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Health Educ Behav published online 6 July 2012
DOI: 10.1177/1090198112444956

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Health Education & Behavior
XX(X) 1–22
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Health Education
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DOI: 10.1177/1090198112444956
http://heb.sagepub.com


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Abstract

This systematic review evaluates interventions using active video games (AVGs) to increase physical activity and summarizes laboratory studies quantifying intensity of AVG play among children and adults. Databases (Cochrane Library, PsychInfo, PubMed, SPORTDiscus, Web of Science) and forward citation and reference list searches were used to identify peer-reviewed journal articles in English through March 2011. Studies that used off-the-shelf AVGs to increase physical activity with quantitative outcomes or studies that quantified intensity of AVG play were included. Information on sample characteristics, AVGs employed, study design and conditions, outcome measures, results, and conclusions was extracted by two researchers. Intervention studies were ranked on design quality. Thirteen interventions and 28 laboratory studies were identified. All laboratory studies demonstrated that AVGs are capable of providing light-to-moderate intensity physical activity. However, only three interventions supported AVGs as an effective tool to significantly increase physical activity or exercise attendance. As AVGs are becoming more popular, additional research is needed to determine how to capitalize on the potential of AVGs to increase physical activity.

Keywords

active video games, energy expenditure, exergames, intervention studies, metabolic equivalent, physical activity, systematic review

Physical inactivity among adults and children is a major contributor to diseases associated with obesity (World Health Organization, 2010). The World Health Organization estimates that physical inactivity is associated with more than 2 million deaths each year, including 10% to 16% of cases of breast cancer, colon cancer, and diabetes as well as 22% of heart disease (World Health Organization, 2010). The Centers for Disease Control and Prevention recommends that adults participate in at least 150 minutes of moderate physical activity every week for disease prevention (Centers for Disease Control and Prevention, 2008a). However, incorporating physical activity into a daily routine is difficult for many children and adults. Recent estimates suggest that U.S. individuals aged 6 years and older spend approximately 55% of the day engaged in sedentary behaviors (Matthews et al., 2008); 25% of Americans do not participate in any leisure-time physical activity (Centers for Disease Control and Prevention, 2008b).

Many formalized attempts have been made to encourage people to be more physically active. These interventions have become technologically sophisticated, using the multimedia capability of websites (Goran & Reynolds, 2005; Marshall, Leslie, Bauman, Marcus, & Owen, 2003) and tailored e-mail messages (Hageman, Walker, & Pullen, 2005).

More recently, a new form of interactive gaming (termed as *exergaming* or *active video gaming*) has emerged, and researchers have begun examining whether these potentially more fun and engaging platforms are equivalent to moderate to vigorous physical activity (MVPA) or have the potential to promote healthy active behaviors. In this systematic review, we adopt the term *active video games* (AVGs) to refer to commercially available off-the-shelf video games that require players' body movements for game play.

Objective

A number of reviews of intervention studies and laboratory energy expenditure studies of AVGs have been published recently (Biddiss & Irwin, 2010; Daley, 2009). However, the most recent systematic review (Biddiss & Irwin, 2010) only

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focuses on children. As more than half of American adults play games (Lenhart, Jones, & Macgill, 2008), and 29% of Americans older than 50 years play video games (Entertainment Software Association, 2011), and nearly a third of adults older than 65 years play games daily (Lenhart et al., 2008), it also is important to review the current literature on the potential of using AVGs for physical activity promotion among adults and older adults. This review will include two different types of studies. The first type is the laboratory study that quantifies the intensity of AVG play to establish whether an AVG is capable of providing the intensity of physical activity recommended. The second type is the intervention study that uses an AVG to increase physical activity. Therefore, the objectives of this review are (a) to systematically summarize laboratory studies that validate the intensity of AVGs as a physical activity promotion tool among children (younger than 18 years) and adults (18 years and older) and (b) to systematically evaluate the effectiveness of intervention studies using AVGs to increase physical activity among children and adults.

Method

Data Source

To ensure a comprehensive inclusion of relevant studies, two waves of literature searches were conducted. The first wave covered literature published between January 1995 to October 2010, and the second wave covered literature published between October 2010 and March 2011. In each wave, three search strategies were adopted. First, two researchers conducted systematic literature searches using five databases (Cochrane Library, PsychInfo, PubMed, SPORTDiscus, and Web of Science) for articles from English language, peer-reviewed publications using the following two groups of keywords in combination: “physical activit*, exercise, weight loss, obesity, motor activit*, leisure activit*, physical fitness, physical education, physical training, sports” and “video game, computer game, active video game, and exergame.” Two researchers screened the search record by evaluating the titles and the abstracts using the inclusion and exclusion criteria. The screening resulted in 69 articles in Wave 1 and 22 articles in Wave 2. The full-text of these 91 articles was obtained. Further evaluation of the full-text using the inclusion and exclusion criteria resulted in 40 articles. The second search strategy was a forward citation search conducted in the Social Science Citation Index using the included articles. No additional articles were found. The third search strategy was a reference list search of the included articles and one additional article was identified. In total, 41 articles were included in this systematic review.

Study Inclusion and Exclusion Criteria

First, the study must have employed at least one off-the-shelf AVG. Research on off-the-shelf AVG arcade games

that are not intended for home use was not included (Ridley & Olds, 2001). Non-off-the-shelf AVG or virtual reality-based computer games were not included. Second, the AVG was either used as a tool to increase the amount of physical activity or was quantified in terms of AVG intensity. Studies that used AVGs for other purposes such as depression (Rosenberg et al., 2010), attention and memory (Russell, 2009), physical fitness (Lotan, Yalon-Chamovitz, & Weiss, 2010), balance (Studenski, Perera, Keller, Spadola-Bogard, & Garcia, 2010), or obesity treatment (Murphy et al., 2009; Radon et al., 2011) were excluded. Third, only studies with objective outcome measures were included. Studies with only qualitative outcomes such as focus group studies or studies with only physical activity-related psychological outcomes (e.g., preference of AVG; Epstein, Beecher, Graf, & Roemmich, 2007) but no quantitative physical activity outcomes were excluded. Fourth, conference proceedings, posters, and abstracts were not included. Fifth, literature review or commentary articles were not included. Sixth, studies that were conducted with physical rehabilitation patients were not included.

