a control group.[25,29] Three studies (38%) used a pretest–posttest design,[26,30,31] and three others (38%) evaluated the feasibility of the intervention by collecting adherence outcomes[27,28] or perspectives on the use of the gaming intervention.[24] Six studies did not report any theoretical framework guiding the design of either the study or the game intervention. The remaining two studies used a gamification framework (leaderboards, surprise element, rewards, feedback, badges, and levels[28]), framework to inform game feedback, or Gagne's learning principles to inform content delivery within the game.[30]

Sample sizes were low, ranging from 10 to 116, with only one study reporting a sample size greater than 50.[29] Study

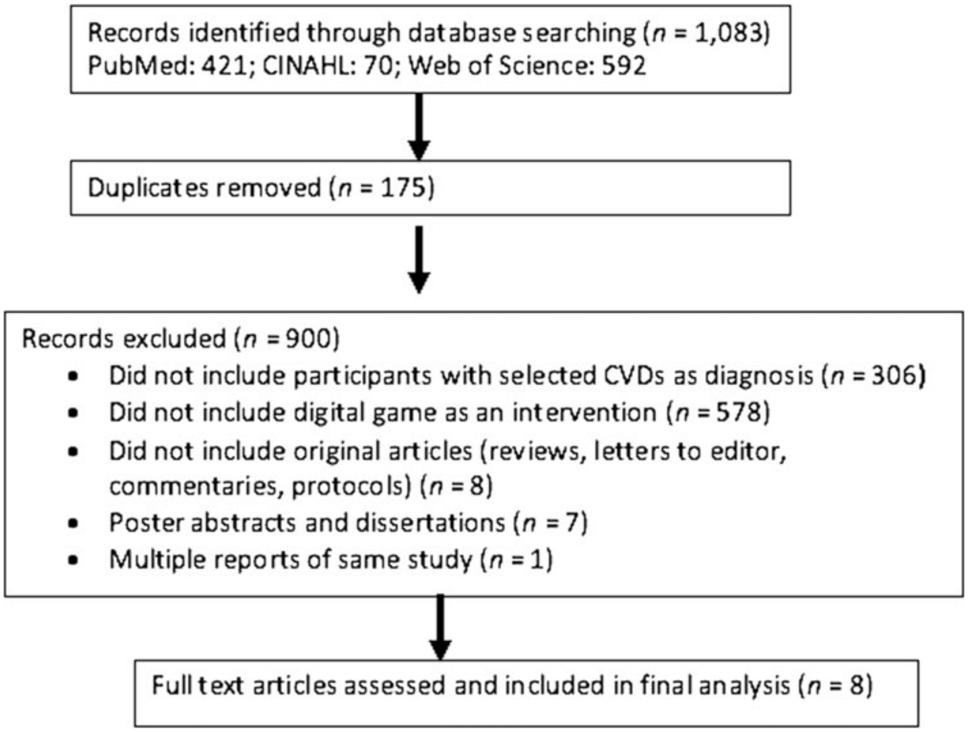

FIG. 1. Literature search strategy.

periods ranged from 2 weeks to 6 months, and in 50% of the studies, the study duration was 6 weeks or fewer.

Participant characteristics

Participants in seven out of the eight studies were 50 years or older, with five studies reporting majority of participants to be in their 60s. Male gender constituted the majority in six studies (75%) with three studies reporting >75% participation by males.[25,27,30] Race was reported in only three studies with two of those studies reporting >80% participation by Whites.[25,30] Finally, the cardiac diseases selected for this review ranged evenly across the studies, with coronary artery disease, hypertension, and myocardial infarction each represented in three studies.

