Role of Video Games in Improving Health-Related Outcomes

A Systematic Review

Brian A. Primack, MD, PhD, Mary V. Carroll, BA, Megan McNamara, MD, MSc, Mary Lou Klem, PhD, MLS, Brandy King, MLIS, Michael Rich, MD, MPH, Chun W. Chan, MD, MPH, Smita Nayak, MD

This activity is available for CME credit. See page A4 for information.

Context: Video games represent a multibillion-dollar industry in the U.S. Although video gaming has been associated with many negative health consequences, it also may be useful for therapeutic purposes. The goal of this study was to determine whether video games may be useful in improving health outcomes.

Evidence acquisition: Literature searches were performed in February 2010 in six databases: the Center on Media and Child Health Database of Research, MEDLINE, CINAHL, PsycINFO, EMBASE, and the Cochrane Central Register of Controlled Trials. Reference lists were hand-searched to identify additional studies. Only RCTs that tested the effect of video games on a positive, clinically relevant health consequence were included. Study selection criteria were strictly defined and applied by two researchers working independently. Study background information (e.g., location, funding source); sample data (e.g., number of study participants, demographics); intervention and control details; outcomes data; and quality measures were abstracted independently by two researchers.

Evidence synthesis: Of 1452 articles retrieved using the current search strategy, 38 met all criteria for inclusion. Eligible studies used video games to provide physical therapy, psychological therapy, improved disease self-management, health education, distraction from discomfort, increased physical activity, and skills training for clinicians. Among the 38 studies, a total of 195 health outcomes were examined. Video games improved 69% of psychological therapy outcomes, 59% of physical therapy outcomes, 50% of physical activity outcomes, 46% of clinician skills outcomes, 42% of health education outcomes, 42% of pain distraction outcomes, and 37% of disease self-management outcomes. Study quality was generally poor; for example, two thirds (66%) of studies had follow-up periods of <12 weeks, and only 11% of studies blinded researchers.

Conclusions: There is potential promise for video games to improve health outcomes, particularly in the areas of psychological therapy and physical therapy. RCTs with appropriate rigor will help build evidence in this emerging area.
(Am J Prev Med 2012;42(6):630 – 638)

Man is most nearly himself when he achieves the seriousness of a child at play.
—Heraclitus, c. 500 BCE

You can discover more about a person in an hour of play than in a year of conversation.
—Plato, c. 400 BCE

Context

In 2009, U.S. retail sales of video games—including portable and console hardware, software and accessories—totaled more than $19.5 billion,[1] which is greater than the gross national product for each of more than 90 world nations.[2] In the U.S. and UK, the best-selling video game title of 2010,"Call of

From the Division of General Internal Medicine, Department of Medicine (Primack, Carroll, Nayak), the Center for Research on Health Care (Primack, Nayak), the Division of Adolescent Medicine, Department of Pediatrics (Primack), Health Sciences Library System (Klem), University of Pittsburgh, Pittsburgh, Pennsylvania; the Department of Internal Medicine (McNamara), Case Western Reserve University, Cleveland, Ohio; Center on Media and Child Health (King, Rich), Children's Hospital Boston; Department of Pediatrics, Harvard Medical School, and Department of Society, Human Development and Health, Harvard School of Public Health (Rich), Boston, Massachusetts; and the Department of Family Medicine (Chan), International Medical University, Kuala Lumpur, Malaysia

Address correspondence to: Brian A. Primack, MD, PhD, 230 McKee Place Suite 600, Pittsburgh PA 15213. E-mail: bprimack@pitt.edu.
0749-3797/$36.00
doi: 10.1016/j.amepre.2012.02.023

Duty: Black Ops," amassed more revenue in its first day of sales than the biggest-ever first-day sales of any book, record album, or movie, including all *Harry Potter* and *Star Wars* titles.[3]

Today's video game players defy traditional stereotypes. The average game player is 34 years old; 40% of players are female, and 26% are aged >50 years.[4] In 2009, 67% of U.S. households owned either a console or a personal computer (PC) used to run entertainment software or both.[4] Thus, video game playing is now a phenomenon woven into the fabric of American life.

Most research related to video games and health has focused on their potential for harm. Ample violence is portrayed in video games, even when they are not labeled as such,[5,6] and exposure to violent video games has been linked to aggressive cognitions, aggressive behaviors, desensitization to violence, and decreases in pro-social behavior.[7] Research further suggests that active participation with violent video games may increase aggression more than equivalent time passively exposed to movie violence.[8]

Video games also provide substantial screen time that has been associated with inactivity and the development of obesity.[9] The playing of video games also has been linked to adolescent risk-taking in traffic,[10] poor school performance,[11] video game addiction,[12] unfavorable changes in hemodynamic parameters,[13] seizures,[14] motion sickness,[15] and physical injuries related to repetitive strain.[16]

However, a growing set of console and PC-based video games aim to increase physical activity and reduce obesity.[17–19] Youth playing these so-called "active" video games expend more energy than those interacting with inactive video games.[9,20–22] In some cases, policymakers have made substantial investments in video games to increase physical activity, despite a lack of effectiveness data. For example, the state of West Virginia recently committed to installing the active video game "Dance Dance Revolution" in all 765 of its public schools.[20]