Data Extraction

Each of the eligible studies was categorized as a laboratory study, in which intensity of playing AVGs was quantified, or an intervention study, in which AVGs were used in an attempt to increase physical activity either at home or in a clinical or professional setting. Two researchers examined the included articles and extracted data including (a) methodological details (e.g., sample characteristics, study design, outcome measures); (b) types of AVGs used; (c) key findings pertaining to activity intensity, for example, metabolic equivalent (MET),¹ change in sedentary behavior and physical activity pattern, body mass index (BMI), and the potential for physical activity promotion (e.g., adherence, motivation for play, enjoyment, rating of perceived exertion), and gender difference; and (d) conclusion.

Data Synthesis

The laboratory studies were ranked by the intensity of the AVG (Table 1). The ranking index includes five levels: (a) L indicates that the METs among all the AVGs tested equal to light intensity physical activity (1.5-2.9 METs), (b) M indicates that all the AVGs tested equal to moderate intensity physical activity (3-6 METs), (c) LM indicates that some of the AVGs tested equal to moderate intensity physical activity (3-6 METs) and some equal to light intensity physical activity (1.5-3 METs), (d) MV indicates some of the AVGs tested equal to moderate intensity physical activity (3-6 METs) and some equal to vigorous intensity physical activity (>6 METs), and (e) LMV indicates that the AVGs tested include light, moderate, and vigorous intensity levels.

The intervention studies were ranked by whether the AVG was found to increase physical activity (Table 2). The ranking

Table 1. Sample Size and Active Video Game Intensity in Laboratory Studies

Study	Sample Size	Sample Age Group	AVG Intensity
Barkley and Penko (2009)	12	A	M
Bonetti, Drury, Danoff, and Miller (2010)	32	A	L ^a
Fawkner, Niven, Thin, MacDonald, and Oakes (2010)	20	C	M
Graf, Pratt, Hester, and Short (2009)	23	C	LM
Graves, Ridgers, and Stratton (2008)	13	C	LM
Graves, Stratton, Ridgers, and Cable (2008)	11	C	L ^b
Graves, Ridgers, Williams, et al. (2010)	42	AC	LM
Guderian et al. (2010)	20	A	LM
Haddock, Brandt, Siegel, Wilkin, and Joung-Kyue (2008)	23	C	M
Haddock, Siegel, and Wikin (2009)	20	C	M
Lanningham-Foster et al. (2006)	25	C	L
Lanningham-Foster et al. (2009)	42	AC	M
Leatherdale, Woodruff, and Manske (2010)	51	A	M ^b
Lyons et al. (2011)	100	A	LM
Maddison et al. (2007)	21	C	LM
Mellecker and McManus (2008)	18	C	M
Miyachi, Yamamoto, Ohkawara, and Tanaka (2010)	12	A	LM
Penko and Barkley (2010)	24	C	L
Sell, Lillie, and Taylor (2008)	19	A	MV
Siegel, Haddock, Dubois, and Wilkin (2009)	13	A	M
Straker and Abbott (2007)	20	C	M
Stroud, Amonette, and Dupler (2010)	19	A	LM
Tan, Aziz, Chua, and Teh (2002)	40	C	M
Unnithan, Houser, and Fernhall (2006)	22	C	LM
Warburton et al. (2009)	14	A	V ^c
White, Schofield, and Kilding (2011)	26	C	LM
Willems and Bond (2009)	10	A	LM ^d
Worley, Rogers, and Kraemer (2011)	8	A	LM ^e

Note. AVG = active video game. L indicates that the metabolic equivalent (MET) among all the AVGs tested equal to light intensity physical activity (1.5-2.9 METs). M indicates that all the AVGs tested equal to moderate intensity physical activity (3-6 METs). LM indicates that some of the AVGs tested equal to moderate intensity physical activity (3-6 METs) and some equal to light intensity physical activity (1.5-3 METs). MV indicates some of the AVGs tested equal to moderate intensity physical activity (3-6 METs) and some equal to vigorous intensity physical activity (>6 METs). LMV indicates that the AVGs tested include light, moderate, and vigorous intensity levels. A = adults (ages 18 years and older); C = children (less than 18 years old). a. Resting energy expenditure was not reported. We estimated oxygen consumption at resting to be 3.5 mL O₂ kg⁻¹ minutes⁻¹ to calculate METs of AVG play.

b. Energy expenditure during AVG was not measured based on calorimetry.

c. Data were not sufficient (not reported in numeric values) to calculate METs. AVG intensity estimated based on data reported.

d. Resting energy expenditure was not reported in the article and the author provided data on e-mail request.

e. Resting energy expenditure was not reported. AVG intensity estimated based on data reported.

index has four levels: (a) + indicates that the AVG treatment was more effective than the no treatment control group in increasing the amount of physical activity, exercise attendance, or energy expenditure in the exercise sessions; (b) 0 indicates that the AVG treatment was not significantly different from the no treatment control group in increasing physical activity; (c) I indicates indeterminate results due to lack of control group or lack of non-AVG comparison group; and (d) - indicates that the comparison group resulted in greater physical activity attendance rate than the AVG treatment group.