Game intervention

Four of the eight studies (50%) used the Nintendo® exergaming platforms of Wii Sports[24–26] or Fit Plus,[31] for participants who played the exergames, and three delivered the games on tablet-based computers[28–30] in which participants were coached on disease management activities. Only one study utilized a sensor (Kinect) and a home computer[27] to capture participation and provide feedback to the game about participants' exercise performance.[27] Two studies used avatar-based games to coach communication with healthcare providers[29] or provide training on exercise routines.[27] One study converted an off-the-shelf casino slot game to deliver information on heart failure SM.[30]

In four of the eight studies, participants were expected to use the game daily;[24,26,28,30] in three studies, two to three times a week[25,27,31] and in the remaining one study only once a month.[29] Human supervision during game sessions was available in only one study.[31] Intermittent telephone contacts by research staff was implemented in two studies[24,27]; the remaining studies did not have any scheduled human contact during the study period, but participants could contact the research staff members if needed. Tailoring of exercise occurred in only two studies; in the study using the Nintendo Wii Fit™ Plus, Borg's Perceived Exertion scale was used to tailor the intensity of exercises for patients by the human supervisor.[31] However, in Vieira et al.'s study, the tailoring was more automated, using the Kinect sensor to provide feedback on exercise movements.[27]

Outcomes and measures

Physiological fitness outcomes reported in three studies (38%) consisted of exercise capacity measured by tests such as a six-minute walk test[26,31] or the Graded Exercise test.[25] Duration of physical activity and energy expenditure were measured using an activity monitor[26] or accelerometer.[25] Klompstra et al.[26] measured self-reported exercise activity with Borg's Rating of Perceived Exertion, a questionnaire for Exercise Self-Efficacy, and the Exercise Motivation Index. The game intervention had uniformly positive results across all three of these studies, with significant improvement in exercise capacity compared with baseline in two of them[26,31] and significant difference in physical activity and energy expenditure compared with the control group in the other one.[25] New diagnosis or higher cardiac functional status was associated with improvement in exercise capacity in Klompstra et al.[26]

The psychological outcomes of self-efficacy, motivation, anxiety, depression, or health-related quality of life were measured in three studies.[25,26,30] The gaming interventions

Table 1. Characteristics of Studies

Study (year), Country	*Study design/theory*	*Sample characteristics*	*Game intervention/timing of use/ location of use*	*Intermittent human contact or supervision*	*Duration of intervention*	*Sample size (dropout rate)*
Klompstra et al.[26] (2014), Sweden	One-group pretest–posttest/none	Diagnosis: Heart failure Gender: 69% male Age (mean): 63 years Race: Not reported	Nintendo Wii Sports (tennis, bowling, baseball, golf, and boxing)/20 min per day/patients' homes	None; however, participants could telephone instructor for questions or guidance	12 Weeks	32 (6%)
Hickman et al.[29] (2015), USA	Nonblinded RCT + pretest–posttest/none	Diagnosis: HTN Gender: 39% male Age (mean): 48 years Race: 24% White	Serious game on a computer that permits users to interact with avatar-based HCPs in a virtual health clinic/20 min during 4 monthly doses/Research study site	None; however, research staff were available to troubleshoot	4 Months	144 (19.4%)
Nelson et al.[31] (2015), Jamaica	One-group pretest–posttest/none	Diagnosis: CAD, MI, HTN Gender: 46% male Age (mean): 62.1 years Race: Not reported	Nintendo Wii Fit Plus (rhythm boxing, free step, obstacle course, free run, island run, super hula hoop, rhythm parade, basic step, and advanced step/40 min of exercise, three times a week/physical therapy clinic	Exercise sessions were supervised by a trained exercise therapist	6 Weeks	30 (7%)
Dithmer et al.[28] (2016), Denmark	Qualitative/gamification principles of feedback, rewards, leaderboards, badges, levels, and game design principles of ''positive emotion,'' ''relationships,'' ''meaning,'' and ''accomplishment''	Diagnosis: CAD, HTN, MI Gender: 60% male Age: 50–69 years (70%) Race: Not reported	Android Tablet-based virtual game for a 2-person team presented with daily challenges/Daily till challenge is completed/Participants' homes	None	2 Weeks	10 (20%)
Radhakrishnan et al.[30] (2016), USA	One-group pretest–posttest/ Gagne's learning principles	Diagnosis: Heart failure Gender: 89% Male Age: 54–94 years White: 84%	A tablet-based casino slot game with content from ''Living with Heart Failure'' booklet/30–45 min of total gameplay/Participants' homes	None	4 Weeks	20 (5%)
Ruivo et al.[25] (2017), Finland	Single-blinded RCT pretest–post-test/none	Diagnosis: low–moderate risk cardiac rehab patients Gender: 81% Male Age: 60 ± 10 years White: 100%	Active videogame Nintendo Wii Sports boxing and canoeing/1-h session twice a week/exercise class	None	6 Weeks	32 (13%)
Vieira et al.[27] (2017), Portugal	Feasibility, one-group study/None	Diagnosis: CAD Gender: 100% Male Age: 55 years (mean) Race: Not reported	Game called Rehabplay uses avatar of patient and virtual physical therapist who performs and provides instructions and feedback informed by the Kinect sensor on exercise/3 sessions per week/participants' homes	Telephone contacts at weeks 4, 10, and 22. In-person at-home meetings at weeks 6 and 18. E-mails and/or text message reminders every week.	6 Months	11 (0%)
Klompstra et al.[24] (2017), Sweden	Qualitative (Parent study: current RCT)/none	Diagnosis: Heart failure Gender: 57% Male Age: 56–81 years Race: Not reported	Nintendo Wii Sports (tennis, bowling, baseball, golf, and boxing)/30 min per day/participants' homes	4 telephone calls by research staff during RCT	12 Weeks	14 (NA) (Parent study: ongoing)