Video games also have been used to distract people from acute or chronic pain.[23,24] They also may represent an effective vehicle to provide health education[19]: they have been developed to educate individuals about fire and street safety,[25] knowledge and self-management of diabetes,[26,27] and self-management of asthma.[28–30] Video games also have potential value in other health-related areas as varied as supporting psychotherapeutic treatment,[31] improving self-esteem,[32] conflict resolution,[33] and improving spirometric measurement.[34] Video games additionally have been used in an effort to enhance the cognitive or physical skills of healthcare providers, such as training surgeons in endoscopic skills.[35,36]

Two recent literature reviews[37,38] were conducted to assess the potential value of video games in promoting health. In one,[37] researchers searched MEDLINE and their personal files for relevant studies. Their[37] emphasis was on the use of video games with "fantasy," and the included articles were not limited by design. Although another set of researchers[38] published a review of both facilitating and debilitating effects of video games, this review focused on the potential benefit of improved visuospatial cognition only, which has questionable clinical benefit. Additionally, most of the studies discovered in these analyses were observational in nature.[37,38] Because the gold standard for medical evidence is the RCT, stronger evidence will be necessary if video games are to be accepted as valuable interventions.[19] Thus, the aim of the current study was to assess the usefulness of video games in improving health-related outcomes as evidenced by studies with rigorous designs.

Evidence Acquisition

Research Question

The research question was defined as: Do results from RCTs indicate that video games can be effective interventions in promoting health and/or improving health outcomes associated with established ICD-9 codes? The scope of the question was not limited based on patient characteristics such as age.

Selection Criteria

A comprehensive research protocol was created (Appendix A, available online at www.ajpmonline.org). For inclusion in this systematic review, studies had to (1) be an RCT; (2) use a video game as the intervention; and (3) test the effect of the video game intervention on a health-promoting, clinically relevant health outcome. For a study to be considered an RCT, participants must have been assigned randomly to intervention and control groups. Studies were excluded if they used nonrandom group assignment (e.g., via an alternation procedure) or if they did not specify whether there was random group assignment. Studies also were excluded if they assessed outcomes only at follow-up, and not at baseline. All studies that met the inclusion criteria published prior to February 2010 were included. Study inclusion was not limited by language, sample size, publication date, age, gender, race, or ethnicity.

A "video game" was defined as described by the *American Heritage Dictionary*: "An electronic or computerized game played by manipulating images on a video display or television screen." In order to be a "game," the intervention was required to: (1) have a system of reward, incentive, and/or objective; (2) be interactive and/or competitive; and (3) be designed for recreational use (i.e., be designed to be "fun"). Studies were excluded if the intervention described did not meet this definition of a video game.

For example, Cohen and colleagues[39] described an RCT to test the effectiveness of a computer-based system to improve expressive language impairment; however, this did not qualify as a game because it was not designed for recreational use. Similarly, computer-based multimedia systems were not considered video games based on these criteria. Studies involving video game interventions of any dose, intensity, and/or length were accepted.

With regard to allowable controls, studies that compared the intervention to nothing, another treatment that did not involve video games, or to a different (control-type) video game were included. For example, studies were included if they assessed the difference between an intervention and a control video game[26,40] or if they compared similar material in either a control or a video game format.[34,41] If the intervention was multimodal, at least 50% of it was required to involve a video game for the study to be included. The video game itself had to be the intervention; studies that assessed the efficacy of some other intervention with computer games as the control were not included.

A "health-promoting, clinically relevant health outcome" was defined as the alleviation of a condition classified as a disorder by the ICD-9 system, or with a known association with an ICD-9 code. Therefore, studies testing the effect of video games on knowledge or management of asthma exacerbations fulfilled this criterion,[29,30,42] because such knowledge and/or management skills have been associated with improvements in asthma outcomes.[43] Similarly, outcomes related to patient–provider communication, patient satisfaction, and treatment adherence were included, because these constructs have been associated with health outcomes.[44] However, a study testing the effect of a video game on improving hand–eye coordination in normal participants did not fulfill this criterion.

Further, studies were considered to meet the criterion of testing a "health-promoting, clinically relevant health consequence" if they had an effect on healthcare providers that was likely to improve outcomes in patients. Thus, studies testing the effect of a video game on improving a nurse's decision-making ability[45,46] or a surgeon's skills[35,36] satisfied this criterion.

Location and Selection of Studies

Systematic literature searches in six databases were performed: the Center on Media and Child Health Database of Research (1956–2010); MEDLINE (1950–2010); Ovid CINAHL (1981–2010); Ovid PsycINFO (1967–2010); EMBASE (1974–2010); and the Cochrane Central Register of Controlled Trials (CENTRAL; via Wiley Interscience; 1948–2010). Search strategies were developed with the assistance of two professional research librarians. When available, search precision was enhanced by the addition of search filters designed to identify RCTs or controlled clinical trials.[47,48]

Initial searches were conducted in these databases between July and November of 2006, and final updated searches were conducted in February of 2010. All specific search terms are included in Appendix B (available online at www.ajpmonline.org). These searches were designed to be very broad so as not to miss any relevant articles. Reference lists of articles found through the database searches were hand-searched to identify additional relevant articles. Two researchers independently reviewed all retrieved articles to identify articles that met inclusion criteria. When they disagreed, the reviewers met to discuss and achieve consensus.