Following previous literature (Norman et al., 2007), the design quality of the intervention studies were rated based on nine methodological characteristics: randomization, use of a

control group, isolation of the AVG, pre-post test design, participant retention, baseline groups equivalence, use of missing data, analysis of power or effect size, and use of validated measures (Tables 3 and 4). Each study's score was calculated as the percentage of the maximum obtainable score. Three researchers independently checked the scores for accuracy.

Results

This systematic review included 41 articles that were classified into two categories: 28 laboratory studies quantifying intensity of AVG play (Table 5) and 13 AVG-based physical activity intervention studies (Table 6).

Table 2. Sample Size, Active Video Game Effectiveness, and Study Design Quality Score

Study	Sample Size ^a	Sample Age Group	Effectiveness	Design Quality Score (Maximum Score = 100)
Adamo, Rutherford, and Goldfield (2010)	26	C	–	89
Chin A Paw, Jacobs, Vaessen, Titze, and van Mechelen (2008)	16	C	I	56
Fogel, Miltenberger, Graves, and Koehler (2010)	4	C	I	33
Graves, Ridgers, Atkinson, and Stratton (2010)	58	C	0	100
Madsen, Yen, Wlasiuk, Newman, and Lustig (2007)	21	C	I	33
Maloney et al. (2008)	60	C	0	89
McDougall and Duncan (2008)	12	C	I	33
Ni Mhurchu et al. (2008)	20	C	+	89
Paez, Maloney, Kelsey, Wiesen, and Rosenberg ^b (2009)	60	C	0	89
Rhodes, Warburton, and Bredin (2009)	29	A	+	100
Trout and Zamora (2006)	26	A	I	56
Warburton et al. (2007)	14	A	+	89
Wollersheim et al. (2011)	11	A	I	22

Note. AVG = active video game. + Indicates that the AVG treatment was more effective than the no treatment control group in increasing the amount of physical activity, exercise attendance, or energy expenditure in the exercise sessions. 0 Indicates that the AVG treatment was not significantly different from the no treatment control group in increasing physical activity. I Indicates indeterminate results because of lack of control group or lack of non-AVG comparison group. – Indicates that the comparison group resulted in greater physical activity attendance rate than the AVG treatment group. A = adults (ages 18 years and older); C = children (less than 18 years old).

a. The sample size is based on the sample size used for data analysis (excluding dropouts).

b. The same study as Maloney et al. (2008).

Laboratory Studies

Of the 28 laboratory studies, sample sizes ranged from 8 to 100 participants. Eleven of the studies included adult samples, 2 used both children and adults, and 15 were aimed at children. All but 5 of the studies used both male and female participants. Five studies examined single gender sample. Most of the laboratory studies consisted of multiple conditions for each participant to play various types of AVGs (5-10 minutes on each game). All but two studies (Graves, Stratton, Ridgers, & Cable, 2008; Leatherdale, Woodruff, & Manske, 2010) used noncalorimetric methods to estimate AVG intensity and energy expenditure. Five studies measured participants' liking or enjoyment of AVGs. Eleven studies also measured participants' perceived exertion of playing AVGs. In the order of most to least common, in general the conditions included AVG play, sedentary game play, and a traditional physical activity, such as walking on a treadmill. The most commonly used AVGs were associated with the *Nintendo Wii* console and the *Wii Balance Board* (e.g., *Wii Sports*, *Wii Fit*), followed by dance pad-based games (e.g., *Dance Dance Revolution [DDR]*, *Zigzag Xer-Dance*) and games for the *PlayStation2 EyeToy*. Other AVG systems included *Exerstation*, a full-body isometric game controller for the *Xbox 360*, *GameBike*, and the *XaviX* system.

Among the 28 studies testing the intensity and energy expenditure of AVG play, two studies (Sell et al., 2008; Warburton et al., 2009) found that some of the AVGs included in the studies equal to vigorous physical activity. Ten studies

found that all the AVGs tested equal to moderate physical activity. Twelve studies found that the AVGs tested equal to light-to-moderate physical activity. Four studies found that the AVGs employed equal to light-intensity physical activity (Bonetti, Drury, Danoff, & Miller, 2010; Graves et al., 2008, Lanningham-Foster et al., 2006; Penko & Barkley, 2010). Eighteen studies reported gender differences, with nine finding significant differences between males and females on at least one of the dependent variables. Five studies recruited single gender sample, and the remaining five studies did not report whether gender difference was examined.

Intervention Studies

The duration of the intervention studies ranged from 5 days to 6 months. Most of the studies took place between 6 and 12 weeks and included a follow-up after the treatment was concluded. Four studies used adult participants, whereas 9 were aimed at children. One study involved female-only participants, 1 study involved male-only participants, and the rest of the 11 studies used both genders. Five of the intervention studies were based out of the home, 4 out of a laboratory, 2 based at school, 1 based at both home and school, and 1 out of a community program. Five studies used accelerometers to objectively measure physical activity. Most of the studies also recorded BMI and heart rate. However, only two studies tested for estimated energy expenditure during AVG play. The most commonly used AVGs were dance pad-based games, such as *DDR*, followed by games involving