CAD, coronary artery disease; HCP, healthcare provider; HTN, hypertension; MI, myocardial infarction; RCT, randomized controlled trial.

Table 2. Measurement, Targeted Behaviors, and Key Findings of Study

Study (year)	Measures	Data collection/ control group	Measured outcomes	Key outcomes	Adherence outcome
Klompstra et al.[26] (2014)	(i) 6MWT (ii) Activity monitor (iii) Daily diary (iv) Borg's rating of perceived exertion (v) Exercise self-efficacy survey (vi) Exercise motivation index (vii) HADS	Baseline and 12 weeks/none	(i) Exercise Capacity (ii) Daily physical activity (iii) Perceived physical effort (iv) Time playing Wii (v) HF symptoms (vi) Self-Efficacy (vii) Motivation (viii) Anxiety and depression	(i) Fifty-three percent significantly increased their exercise capacity after 12 weeks. (ii) No significant difference was found in daily physical activity, motivation, self-efficacy, anxiety, and depression between baseline and 12 weeks. (iii) Daily mean time spent exergaming was 28 min (iv) HF symptoms and perceived physical effort were not related to the time spent exergaming	(i) Over the 12-week study period, patients gradually decreased the number of minutes exergaming, although they still remained above the advised 20 min per day (ii) Having grandchildren and being male were related to more time spent exergaming
Hickman et al.[29] (2015)	(i) Three serial blood pressure measurements using automatic sphygmomanometer	Baseline and 4 monthly follow-up/screen-based hypertension education	(i) Reduction in systolic blood pressure and diastolic blood pressure	(i) No significant between-group difference in blood pressure reduction over time (ii) Significant within-group reductions in systolic and diastolic blood pressures across time in intervention group	(i) Twenty-one percent dropout in intervention group vs. 17% dropout in control group
Nelson et al.[31] (2015)	(i) 6MWT (ii) Visual analog scale	Baseline and 6 weeks/none	(i) Exercise capacity (ii) Enjoyment	(i) Significant increase in 6MWT ($P=0.001$) (ii) Average enjoyment score was 9.1	(i) Twenty-eight participants adhered with the 40-min training session over 6 weeks. The exercise sessions were supervised by a trained exercise therapist.
Dithmer et al.[28] (2016)	(i) Log files of patients' use of game (ii) Qualitative interviews with 10 patients and 6 teammates	Baseline and 2 weeks/none	Assess the potential of gamification as a tool in a digital game prototype for heart patients and their relatives participating in a tele-rehabilitation program	(1) ''The Heart Game'' acted as a daily reminder to all the patients of certain exercises they had to do and lifestyle changes they needed to make. (2) Gamification (i) Leaderboards perceived as more important than points. (ii) Surprise element in daily challenges was found motivating by all 10 teams.	Eight out of 10 teams completed the daily challenges over 2 weeks. Two teams dropped out after 10 days due to vacation plans. Nine out of the 10 patients expressed that including spouses helped them to complete tasks.
Radhakrishnan et al.[30] (2016)	(1) Atlanta Heart Failure Knowledge Test (2) Self-care of Heart Failure Index (i) Self-maintenance behaviors (ii) Self-efficacy (3) Postgame survey on usability and game perceptions	Baseline and 4 weeks/none	(1) HF Knowledge (2) HF self-management, and self-efficacy (3) HF participants' perceptions of the game	(1) Significant improvement in HF self-management knowledge ($P=0.007$) (2) Nonsignificant improvement in HF self-maintenance behaviors ($P=0.11$), and no difference in HF self-efficacy scores (3) 89% found the game interesting, 79% enjoyable, and 100% easy to play. Game was found useful in providing tips, reminders, and information for those with lower education or with a recent HF diagnosis. Participants' lack of preference for games or digital media were barriers. Participants with lower education level ($P=0.01$) and age ($P=0.01$) preferred games to any other medium for receiving information.	One out of 20 participants completed the baseline surveys but dropped out before playing the game due to hospitalization.