Data Extraction

Data were extracted independently by two researchers who were different from those who retrieved studies. Extracted data included (1) study background information such as study location and source of funding; (2) sample-related information such as sample size and participant demographics; (3) intervention- and control-related information, such as descriptions of the intervention and control and the duration and intensity of the intervention; (4) outcomes-related information such as the primary and secondary outcomes of interest; and (5) quality-related information including drop-out rate, intention-to-treat analysis, and blinding. Because of the volume and complexity of abstraction information, extracted data from the two different reviewers were not compared statistically. However, a series of meetings were held to compare responses, and the few discrepancies noted were adjudicated by a third reviewer.

For each study, one primary outcome was assigned. When the primary outcome was not stated explicitly by the authors, the most frequently mentioned outcome, or the first outcome within a composite score, was selected. When no single outcome was mentioned most frequently, the first outcome described in the "results" section was selected as the primary outcome. All other outcomes were considered secondary outcomes. Coders based their findings of outcome measures presented in the included studies only.

Data Analysis

Because of the wide variety of outcomes assessed and the lack of standard measurements for the few outcomes that different studies had in common, meta-analyses to quantitatively combine the data were not performed. Instead, data were qualitatively described using standard methods of systematic review described by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[49] Appendix C (available online at www.ajpmonline.org) presents the PRISMA checklist for this analysis.

A funnel plot was used to assess for evidence of publication bias for studies reporting sufficient primary outcomes data.[50] In the absence of publication bias, a funnel plot should demonstrate greater variation in outcomes for smaller (less-precise) studies than larger studies, and be relatively symmetric. Funnel plot visual inspection was not suggestive of publication bias.

Finally, a sensitivity analysis was conducted to assess the robustness of the results to categorization of outcomes. Specifically, outcomes were summarized across types of studies while stratifying for the type of outcome (primary versus secondary versus all outcomes). This was done to ensure that overall results were not driven by primary or secondary outcomes alone.

Evidence Synthesis

Study Identification and Selection

The search strategy yielded 1452 unique articles. Of the 1452 articles, 38 (2.6%) met inclusion criteria (Figure 1). The two researchers who reviewed articles for inclusion had substantial agreement after their first independent assessments (% agreement=98.4%; κ=0.70, $p<0.0001$) according to the Landis and Koch framework.[51] After adjudication, consensus was achieved easily in 100% of cases. Each article was assigned a single primary reason for exclusion. The most common reason for study exclusion was lack of a health-promoting, clinically relevant health outcome (n=668, 46%). However, more than one third of articles (n=545, 38%) were excluded for not involving video games that meet the current definition, and 14% (n=201) were excluded for not being RCTs.

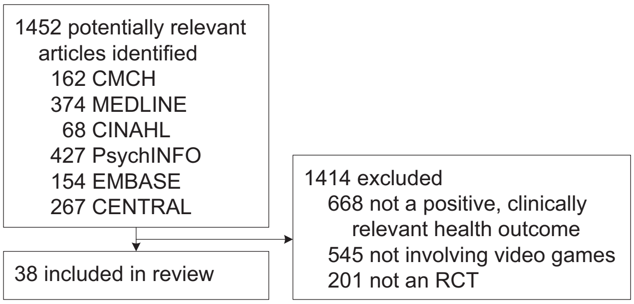

Figure 1. Study selection flowchart

Note: Numbers indicated for each database represent unique contributions from that database after elimination of duplicates. Although many articles did not meet inclusion criteria for more than one reason, each article was assigned a primary reason for exclusion.

CMCH, Center for Media and Child Health (Harvard University database); CENTRAL, Cochrane Central Register of Controlled Trials; CINAHL, Ovid CINAHL

Study Characteristics

Each study was assigned to one of six primary categories based on the general purpose of the video game intervention (Appendix D, available online at www.ajpmonline.org). Of the 38 eligible studies, nine (24%) involved video games for physical therapy (e.g., for rehabilitation after a stroke)[41,52–59] and six (16%) used video games for psychological therapy (e.g., to reduce post-traumatic flashbacks).[32,60–64] Additionally, seven studies (18%) used video games for health education[29,30,65–69] and four (11%) to assist with disease self-management.[27,28,42,70] Five (13%) used video games to distract from discomfort and/or procedures[24,71–74] and four (11%) used video games to increase physical activity.[18,75–77] Finally, three (8%) used video games to improve clinician knowledge or skill.[35,78,79]

Health topics commonly addressed included asthma (n=5); age-related morbidity such as postural instability or cognitive decline (n=4); physical activity (n=4); stroke (n=3); and cancer (n=3). Other less commonly addressed health topics ranged widely and included dyslexia, cerebral palsy, type I diabetes, burns, and self-esteem. The studies included a total of 2662 participants, for a mean of 70 (SD=73) participants per study. Mean study age demonstrated a distribution with three peaks: although 50% of studies involved those of average age ≤19 years, 28% focused on those aged 20–49 years, and 22% involved those aged 50–80 years (Appendix D, available online at www.ajpmonline.org). Results did not differ across age groups for the primary outcomes; however, there were more-positive secondary and overall outcomes for the group aged 20–49 years (Table 1).