Table 3. Design Quality Scoring Criteria for Intervention Studies

Scoring Criteria of Intervention Studies	
Individual randomization	YES: Participants were randomized to study conditions at the individual, stratified, or block levels. NO: Authors failed to mention randomization, specify another method of assigning group status, or group-level randomization with individual level analysis.
Control group	YES: Study included a comparison group—no treatment, delayed treatment, or alternate treatment. NO: Study did not include a comparison group of any type.
Isolate AVG	YES: Design allowed for test of effectiveness of the AVG, for example, AVGs were tested alone and compared against a group with no AVGs. NO: Tests in which the AVG cannot be directly parsed out for analysis. For instance, the AVG was used in conjunction with another treatment option.
Pre–post test design	YES: Behavior assessment was assessed before and after the intervention. NO: Behavior assessment was administered after the intervention.
Retention	YES: Study retention was at least 70% of participants who initially agreed to be in the study, as calculated by entire sample not by groups. For studies that did not report retention or dropout rates, retention can be calculated using the sample sizes used for analyses (e.g., 300 randomized, but only 250 were included in analyses, 83.3% retention). NO: Study retention was less than 70% of participants who initially agreed to be in the study, as calculated by the entire sample not by groups.
Baseline groups equivalence	YES: Tests were conducted to determine if groups were equivalent at baseline on important variables (height, weight, BMI, etc.). NO: Baseline tests indicate groups have differences at baseline. UK: Tests are not mentioned.
Missing data	YES: Analyses were conducted with consideration for missing data that maintain fidelity of the randomization (e.g., intent to treat, imputation) or 100% retention. NO: Listwise case deletion (completer analysis). Studies that failed to explicitly mention how they dealt with missing data. Authors compared the “dropped subgroup” with the selected or randomized sample but did not consider the impact of the dropped subgroup on randomization (e.g., intent to treat or imputation).
Power analysis	YES: Power analysis was conducted to determine sample size and/or effect size. NO: Neither sample size was determined by power analysis nor was effect size reported.
Validity of measures	YES: Descriptions of measures included reliability and validity information, either as reference or coefficients. Measures were considered to be known, well-established measures. Objective measures were used as indications of behaviors. NO: Descriptions of measures did not include reliability and validity measures. Objective behaviors were used as proxy measures.
Design quality score	Percentage of YES coded

Note. AVG = active video game; BMI = body mass index.

the *PlayStation 2 EyeToy*. Other AVGs included games played on the *Wii* console (e.g., *Wii Sports*) and the *GameBike* system.

Among the 13 intervention studies, 8 employed randomized control trials (Table 3). Samples sizes ranged from 12 to 60 participants. The design quality of the studies ranged from a score of 22 to 100, with a mean score of 68. Two thirds of the studies explained how they dealt with missing data or did not have missing data. Three studies conducted power analysis for sample size calculation. Two studies failed to retain at least 70% of the participants.

Three studies found that the AVG treatment was more effective than the control group or the comparison group in increasing the amount of physical activity or exercise attendance. Three studies found no difference between the AVG intervention and the control group. One study found

that the AVG treatment was worse than the comparison condition in influencing exercise attendance and energy expenditure during exercise. Six studies had indeterminate results, indicating that the study design was not adequate to demonstrate whether the AVG intervention was effective due to lack of a control group or non-AVG comparison group.

Discussion

The goal of this systematic review was to provide a comprehensive synthesis of the current state of knowledge pertaining to the potentials of AVGs for physical activity promotion for both children and adults. Forty-one studies published between 2002 and 2011 were included in this review, adding 18 laboratory studies and 7 intervention studies that were not

Table 4. Design Quality Analysis of Intervention Studies

Study	Individual Randomization	Control Group	Isolate AVG	Pre-Post Test Design	Retention $\geq 70\%$	Baseline Groups Equivalence	Missing Data	Power Analysis	Validated Measures	Design Quality Score (Maximum Score = 100)
Adamo, Rutherford, and Goldfield (2010)	Y	Y	Y	Y	Y	Y	N	Y	Y	89
Chin A Paw, Jacobs, Vaessen, Titze, and van Mechelen (2008)	Y	Y	N	Y	N	Y	N	N	Y	56
Fogel, Miltenberger, Graves, and Koehler (2010)	N	N	N	Y	Y	N	Y	N	N	33
Graves, Ridgers, Atkinson, and Stratton (2010)	Y	Y	Y	Y	Y	Y	Y	Y	Y	100
Madsen, Yen, Wlasiuk, Newman, and Lustig (2007)	N	N	N	Y	Y	N	N	N	Y	33
Maloney et al. (2008)	Y	Y	Y	Y	Y	Y	Y	N	Y	89
McDougall and Duncan (2008)	N	N	N	N	Y	N	Y	N	Y	33
Ni Mhurchu et al. (2008)	Y	Y	Y	Y	Y	Y	Y	N	Y	89
Paez, Maloney, Kelsey, Wiesen, and Rosenberg (2009)	Y	Y	Y	Y	Y	Y	Y	N	Y	89
Rhodes, Warburton, and Bredin (2009)	Y	Y	Y	Y	Y	Y	Y	Y	Y	100
Trout and Zamora (2006)	N	N	N	Y	Y	Y	Y	N	Y	56
Warburton et al. (2007)	Y	Y	Y	Y	Y	Y	Y	N	Y	89
Wollersheim et al. (2011)	N	N	N	Y	N	N	N	N	Y	22

Note. AVG = active video game.

included in Biddiss and Irwin (2010). The discussion section is organized by the summary of findings and implications of laboratory studies and intervention studies for two age groups: children and adults. Limitations are also discussed.

AVG Intensity

This review included 28 laboratory studies quantifying intensity and energy expenditure of AVGs among healthy children and adults, which adds substantially more studies to the summary of 12 such studies in Biddiss and Irwin (2010). All the lab studies that compared enjoyment of AVGs and other traditional exercise activities found that AVGs were better liked than traditional exercises, such as treadmill walking or jogging (Barkley & Penko, 2009; Graves, Ridgers, Williams, et al., 2010; Penko & Barkley, Sell et al., 2008).