(*continued*)

Table 2. (Continued)

Study (year)	*Measures*	*Data collection/ control group*	*Measured outcomes*	*Key outcomes*	*Adherence outcome*
Ruivo et al.[25] (2017)	(i) Attendance rate (ii) Adverse medical events (not defined) (iii) Graded Exercise Test, duration, and energy expenditure using a Bruce ramp protocol (iv) RT3™ accelerometer (v) HADS (vi) Positive and Negative Affect Scale (viii) MacNew Heart Disease-related Health Quality of Life Questionnaire	Baseline, 6 weeks, and 8 weeks/1-h session twice a week of aerobic, resistance, and flexibility training using 9 circuit stations	(i) Adherence (ii) Safety (iii) Exercise capacity (iv) Daily physical activity (v) Energy expenditure (vi) Anxiety (vii) Depression (viii) Negative effect (ix) HF-r/t quality of life, global, physical, and emotional	(i) No significant difference between groups in the proportion of patients experiencing adverse medical events during the intervention (ii) Significant improvement in physical activity and associated energy expenditure in AVG group, compared with controls (iii) No difference between groups in improving the psychosocial parameters of anxiety, depression, negative effect, and quality of life. (iv) 93.3% did not perceive to be at increased risk of injury, and AVG was not difficult to use (86.7%). AVGs were enjoyed by 93%, preferring them to no audiovisual supplementation at all in 86.7% of the cases.	(i) 6% dropout in intervention group vs. 19% dropout in control group ($P<0.05$). AVG supplementation had a weighted mean effect size of –0.68 (95% CI, –0.16 to –1.21). (ii) Despite the dropout trend, the median individual attendance rate showed no difference between groups, averaging 96%. (iii) AVGs were considered an extra stimulus to come to class by 46.7%, and 60% would consider using them at home in the future.
Vieira et al.[27] (2017)	(i) Attendance at each session (ii) Yes/No survey on Kinect opinions	6 Months after intervention initiation/none	(i) Rate of adherence (ii) Opinion on the use of Kinect	(i) 91% ($n=10$) enjoyed the artwork, while 100% ($n=11$) agreed on the importance and usefulness of the automatic counting of the number of repetitions; moreover, 64% ($n=7$) reported motivation to continue performing the program after the end of the study, and 100% ($n=11$) recognized Kinect as an instrument with potential to be an asset in cardiovascular rehabilitation. Criticisms included limitations in motion capture and gesture recognition, 91% ($n=10$), and the lack of home space, 27% ($n=3$).	Rate of adherence ranged between 56% and 100%, with an average percentage of 77%. The adherence in the first 3 months was around 82%, but in the final 3 months decreased to 70%.
Klompstra et al.[24] (2017)	Content analysis of interviews with purposive sample	After 6 months of intervention (Parent RCT study: Data collection at baselines and 3 months/Control: Motivational support through scripted phone calls only)	Patients' perceptions of the experience of exergaming	Themes emerged for: (1) making exergaming work–by setting goals, such as trying to gain a higher score every time they played, fitting exergaming with their daily life routine, realistic virtual environment, familiarity with the game in real life (2) added value of exergaming–exergaming helped increase physical fitness, was enjoyed especially when they were recovering from deterioration and was convenient to use in-home (3) Low appeal of exergaming–feeling too tired or bored, perception of too little fitness through exergame, preference for groups vs. exercising alone and daily life activities as distractions	Not applicable (Parent RCT study: ongoing)