Intervention and control conditions are described in Appendix D (available online at www.ajpmonline.org). Seventeen (45%) studies utilized intervention games that are already commercially available for entertainment, such as the active game *Dance Dance Revolution*™ which requires weight-bearing activity on floor pads to interact with the game[53,75,76]; *Rise of Nations*® in which participants build new cities and improve country infrastructure[60]; or *Tetris*® in which a player manipulates falling shapes, fitting them together efficiently.[56,61] However, other studies utilized games that were developed for specific therapeutic purposes, such as *Packy & Marlon*, an interactive video game in which two adolescent elephant friends must save a summer diabetes camp from rats and mice who have disrupted the camp's food and diabetes supplies,[26] or *Re-Mission*®, an action game in which players carry out missions inside three-dimensional models of 19 young patients being treated for cancer.[65,70]

Study Outcomes and Quality

Because each study was assigned a single primary outcome, there were 38 primary outcomes (Appendix D, available online at www.ajpmonline.org). An outcome was considered "positive" if the video game intervention was superior to the control based on significance criteria for that study. Otherwise, the outcome was "negative." Study outcomes differed by game purpose category (Table 1). For example, only 50% of studies that aimed to improve disease self-management had positive primary outcomes, compared with 67%–100% for all other game types (e.g., physical therapy, psychological therapy, distraction from pain).

Among the 38 studies, a total of 157 secondary health outcomes were examined, for a total of 195 primary and secondary outcomes (Table 1). Although results were similar overall, secondary outcomes were somewhat less frequently positive (44%) than primary outcomes. Secondary outcomes were least often positive for studies of health education (33%) and distraction from discomfort (29%). Including both primary and secondary outcomes, the intervention games that most commonly resulted in positive outcomes were those related to psychological therapy (69%) and physical therapy (59%).

In general, outcomes were more frequently positive among the studies that were of shorter duration (Table 1); 70% of studies that were less than 12 weeks in duration reported positive primary outcomes, compared to 55% of studies 12 weeks or longer in duration. Outcomes were positive for all of the eight studies that involved only a one-time intervention. Of the four studies with durations of 24 weeks or longer, only one reported a positive primary outcome. Of the 33 studies reporting follow-up rate, the average retention rate was 93%.

Several representative study quality measures were selected, including those specified in the PRISMA statement (blinding, method of randomization, and intention-to-treat analyses).[49] Blinding was reported in only five of 38 studies (13%). In three of these studies, researchers were blinded to group assignment,[29,59,70] while in the fourth and fifth re-

Table 1. Outcomes of video game trials presented by health goal and outcome type, *n* (%)

			Primary *n*=38		Secondary *n*=157		All *n*=195	
	Studies[a]	Outcomes[a]	−	+	−	+	−	+
Category								
Physical therapy	9 (24)	32 (16)	3 (33)	6 (67)	10 (43)	13 (57)	13 (41)	19 (59)
Psychological therapy	6 (16)	26 (13)	1 (17)	5 (83)	7 (35)	13 (65)	8 (31)	18 (69)
Health education	7 (18)	31 (16)	2 (29)	5 (71)	16 (67)	8 (33)	18 (58)	13 (42)
Disease self-management	4 (11)	35 (18)	2 (50)	2 (50)	20 (65)	11(35)	22 (63)	13 (37)
Distraction from discomfort	5 (13)	26 (13)	0 (0)	5 (100)	15 (71)	6 (29)	15 (58)	11 (42)
Physical activity	4 (11)	32 (16)	1 (25)	3 (75)	15 (54)	13 (46)	16 (50)	16 (50)
Clinician skills	3 (8)	13 (7)	2 (33)	1(67)	5 (50)	5 (50)	7 (54)	6 (46)
Age (years)[b]								
1–19	19 (53)	99 (52)	6 (32)	13 (68)	52 (65)	28 (35)	58 (59)	41 (41)
20–49	9 (25)	47 (25)	3 (33)	6 (67)	13 (34)	25 (66)	16 (34)	31 (66)
50–80	8 (22)	43 (23)	2 (25)	6 (75)	21 (60)	14 (40)	23 (53)	20 (47)
All	38 (100)	195 (100)	11 (29)	27 (71)	88 (56)	69 (44)	99 (51)	96 (49)

[a]Because of rounding, total percentages do not equal 100.
[b]For two studies, age range was not reported.

searchers were blinded to outcome assessment.[65,76] Method of randomization was explicitly described in only eight of the 38 studies (21%), with only four of 38 (11%) specifying allocation concealment using opaque envelopes. Finally, only four of 29 studies (14%) specified the use of intention-to-treat analyses (for nine of the 38 studies, intention-to-treat analyses were not necessary because there were no participants lost to follow-up).

Study duration and intensity of intervention varied widely and are reported in Appendix E (available online at www.ajpmonline.org). Mean study duration was 9 weeks (SD=11); the longest study duration was 1 year. Mean weekly intervention frequency was 2.6 (SD=1.9).