Children. This review added seven studies on AVG intensity and energy expenditure among children that were not included in Biddiss and Irwin (2010). These seven studies provide a consistent finding that playing AVGs generally is equivalent to light-to-moderate physical activity among children. In addition, children rated the perceived exertion of playing AVGs to be similar to activities with lower intensity (Haddock, Siegel, & Wikin, 2009). In other words, AVG play demands physical exertion from the players yet they are so engaged in the games that they are not aware of the physical

exertion. This suggests that AVG may be a good starting point to engage sedentary children to a more active lifestyle by overcoming one of the most significant barriers of physical activity—fatigue. However, it needs to be noted that only relying on AVGs as a tool for physical activity among children is not enough since the light-to-moderate intensity of AVG play does not meet the daily 60-minute MVPA goal for children.

Adults. This review provides the first systematic summary of intensity of AVG play among adults, which reveals similar results as in the children sample. The intensity of AVG play among adults was light to moderate. Adults rated the perceived exertion of AVG play to be similar to activities with higher metabolic requirement (Warburton et al., 2009), suggesting that AVGs also are a good tool to involve physical inactive adults to start a more active lifestyle. In particular, two studies also examined AVG play among older adults (Graves, Ridgers, Williams, et al., 2010; Guderian et al., 2010). Not surprisingly, energy expenditure of AVG play among older adults was found to be less than children and young adults. In fact, older adults enjoyed the lower intensity AVGs such as *Wii Fit* more than their younger counterparts (Graves, Ridgers, Williams, et al., 2010). Seniors' rating of the perceived exertion of an AVG (*Wii Fit*) was relatively low (Guderian et al., 2010). Overall, the light-to-moderate intensity of AVGs suits the recommended physical activity

Table 5. Summary of Laboratory Study Characteristics

Authors	Sample	Study Design	Experimental Conditions	Exergame and Duration	Gender Differences	Key Measures	Key Results	AVG Metabolic Equivalent
Barkley and Penko (2009)	N = 12 (M = 6, F = 6); Ages: Male: 35.7 ± 13.3; Female: 27.3 ± 10.9	CB; PR-PT, WS	1. Treadmill walking using a controller that relied on full-body isometric muscle resistance to manipulate on-screen character (solo and against another player) 2. Sedentary sports game 3. Wii game	Wii Boxing—10 minutes	Significant difference of increase of VO ₂ for genders from sedentary to Wii Sports Boxing	Anthropometry, heart rate (HR), VO ₂ , RPE (rate of perceived exertion), liking of activity, average METs	Average METs of Wii Boxing was 4.2 METs. Significant increase in HR, VO ₂ , and perceived exertion from treadmill walking to Wii Boxing. RPE and liking were significantly greater for Wii than all other conditions.	Study authors reported average MET of Wii Boxing to be 4.4 METs
Bonetti et al. (2010)	N = 32 (M = 32); Ages: 18-30; with less than 20% body fat	MS	Experiment group: play using a controller that relied on full-body isometric muscle resistance to manipulate on-screen character (solo and against another player) Control: play using conventional handheld controller (solo and against another player)	Fuzion Frenzy Xbox 360	NA	HR, VO ₂ , RPE, energy expenditure (EE)	Significantly greater VO ₂ and EE for treatment group in both solo and competitive play than control group. No significant difference in HR and RPE between experiment and control groups. No significant differences between solo and multiplayer for any group.	Resting energy expenditure was not reported. By estimating oxygen consumption at resting to be 3.5 mL O ₂ ·kg ⁻¹ ·min ⁻¹ , we estimated MET of AVG play to be 2.74 METs.
Fawkner et al. (2010)	N = 20 (F = 20); Ages: 14 ± 0.3	PR-PT, WS	Exercise with video game (3 levels of difficulty)	Exerstation (full-body isometric controller)—30 minutes Zigzag Xer-Dance—10 minutes for each difficulty level	NA	Anthropometry, VO ₂ , EE, HR, RPE, respiratory exchange ratio (RER)	Significant increase in all response variables (apart from RER) between rest and each of the three levels of DDR.	MET of the three levels of AVG was calculated to range from 3.1 to 3.5 METs based on the resting and game play VO ₂ data. However, study authors reported 3.8-4.3 METs for the three AVG levels after applying equations used for Caucasian adolescent girls for the estimation of basal metabolic rate.
Graf, Pratt, Hester, and Short (2009)	N = 23 (M = 14, F = 9); Ages: 10-13	PR-PT, WS	1. Dance game (two levels) Dance Revolution (DDR)	Dance Dance Revolution (DDR)	Significant difference for boys' EE when playing DDR and bowling than girls	Anthropometry, HR, VO ₂ , expired ventilatory rate, RPE, step rate	Significant difference of RPE between DDR Levels 1 and 2. Significant increases in VO ₂ , EE, and HR for walking, Wii Sports and DDR. Walking and AVG significantly increased EE, VO ₂ , and HR compared with rest.	MET of the AVGs was calculated to range from 2.7 to 5.0 METs based on the resting and game play VO ₂ data.

(continued)

Table 5. (continued)