6MWT, six-minute walk test; AVG, active video game; HADS, Hospital Anxiety and Depression Scale; HF, heart failure.

had no effect on psychological outcomes with none of these three reporting any difference from baseline or in comparison with a control group. Similarly, in the two studies in which clinical outcomes of adverse medical events[25] or blood pressure were measured,[29] the game intervention groups did not differ from the control groups, despite improvement in blood pressure from baseline.[29] Blood pressure significantly improved among females and those with lower body mass index in under-powered secondary statistical analyses.[29] However, the game intervention improved heart failure SM knowledge significantly in one study, with a high effect size of 0.85.[30]

Adherence to game interventions was reported in all of the reviewed studies using log files on game use or attendance rates for in-class game sessions. Across all studies, the average adherence rate to the game interventions toward the end of the study period ranged from 70% to 100%. In an in-class Wii Sports active intervention,[25] the study dropout rate in the videogame intervention group was lower than in the control group (6% vs. 19%), but there was no difference in individual adherence rates between the groups. However, in a study that compared screen-based games with other screen-based media once a month, the study dropout rate was higher in the intervention group than in the control group.[29] Three studies reported that social support through higher involvement of spouses or grandchildren facilitated adherence.[24,26,28]

Perceptions about the respective game interventions were addressed in five studies (63%).[24,26–28,30,31] Surprisingly, given that these were pilot or feasibility studies, only one of them evaluated usability as an outcome.[30] The game interventions were found enjoyable by 79% to 93% of participants across the five studies; in one study, the intervention was perceived as safe to use and was preferred over other media to stimulate exercise behaviors.[25] Only one of the five studies reported on characteristics of participants who preferred the games[30] (Table 2). In this study, participants with education level below high school or older adults in the younger age group (50–69 years) preferred the digital game to other medium for receiving information on SM of heart failure.[30] Gamification elements of leaderboards, gaining higher points, and surprise challenges added to the appeal of the games.[28] The games were valued for their ability to function as reminders, provide tips on disease SM, convenient in-home use, and motivation for exercise behaviors.[24,26–28,30] Barriers to game use included participants' being tired or bored, lack of interest in digital games, perception of lower fitness possible through games, sensor limitations in accurately capturing participants' movements and gestures, conflicts with daily life routine, and preferences for group exercise.[24,26,28,30]

Discussion

Our scoping review identified only eight studies examining the impact of digital games on CVD SM behaviors. Moreover, majority of the studies were feasibility studies with small sample sizes and short durations that prevented a longitudinal investigation of the digital games' impact on behavioral changes. Therefore, the evidence to examine the effectiveness of digital game interventions through systematic review or meta-analyses is still limited. Several implications for research on game interventions for CVD SM in the home setting can be made: larger, higher-quality studies such as those guided by the CONSORT[32] guidelines are needed; conceptual frameworks such as a taxonomy of behavior change techniques[33] or Fogg's Behavioral Model[34] that apply technology to adopt behavioral changes are needed to inform the design of the game interventions for behavior modification; and tests are needed to evaluate the effectiveness of game elements such as competition through leaderboards, immediate feedback, rewards and incentives based on real-time behaviors, empathy with avatars in avatar-related game genres, or elements of human contact or social support. Currently, a large multicenter RCT of 600 HF patients in Sweden is examining the impact of exergames on physical activity which addresses several of our suggested implications for research on game interventions for CVD SM.[35]

Health disparities are common in CVD, due to higher proportion of CVD diagnoses among racial and ethnic minorities.[36] Digital games' broad cross-cultural appeal was demonstrated with studies conducted in seven different countries. The portability of gaming platform holds potential for scaling game interventions to large numbers. Therefore, future studies should report participants' race and ethnicity to enable examination of the impact of digital games for CVD SM behaviors among diverse groups. In addition, CVD incidences are nearly similar in both males and females.[37] Males participated in larger numbers in the game intervention studies included in our review which differed from other reviews on gaming interventions with older adults.[18,38] Therefore, recruitment efforts in future studies should be tailored to attract higher female participation, and games should be designed to meet the needs and interests of females with CVD.