Discussion

The present study synthesizes the results of 38 RCTs, each of which tested the ability of a video game intervention to promote health and/or ameliorate disease. It finds that video games have been evaluated for a wide variety of health-related purposes among participants of all ages, most commonly for their ability to train patients and clinicians physically or psychologically. However, they also have been studied with respect to health education, disease self-management, distraction from pain, and promotion of increased physical activity. Of these areas, studies of video games involving physical or psychological therapy most frequently were successful at achieving their purpose, whereas those that aimed to improve disease management were least successful. Finally, studies conducted to date in this area generally have been of low quality with relatively brief follow-up periods.

These findings are consistent with prior scholarly works related to positive uses of video games,[17,37,38] having described some of the same studies. However, the current study was unique from these other reviews in three ways. First, it cast a wide net with regard to topic, aiming to discover the various health-related purposes to which video games have been applied, instead of focusing on particular health topics. Second, it was more selective in terms of quality, accepting only studies that met the rigorous criteria of an RCT. Finally, this systematic review is unique in its rigor, having adhered closely to current guidelines related to search criteria, study selection, data extraction, and data synthesis.[49]

It is an important finding that there are potential health-related benefits from using video games to address a variety of health conditions and sociodemographic groups. Video gaming represents a multibillion-dollar industry in the U.S., and entertainment-related use is increasing among participants of all ages.[4] Thus far, the entertainment and educational power of this medium for pro-social purposes has centered on younger participants, focusing on education, disease management for youth with particular common conditions (e.g., asthma, juvenile diabetes), and promotion of physical activity.

Interestingly, many studies included in this review also targeted individuals aged 50–80 years, often focusing on reduction of age-related changes such as postural instability or cognitive decline. However, the greatest opportunity with respect to age group for further studies of video games to improve health may be for individuals aged 30–50 years. Although individuals in this age group, like others, wrestle with multiple concerns related to health promotion and disease prevention (e.g., diet, exercise, mental health, and substance use), no studies in this review were designed for individuals of these ages.

Although many people associate video gaming with the male gender, 40% of players are now female.[4] All studies included in this review included both men/boys and women/girls, and most studies included about half women/girls. It may be valuable for future RCTs of video games to evaluate whether gender is associated with the efficacy of various video games to improve health outcomes.

In this qualitative analysis of 195 reported primary and secondary outcomes in all 38 studies included in this systematic review, positive results were reported most frequently by studies using video games for physical therapy, psychological therapy, or physical activity. Video games particularly may be suited to these applications because they can make potentially monotonous, repetitive tasks more compelling. Thus, as evidence accumulates, it may be valuable to assess the extent to which adherence mediates any association found between video game use and training-related outcomes; and whether adherence to these video games persists over time.

Simultaneously, it will be important to assess the tradeoffs inherent in the use of video games instead of other modalities. For example, estimated calorie expenditure per hour when using a simulator for skiing is likely to be substantially lower than calorie expenditure during actual skiing. Thus, it will be important to assess carefully the balance of benefits and drawbacks of video games compared to other modalities.

Compared with secondary outcomes, primary outcomes somewhat more commonly were found to be positive. This may be because authors select primary outcomes they feel are likely to be achieved, whereas secondary outcomes may be more exploratory in nature. Although outcomes were positive for each of the eight studies that involved only a one-time intervention and only one of the four longer studies, the shorter studies were generally of lower quality and less ambitious. Therefore, it should not be concluded that it is preferable to have shorter duration of intervention, and future studies should compare interventions of various lengths.

The results suggest not only that few RCTs have been conducted in this area but also that the RCTs conducted have been of relatively low quality. Almost all of the studies with higher-quality design features reported positive results; this provides reassurance that the current findings of potential health benefits of video games are not simply a consequence of low-quality studies. However, higher-quality studies remain relatively uncommon in this area.

Some measures of quality may be more difficult to achieve when studying a video game as opposed to other types of interventions. For example, only 11% of eligible studies blinded researchers, because researchers were often heavily involved in helping operate and/or facilitate the video games (e.g., when stroke or fracture victims were assisted with rehabilitation).[52,54,58] This also may reflect challenges to obtaining funding for most costly studies in this area. Despite challenges such as these, other quality measures should be achieved easily; for example, all research teams should be able to adhere closely to CONSORT guidelines related to appropriate randomization procedures and concealment of allocation.[80]

Limitations

The present study included only RCTs. It is possible that other video game interventions are highly successful but only have been reported using observational trials. However, this important inclusion criterion was maintained to evaluate a higher level of evidence for the usefulness of video games to improve health outcomes than prior reviews on this topic. Another limitation of this systematic review was that some of the study selection criteria used are inherently subjective, such as the definition of what constitutes a "game." Despite this inherent limitation, bias was minimized by carefully defining the current selection criteria with specific protocols and examples, and by comparing the assessment of each study completed by two researchers working independently using established measures of inter-rater reliability.

Another limitation is that coders relied on authors' selection of appropriate measures to operationalize their outcomes. It may be valuable for future assessments to more rigorously examine reliability and validity of these measures. Additionally, because each of the included studies was relatively small, the total number of study participants assessed in all 38 studies was only 2662. Finally, it was not possible to employ formal techniques of meta-analysis because of the wide diversity in study interventions and outcome measures.