Authors	Sample	Study Design	Experimental Conditions	Exergame and Duration	Gender Differences	Key Measures	Key Results	AVG Metabolic Equivalent
Graves, Riddgers, and Stratton (2008)	N = 13 (M = 7, F = 6); Ages: 11-17	PR-PT, RO, WS	2. Wii games	Wii bowling	No significant difference in EE between boys and girls for rest, walking, or boxing		The highest EE was measured at Level 3 of the dance game; the highest RPE was Level 2 of dance game, followed by the boxing AVG and fastest treadmill setting.	
			3. Treadmill at 3 different velocities while watching cartoons	Wii boxing—15 minutes of each	Near significant difference for boys' decline in small-artery elasticity			
			4. Watching television	Wii Sports (bowling, tennis, boxing)—15-minute sessions of each game followed by 5 minutes of rest	Significant increase for girls' HR during active games compared with boys	Anthropometry, HR, VO ₂ , EE activity counts by accelerometer, METs	EE and HR were highest during AVG boxing game compared with all other games.	Authors reported MET of the AVGs ranged from 2.2 to 3.2 METs.
			1. Sedentary game					
Graves, Riddgers, Williams, et al. (2010)	N = 42 (M = 27, F = 15); Ages: 11-17 (N = 14); 21-38 (N = 15); 45-70 (N = 13); M = 15, F = 27	PR-PT, WS	2. Wii games at the next session	Wii Balance Board: (Yoga, muscle conditioning, balance, aerobics)—2 sessions: Familiarization and lab session with each game play for 10 minutes, resting 5 minutes in between	Not reported	Anthropometry, VO ₂ , EE, METs, HR, enjoyment	Wii Fit activities were significantly more active than handheld gaming and lower than treadmill activities.	Author reported MET of the AVGs ranged from 1.7 to 3.6 METs.
			3. Treadmill jogging					
	4-7. Wii balance board games						Enjoyment of all Wii games except the yoga game was greater than handheld gaming and treadmill walking. Older adults enjoyed the treadmill more than young adults and adolescents and had significantly lower EE than the other groups.	

(continued)

Table 5. (continued)

Authors	Sample	Study Design	Experimental Conditions	Exergame and Duration	Gender Differences	Key Measures	Key Results	AVG Metabolic Equivalent
Graves, Stratton, Ridgers, and Cable (2008)	N = 11 (M = 6, F = 5); Ages: 13-15	PR-PT, WS	All participants played sedentary video games for 2 hours a week without exposure to Wii. For the experiment, participants played 1 sedentary session and 3 active gaming sessions	Wii Sports (bowling, tennis, boxing)—15-minute sessions of each game followed by 5 minutes of rest	Significant difference in boys' predicted EE during AVG tennis game than girls	Anthropometry, IDEEA system for EE	Significant increase for EE for AVGs compared with sedentary games.	MET of the AVGs was calculated to range from 2.3 to 2.5 MET's based on resting EE (calorimetry data) and AVG EE (non-calorimetry) data.
Guderian et al. (2010)	N = 20 (M = 10, F = 10); Ages: M = 58.1 ± 8.8	PR-PT, WS	1. Warm-up active gaming sessions	Nintendo Wii Fit Games: Walk/Jog, Soccer, Hula Hoop, Ski, Step, Penguin Play each game 2-6 minutes Two sessions on nonconsecutive days	Significant difference in EE, likely because the men are heavier than the women	Anthropometry, HR, VO ₂ , EE, RPE, METs	HR for the AVG was 108.1 ± 18 beats/min, EE for the AVG was 116.2 ± 40.9 kcal/session. RPE was low (2.6 ± 0.9).	Authors reported average MET of AVGs to be 3.5 METs.
Haddock, Brandt, Siegel, Wilkin, and Joung-Kyue (2008)	N = 23 (M = 18, F = 5); Ages: 7-14, overweight	PR-PT, WS	XaviX Games	Jackie Chan Studio Fitness Games (Action Run, Vigorous Step, Dash, Reaction Time)—30 minutes in total	None reported	Anthropometry, VO ₂ , EE, RER	Significant difference in VO ₂ and EE during video game play time compared with rest.	Average MET was calculated to be 3.5 METs based on reported VO ₂ during AVG and at rest.
Haddock Siegel, and Wilkin (2009)	N = 20 (M = 13, F = 7); Ages: 7-14	PR-PT, RO, WS	1. Familiarization, testing session 2. Testing Session No. 1 (GameBike with cars) 3. Testing Session No. 2 (stationary biking)	Disney's Cars—20 minutes	No significant differences found between boys and girls on baseline characteristics	Anthropometry, HR, VO ₂ , RPE	Significant increase in VO ₂ and EE with the addition of a video game to the stationary biking condition. No significant difference in HR or RPE between two conditions.	The average MET of AVG was calculated to be 4.7 METs based on reported resting EE and AVG EE.
Lanningham-Foster et al. (2006)	N = 25 (M = 12, F = 13); Ages: 8-12; Overweight: 10; Normal weight: 15	PR-PT, WS	1. Watching TV seated 2. Playing sedentary video game seated 3. Watching television while walking on treadmill at 1.5 miles per hour 4. playing AVG	DDR, PS2 Eye Toy (Nicktoon's Movin')—3-minute familiarization and 15-minute of each AVG play followed by 5-minute rest	None found	Anthropometry, EE	Significant increase in EE when playing exergames compared with sitting, watching TV, and seated video gaming.	MET was calculated to be 2.1 MET's and 2.7 MET's for Eye Toy and DDR, respectively, based on reported resting EE and AVG EE.

Table 5. (continued)