The limited evidence from the articles in this review reveals that among older adults, games enjoyed a high rate of acceptability, were safe to use, and showed a potential to improve exercise outcomes related to CVD SM, but that they had no effect on psychological outcomes. However, the mediating variable model of effectiveness posits that behavior change interventions influence behavioral outcomes by changing the causal mediating variables.[39] Selecting psychosocial causal mediators that may not be related to the behavioral outcome or low reliability of measures of psychosocial characteristics may have impaired the ability to detect relationships between the game intervention and the psychological outcomes.

Although adherence rate and duration of exercise time decreased toward the end of the studies, the overall adherence rates were still much higher (70%) than that for traditional cardiac rehabilitation approaches, which achieve about only 10%–50% adherence.[40–42] In-home convenience is highly valuable to participants with cardiac diseases, which is why the game interventions delivered at home typically had higher adherence rates in our review. At the same time, when a study included human supervision,[31] intermittent contact by human personnel,[27] or social support through play with spouses or grandchildren,[28] adherence rates were higher even for study duration as long as 6 months.[27] These preliminary observations suggest that additional human contact may be necessary to increase adherence. Gaming interventions' advantage may lie at least, in part, in their potential to supplement a large portion of human contact, which might also be cost effective given clinician shortages.

Some older adults with CVD may not prefer games or digital media as a SM tool, owing to disease-related fatigue or depression, feeling bored with the game, prioritizing other life activities, or preferences for greater human interactivity.[24,30] Perhaps, games can be rotated so that players are constantly stimulated by new challenges. Using a hybrid tailored approach with more human support for those who desire it could provide opportunities to refocus the direction of CVD care delivery, for example, through efforts toward alleviating fatigue and depression.

The majority of the games in this review only targeted the physical activity behavior. The potential of game interventions for CVD SM behaviors, including symptom monitoring, dietary modification, medication management, and crisis recognition, needs to be explored. Pairing digital games with sensors that can objectively track real-time behaviors such as weight monitoring or medication compliance could activate game incentives[43] and enable contextually relevant feedback (e.g., to reduce fluid intake or call a doctor to discuss weight gain). Objective tracking of adherence in weight-monitoring and physical activity behaviors, although cumbersome, has demonstrated stronger association with improved health outcomes than has self-reported adherence.[44,45] Contemporary advances in network connectivity between physical devices and digital games on mobile devices (e.g., as in the ''Internet of Things'')[46] have enabled mobile devices to seamlessly capture real-time behavior data from behavior-tracking physical devices. In a review of personal health technology for CVD prevention, Franklin et al.[47] found that self-monitoring technology tools were most effective for health behavior change when they were combined with personalized feedback. A digital game's appealing features (e.g., rewards and story progress) can be enhanced by personalized feedback from sensors to motivate engagement in and generate habit formation of CVD SM behaviors, resulting in improved health outcomes. Such an innovative solution to patient engagement can make healthcare participatory, personalized, predictive, and preventive as defined by the precision medicine initiative.[48]

Conclusion

In this scoping review, we have presented the findings and implications of evidence from eight studies on use of gaming interventions for CVD SM. Existing evidence demonstrates the paucity of studies on digital games for CVD SM behaviors precluding the need to undertake a full systematic review. Future studies examining the impact of digital games should include larger sample sizes, longer durations, game-design guided by behavioral change theoretical frameworks, and CVD SM behaviors in addition to physical activity behaviors.

Acknowledgments

Editorial support with article development was provided by Dr. John Bellquist at the Cain Center for Nursing Research and the Center for Transdisciplinary Collaborative Research in Self-management Science (P30, NR015335) at The University of Texas at Austin School of Nursing.

Author Disclosure Statement

No competing financial interests exist.

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Address correspondence to:
Kavita Radhakrishnan, PhD, RN, MSEE
School of Nursing
The University of Texas–Austin
1710 Red River Street
Austin, TX 78701-1499

E-mail: kradhakrishnan@mail.nur.utexas.edu