Conclusion

Despite these limitations, this comprehensive systematic review demonstrates that video games may have potential for improving health in a wide variety of areas, for a variety of sociodemographic groups. This is a valuable finding, particularly given the growing popularity and ubiquity of video games worldwide. To most effectively assess the potential benefits of video games for health, it will be important for further research to utilize (1) RCT methodology when appropriate; (2) longer follow-up duration; (3) improved measures of quality, such as randomization and blinding; and (4) standardized measurement tools and careful attention to the quality of outcome measures.

During this work, BAP was supported in part by awards from the National Cancer Institute (K07-CA114315 and R01-CA140150); a Physician Faculty Scholar Award from the Robert Wood Johnson Foundation; and a grant from the Maurice Falk Foundation. SN is supported by grant KL2 RR024154-02 from the National Center for Research Resources, a component of the NIH, and NIH Roadmap for Medical Research. The authors thank James Bost, PhD, for his assistance with study design. The authors thank Isabel Lopes, MSLIS, and Ariel Shensa, MA, for their assistance with abstraction and translation of an article in Spanish. The authors thank Ian L. Kane for assistance with literature searches and data management. BAP had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

No financial disclosures were reported by the authors of this paper.

References

1. Riley DM. 2009 U.S. Video game industry and PC game software retail sales reach $20.2 billion. Port Washington NY: NPD Group, 2010.
2. World Bank. World development indicators database: gross domestic product 2009 (siteresources.worldbank.org/DATASTATISTICS/Resources/GDP.pdf). Washington DC: World Bank, 2010.
3. Robinson A. Black Ops annihilates record Harry Potter weekend. Computer and Video Games 2010, Nov 22.
4. Entertainment Software Association. Game Player Data. www.theesa.com/facts/gameplayer.asp.
5. Haninger K, Thompson KM. Content and ratings of teen-rated video games. JAMA 2004;291:856–65.
6. Thompson KM, Haninger K. Violence in E-rated video games. JAMA 2001;286:591–8.
7. Anderson CA, Bushman BJ. Effects of violent video games on aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, and prosocial behavior: a meta-analytic review of the scientific literature. Psychol Sci 2001;12:353–9.
8. Polman H, de Castro BO, van Aken MA. Experimental study of the differential effects of playing versus watching violent video games on children's aggressive behavior. Aggress Behav 2008;34:256–64.
9. Lanningham-Foster L, Jensen TB, Foster RC, et al. Energy expenditure of sedentary screen time compared with active screen time for children. Pediatrics 2006;118:e1831–e1835.
10. Beullens K, Roe K, Van den Bulck J. Video games and adolescents' intentions to take risks in traffic. J Adolesc Health 2008;43:87–90.
11. Gentile DA, Lynch PJ, Linder JR, Walsh DA. The effects of violent video game habits on adolescent hostility, aggressive behaviors, and school performance. J Adolesc 2004;27:5–22.
12. Griffiths MD, Hunt N. Dependence on computer games by adolescents. Psychol Rep 1998;82:475–80.
13. Borusiak P, Bouikidis A, Liersch R, Russell JB. Cardiovascular effects in adolescents while they are playing video games: a potential health risk factor? Psychophysiology 2008;45:327–32.
14. Kasteleijn-Nolst Trenite DG, Martins da Silva A, Ricci S, et al. Video games are exciting: a European study of video game-induced seizures and epilepsy. Epileptic Disord 2002;4:121–8.
15. Stoffregen TA, Faugloire E, Yoshida K, Flanagan MB, Merhi O. Motion sickness and postural sway in console video games. Hum Factors 2008;50:322–31.
16. Zapata AL, Moraes AJ, Leone C, Doria-Filho U, Silva CA. Pain and musculoskeletal pain syndromes related to computer and video game use in adolescents. Eur J Pediatr 2006;165:408–14.
17. Brown D. Playing to win: video games and the fight against obesity. J Am Diet Assoc 2006;106:188–9.
18. Warburton DE, Bredin SS, Horita LT, et al. The health benefits of interactive video game exercise. Appl Physiol Nutr Metab 2007;32:655–63.
19. Griffiths M. Video games and health. Br Med J 2005;331:122–3.
20. Schiesel S. P.E.classes turn to video game that works legs. New York Times 2007, Apr 30.
21. Graves L, Stratton G, Ridgers ND, Cable NT. Comparison of energy expenditure in adolescents when playing new generation and sedentary computer games: cross sectional study. Br Med J 2007;335:1282–4.
22. Lenzer J. U.S. heart association endorses active video games. Br Med J 2010;340:c2802.
23. Das DA, Grimmer KA, Sparnon AL, McRae SE, Thomas BH. The efficacy of playing a virtual reality game in modulating pain for children with acute burn injuries: a randomized controlled trial [ISRCTN87413556]. BMC Pediatr 2005;5:1.
24. Gold JI, Kim SH, Kant AJ, Joseph MH, Rizzo AS. Effectiveness of virtual reality for pediatric pain distraction during I.V. placement. Cyberpsychol Behav 2006;9:207–12.
25. Coles CD, Strickland DC, Padgett L, Bellmoff L. Games that "work": using computer games to teach alcohol-affected children about fire and street safety. Res Dev Disabil 2007;28:518–30.
26. Brown SJ, Lieberman DA, Gemeny BA, Fan YC, Wilson DM, Pasta DJ. Educational video game for juvenile diabetes: results of a controlled trial. Med Inform 1997;22:77–89.
27. Kumar VS, Wentzell KJ, Mikkelsen T, Pentland A, Laffel LM. The DAILY (Daily Automated Intensive Log for Youth) trial: a wireless, portable system to improve adherence and glycemic control in youth with diabetes. Diabetes Technol Ther 2004;6:445–53.
28. Bartholomew L, Gold R, Parcel G, et al. Watch, discover, think, and act: evaluation of computer-assisted instruction to improve asthma self-management in inner-city children. Patient Educ Couns 2000;39:269–80.
29. Rubin DH, Leventhal JM, Sadock RT. Educational intervention by computer in childhood asthma: a randomized clinical trial testing the use of a new teaching intervention in childhood asthma. Pediatrics 1986;77:1–10.
30. Yawn BP, Algatt-Bergstrom PJ, Yawn RA, et al. An in-school CD-ROM asthma education program. J Sch Health 2000;70:153–9.
31. Wilkinson N, Ang RP, Goh DH. Online video game therapy for mental health concerns: a review. Int J Soc Psychiatry 2008;54:370–82.
32. Baccus JR, Baldwin MW, Packer DJ. Increasing implicit self-esteem through classical conditioning. Psychol Sci 2004;15:498–502.
33. Marks N. Games without frontiers. Br Med J 2006;333:863.1.
34. Vilozni D, Barker M, Jellouschek H, Heimann G, Blau H. An interactive computer-animated system (SpiroGame) facilitates spirometry in preschool children. Am J Respir Crit Care Med 2001;164:2200–5.