Authors	Sample	Study Design	Experimental Conditions	Exergame and Duration	Gender Differences	Key Measures	Key Results	AVG Metabolic Equivalent
Lanningham-Foster et al. (2009)	N = 42 (M = 21, F = 21); Children = 22 (M = 11, F = 11); Ages: 9-14; Adults = 20 (M = 10, F = 10); Ages: 18-56	PR-PT, WS	1. Standing	Wii Sports Boxing—3-minute familiarization and 10-minute AVG play	None reported	Anthropometry, EE, activity count	Significant increase in EE during Wii play compared with all other activities.	MET of Wii Sports playing was calculated to be 4.2 METs for children and 3.1 METs for adults based on reported resting EE and AVG EE.
Leatherdale, Woodruff, and Manske (2010)	N = 51 (M = 30, F = 21); Ages: 18.9 ± 0.9	PR-PT, WS	1. Inactive video game 2. Watching television seated 3. Sitting and playing sedentary video game 4. Playing Wii games 1. Inactive video game Mario Tennis Gamecube	Wii Sports Tennis—30 minutes	Significant difference in EE when playing either the GameCube or the Wii for males compared with females.	Anthropometry, EE based on armband, HR, time active, METs	Significant increase in EE when playing the Wii compared with inactive video gaming.	The authors estimated the average MET of AVG was 5.4 METs (noncalorimetry).
Lyons et al. (2011)	N = 100 (M = 50, F = 50); Ages: 18-35, 55% overweight	PR-PT, RO, WS	1. Traditional controller games shooter game (sedentary) 2. Wii games	AVGs include Guitar Hero III: Legends of Rock, Rock Band 2, DDR, Wii Fit balance, aerobit, jogging, penguin slide, hula hoop, and skiing. Games played for 13 minutes each, 5-10 minutes resting for a total of 4 hours	Gender not significantly different for EE. No gender differences in enjoyment.	Anthropometry, Enjoyment, EE, VO ₂	Significant increase in active time when playing the Wii. Significant difference in EE across AVG game type compared with sedentary games. Band simulation games were the most enjoyable. The AVGs with greater METs were perceived to be less enjoyable than other more sedentary games. Nonoverweight participants enjoyed games less than overweight participant.	MET of AVGs was calculated to range from 1.7 METs to 4.0 METs based on the reported rest EE and AVG EE.
Maddison et al. (2007)	N = 21 (M = 11, F = 10); Ages: 10-14	PR-PT, RO, WS	1. Inactive video game 2. Wii remote controller shooter game (sedentary) 3. Instrument controller 4. Dance pad game 5. Wii balance board games 2. Playing AVG	EyeToy Knockout Homerun Groove Antigravity PS2 Dance UK	None found	Anthropometry, HR, VO ₂ , EE, activity count, METs	Significant increase for EE, HR, and activity counts for active games compared with resting and nonactive games.	Authors reported MET of AVGs ranged from 2.3 METs to 5 METs.

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Table 5. (continued)

Authors	Sample	Study Design	Experimental Conditions	Exergame and Duration	Gender Differences	Key Measures	Key Results	AVG Metabolic Equivalent
Mellecker and McManus (2008)	N = 18 (M = 11, F = 7); Ages: 6-12	PR-PT, WS	1. Seated bowling	20-Minute familiarization period followed by 5 minutes of rest and 5 minutes of playtime for each condition Xavix bowling	Not reported	Anthropometry, VO ₂ HR, EE	Significant increase in EE during seated gaming, and AVG compared with rest. Significant increase in EE in AVG compared with seated gaming. Significant increase in HR during AVG compared with rest and seated gaming.	MET of AVGs was calculated to range from 2.0 to 5.0 based on reported resting EE and AVG EE.
Miyachi, Yamamoto, Ohkawara, and Tanaka (2010)	N = 12 (M = 7, F = 5); Ages: 25-44	PR-PT, RO	1. Wii Sports games 2. Active bowling 3. Active mat game	5-Minute familiarization and 5 minutes game play Wii Fit Plus: 63 activities classified as yoga, resistance, balance, and aerobic exercises Wii Sports (golf, bowling, tennis, baseball, boxing)	No significant difference in MET between genders.	VO ₂ , Anthropometry, METs	Significant difference in MET between yoga and balance exercises and resistance and aerobic exercises (all Wii). Wii Sports golf, bowling, baseball, tennis, and boxing had markedly lower MET values than actual sports. Wii Sports Yoga and resistance exercises were similar to actual sports.	Authors reported the average MET of the 68 AVG activities ranged from 1.3 to 5.6 METs.
Penko and Barkley (2010)	N = 24 (M = 12, F = 12); Ages: M = 12; Overweight = 11; Lean = 13	CB, PR-PT, WS	3. Wii Fit Plus balance and resistance exercises 1. Treadmill walking	Play each activity for at least 8 minutes Wii Sports Boxing—10 minutes	No main or interaction effects of gender	Anthropometry, HR, VO ₂ , liking, RRV (relative reinforcing value), liking, RPE	VO ₂ HR significantly increased from resting to sedentary game play to treadmill walking to AVG. VO ₂ significantly increased from resting to sedentary to treadmill walking to AVG. Liking did not differ between treadmill and sedentary condition, but it was greater for the AVG than the other conditions.	MET of playing Wii Sports Boxing was calculated to be 2.3 METs based on resting VO ₂ and AVG VO ₂ data.
			2. Physically Active Wii game 3. Sedentary video game					

(continued)

Table 5. (continued)

Authors	Sample	Study Design	Experimental Conditions	Exergame and Duration	Gender Differences	Key Measures	Key Results	AVG Metabolic Equivalent
Sell, Lillie, and Taylor (2008)	N = 19 (M = 19); Ages: 21.8 ± 3.5	PR-PT, BS	1. Graded treadmill walking	DDR—30 minutes	NA	Anthropometry, HR, VO ₂ , EE, step count, RPE, RER, enjoyment	RPE was not significantly different for the treadmill from other conditions, but it was significantly different for the AVG than the sedentary game. Lean children had greater RRV from the AVG relative to the sedentary condition, while overweight children's RRV did not differ from the two conditions.	MET was calculated to be 3.4 METs for inexperienced players and 6.5 METs for experienced players based on reported rest VO ₂ and AVG VO ₂ data.
Siegel et al. (2009)	N = 13 (M = 6, F = 7); Ages: 26.6 ± 5.7	PR-PT, WS	2. DDR game play Subjects chose to play three active video games and they could switch between games	3-Kick	Significant increase in EE for males compared with females	Anthropometry, VO ₂ , HR, EE	AVG play over treadmill walking. Significant increase from baseline for HR and EE when playing AVGs.	
Straker and Abbott (2007)	N = 20 (M = 12, F = 8); Ages: 9-12	PR-PT, WS	1. DVD watching 2. Played games using different video game devices (handheld, gamepad, keyboard, wheel, PS2 EyeToy)	Jackie Chan Studio Fitness Power Boxing Disney's Cars Piston Cup Race EyeToy Cascade 30 minutes in total	No significant gender main effects or device by gender interaction effects for HR, VO ₂ and EE.	Anthropometry, HR, VO ₂ , EE	Significant increase in VO ₂ for the 3-kick game than the boxing game. No significant difference between three AVGs for HR.	MET of AVG play was calculated to range from 3.3 to 4.7 METs based on reported rest EE and AVG EE data.
							The AVG had significantly greater levels for all measures compared with the other devices. The wheel was significantly greater than DVD for all variables and was greater than the keyboard for all except HR. The handheld was significantly less than the gamepad for all except HR.	MET of AVG (EyeToy game) was calculated to be 3.3 METs based on reported resting EE (watching DVD) and AVG EE data.