35. Rosenberg BH, Landsittel D, Averch TD. Can video games be used to predict or improve laparoscopic skills? J Endourol 2005;19:372–6.
36. 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;142:181–6; discusssion 186.
37. Baranowski T, Buday R, Thompson DI, Baranowski J. Playing for real: video games and stories for health-related behavior change. Am J Prev Med 2008;34:74–82.
38. Ferguson CJ. The good, the bad and the ugly: a meta-analytic review of positive and negative effects of violent video games. Psychiatr Q 2007;78:309–16.
39. Cohen W, Hodson A, O'Hare A, et al. Effects of computer-based intervention through acoustically modified speech (Fast ForWord) in severe mixed receptive-expressive language impairment: outcomes from a randomized controlled trial. J Speech Lang Hear Res 2005;48:715–29.
40. Beale IL, Kato PM, Marin-Bowling VM, Guthrie N, Cole SW. Improvement in cancer-related knowledge following use of a psychoeducational video game for adolescents and young adults with cancer. J Adolesc Health 2007;41:263–70.
41. Lin DH, Lin YF, Chai HM, Han YC, Jan M. Comparison of proprioceptive functions between computerized proprioception facilitation exercise and closed kinetic chain exercise in patients with knee osteoarthritis. Clin Rheumatol 2007;26:520–8.
42. Shames RS, Sharek P, Mayer M, et al. Effectiveness of a multicomponent self-management program in at-risk, school-aged children with asthma. Ann Allergy Asthma Immunol 2004;92:611–8.
43. Janson SL, Fahy JV, Covington JK, Paul SM, Gold WM, Boushey HA. Effects of individual self-management education on clinical, biological, and adherence outcomes in asthma. Am J Med 2003;115:620–6.
44. McKinstry B, Walker J, PorterM, et al. The impact of general practitioner morale on patient satisfaction with care: a cross-sectional study. BMC Fam Pract 2007;8–57.
45. Bhoopathi PS, Sheoran R, Adams CE. Educational games for mental health professionals: a Cochrane review. Int J Psychiatr Nurs Res 2007;12:1497–502.
46. Hansen MM. Versatile, immersive, creative and dynamic virtual 3-D healthcare learning environments: a review of the literature. J Med Internet Res 2008;10:e26.
47. Eady AM, Wilczynski NL, Haynes RB. PsycINFO search strategies identified methodologically sound therapy studies and review articles for use by clinicians and researchers. J Clin Epidemiol 2008;61:34–40.
48. Walker-Dilks C, Wilczynski NL, Haynes RB. Cumulative Index to Nursing and Allied Health Literature search strategies for identifying methodologically sound causation and prognosis studies. Appl Nurs Res 2008;21:98–103.
49. Moher D, Liberati A, Tetzlaff J, Altman D; PRISMA Group. Preferred Reporting Items for Systematic reviews and Meta-Analyses: the PRISMA statement. PLoS Med 2009;6:e1000097.
50. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. Br Med J 1997;315:629–4.
51. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.
52. Broeren J, Claesson L, Goude D, Rydmark M. The possibilities of VR and computer games in an activity center for community dwelling persons with stroke. Int J Stroke 2008;3:354.
53. Brumels KA, Blasius T, Cortright T, Oumedian D, Solberg B. Comparison of efficacy between traditional and video game based balance programs. Clin Kinesiol 2008;62:26–31.
54. Cameirao MS, Badia SB, Oller ED, Verschure PF. Stroke rehabilitation using the Rehabilitation Gaming System (RGS): initial results of a clinical study. Ann Rev CyberTher Telemed 2008;6:146–51.
55. Fitzgerald D, Trakarnratanakul N, Smyth B, Caulfield B. Effects of a wobble board-based therapeutic exergaming system for balance training on dynamic postural stability and intrinsic motivation levels. J Orthop Sports Phys Ther 2010;40:11–9.
56. Goldstein J, Cajko L, Oosterbroek M, Michielsen M, van Houten O, Salverda F. Video games and the elderly: effects on reaction time, cognitive functioning and well-being. Gedrag & Gezondheid: Tijdschrift voor Psychologie en Gezondheid 1997;25:296–302.
57. Jannink MJ, van der Wilden GJ, Navis DW, Visser G, Gussinklo J, Ijzerman M. A low-cost video game applied for training of upper extremity function in children with cerebral palsy: a pilot study. Cyberpsychol Behav 2008;11:27–32.
58. Jarus T, Shavit S, Ratzon N. From hand twister to mind twister: computer-aided treatment in traumatic wrist fracture. Am J Occup Ther 2000;54:176–82.
59. Yavuzer G, Senel A, Atay MB, Stam HJ. "Playstation eyetoy games" improve upper extremity-related motor functioning in subacute stroke: a randomized controlled clinical trial. Eur J Phys Rehabil Med 2008;44:237–44.
60. Basak C, Boot WR, Voss MW, Kramer AF. Can training in a real-time strategy video game attenuate cognitive decline in older adults? Psychol Aging 2008;23:765–77.
61. Holmes EA, James EL, Coode Bate T, Deeprose C. Can playing the computer game "Tetris" reduce the build-up of flashbacks for trauma? A proposal from cognitive science. PLoS One [Electronic Resource] 2009;4:e4153.
62. Jimenez JE, Rojas E. Effects of tradislexia videogame on phonological awareness and word recognition in dyslexic children. Psicothema 2008;20:347–53.
63. Rezaiyan A, Mohammadi E, Fallah PA. Effect of computer game intervention on the attention capacity of mentally retarded children. Int J Nurs Pract 2007;13:284–8.
64. Russoniello CV, O'Brien K, Parks JM. The effectiveness of casual video games in improving mood and decreasing stress. J CyberTher Rehabil 2009;2:53–66.
65. Beale IL, Kato PM, Marin Bowling VM, Guthrie N, Cole SW. Improvement in cancer-related knowledge following use of a psychoeducational video game for adolescents and young adults with cancer. J Adolesc Health 2007;41:263–70.
66. Pempek TA, Calvert SL. Tipping the balance: use of advergames to promote consumption of nutritious foods and beverages by low-income African American children. Arch Pediatr Adolesc Med 2009;163:633–7.
67. Peng W. Design and evaluation of a computer game to promote a healthy diet for young adults. Health Commun 2009;24:115–27.
68. Brown SJ, Lieberman DA, Germeny BA, Fan YC, Wilson DM, Pasta DJ. Educational video game for juvenile diabetes: results of a controlled trial. Med Inform 1997;22:77–89.
69. Huss K, Winkelstein M, Nanda J, Naumann PL, Sloand ED, Huss RW. Computer game for inner-city children does not improve asthma outcomes. J Pediatr Health Care 2003;17:72–8.
70. Kato PM, Cole SW, Bradlyn AS, Pollock BH. A video game improves behavioral outcomes in adolescents and young adults with cancer: a randomized trial. Pediatrics 2008;122:e305–e317.
71. Miller K, Rodger S, Bucolo S, Wang XQ, Kimble RM. Multimodal distraction to relieve pain in children undergoing acute medical procedures. Chin J Burns 2009;25:352–6.
72. Patel A, Schieble T, Davidson M, et al. Distraction with a hand-held video game reduces pediatric preoperative anxiety. Paediatr Anaesth 2006;16:1019–27.
73. Seyrek SK, Corah NL, Pace LF. Comparison of three distraction techniques in reducing stress in dental patients. J Am Dent Assoc 1984;108:327–9.
74. Vasterling J, Jenkins RA, Tope DM, Burish TG. Cognitive distraction and relaxation training for the control of side effects due to cancer chemotherapy. J Behav Med 1993;16:65–80.
75. Maloney AE, Bethea T, Kelsey KS, et al. A pilot of a video game (DDR) to promote physical activity and decrease sedentary screen time. Obesity 2008;16:2074–80.

76. Murphy EC, Carson L, Neal W, Baylis C, Donley D, Yeater R. Effects of an exercise intervention using Dance Dance Revolution on endothelial function and other risk factors in overweight children. Int J Pediatr Obes 2009;4:205–14.
77. Ni Mhurchu C, Maddison R, Jiang Y, Jull A, Prapavessis H, Rodgers A. 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.
78. Schlickum MK, Hedman L, Enochsson L, Kjellin A, Fellander-Tsai L. Systematic video game training in surgical novices improves performance in virtual reality endoscopic surgical simulators: a prospective randomized study. World J Surg 2009;33:2360–7.
79. Sward KA, Richardson S, Kendrick J, Maloney C. Use of a web-based game to teach pediatric content to medical students. Ambul Pediatr 2008;8:354–9.
80. Schulz KF, Altman DG, Moher D; the CONSORT Group. CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. Br Med J 2010;340:c332.

Appendix

Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.amepre.2012.02.023.

A pubcast created by the authors of this paper can be viewed at www.ajpmonline.org/content/video_pubcasts_collection.