(continued)

Table 5. (continued)

Authors	Sample	Study Design	Experimental Conditions	Exergame and Duration	Gender Differences	Key Measures	Key Results	AVG Metabolic Equivalent
Stroud Amonette and Dupler (2010)	N = 19; M = 12 (Age: 30.2 ± 6.4), F = 7 (Age: 29.1 ± 7.8)	PR-PT, RO, WS	1. Treadmill	Wii Sports: Bowling	No significant difference	Anthropometry, VO ₂ , HR, EE	The high AVG condition had the greatest value in all variables compared with low AVG and sedentary game, and rest.	MET was calculated to be 1.5 METs for low activity AVG and 3.2 METs for high activity AVG based on reported rest EE and AVG EE.
Tan, Aziz, Chua, and Teh (2002)	N = 40 (M = 21, F = 19); Ages: 17.5 ± 0.7	PR-PT, WS	1. DDR 2. Game playing of 3 video games: control (sedentary game), low activity AVG, and high activity AVG	Mario and Sonic at the Olympic Games 2 sessions (10 minutes each)	Significantly greater value of VO ₂ for males than female in AVG	Anthropometry, HR, VO ₂ , RPE	Mean HR was 137 beats/min. Mean VO ₂ was 24.6 mL kg ⁻¹ min ⁻¹ . RPE was 11.	MET of AVG was calculated to be 3.5 METs based on reported rest VO ₂ and AVG VO ₂ data.
Umnithan, Houser, and Fernhall (2006)	N = 22 (M = 16, F = 6); Ages: 11-17; Overweight: 10; Normal weight: 12	PR-PT, BS	1. Treadmill walking	DDR 12-minute game play session Participants danced for a total of six songs.	Not reported	Anthropometry, EE, VO ₂ , HR, RER	VO ₂ overweight children expended significantly more calories/min playing AVG.	MET of AVG was calculated to be 2.4 METs for overweight children and 3.0 for nonoverweight children based on rest VO ₂ and AVG VO ₂ data.
Warburton et al. (2009)	N = 14 (F = 7, M = 7); Ages: 24.6 ± 4.2	PR-PT, RD, BS	1. Stationary cycling at 3 workloads 2. DDR	ATV Off-road Fury for GameBlade 3 sessions over 3 days	Males had significantly higher VO ₂ and EE. Females had significantly higher HR	Anthropometry, RPE, EE, HR, VO ₂	Significantly greater value in VO ₂ , HR, and EE in AVG condition than stationary cycling condition. No difference in RPE.	Unable to calculate specific AVG MET (specific numeric EE data were not reported). However, based on the data reported (energy expenditure was 240-320 kcal over 30-minute period for participants with average weight of 70 kg), AVG MET should be over 6 METs.

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Table 5. (continued)

Authors	Sample	Study Design	Experimental Conditions	Exergame and Duration	Gender Differences	Key Measures	Key Results	AVG Metabolic Equivalent
White, Schofield, and Kilding (2011)	N = 26 (M = 26); Ages: 1.4 ± 0.8	PR-PT, RO, WS	Randomly assigned AVGs (10 minutes of each game) and sedentary activity (resting, watching television and sedentary gaming)	Wii Sports: (boxing, tennis, bowling)	NA	Anthropometry, EE, HR, VO ₂ shuttle run, METs	EE significantly higher for all AVGs than sedentary activity, HR increased significantly during all activities, with the greatest for boxing. Running EE significantly higher than AGVs. No significant difference between walking and Wii boxing and step aerobics. No differences in VO ₂ , EE, or HR for fitness levels of participants during AVG play.	Authors reported MET of AVGs to range from 1.9 to 3.2 METs.
Willems and Bon (2009)	N = 10 (M = 7, F = 3); Ages: 20-22	PR-PT, WS	1. Wii Sports tennis, baseball, boxing 2. Treadmill walking	Wii Fit: (step aerobics, skiing) 8 minutes of each game analyzed Wii Sports: (tennis, baseball, boxing)	No significant gender differences	Anthropometry, VO ₂ , HR, EE, RER	The HR for tennis and baseball was lower than boxing and treadmill walking. There was no difference in average HR for boxing and walking.	MET of AVGs was calculated to range from 1.9 to 3.2 METs based on resting VO ₂ (not reported in study but provided by authors) and reported AVG VO ₂ data.
Wonley, Rogers, and Kraemer (2011)	N = 8 (F = 8); Ages: 21.88 ± 2.2	CB, WS	Wii fit	Wii Fit: Aerobic step, hula (3, 10 minutes of each game stage)	NA	Anthropometry, VO ₂ , HR, BP, RPE, EE	Boxing and walking had higher VO ₂ levels than tennis or baseball. Boxing had higher EE than baseball, but not tennis or walking. AVG and walking RER values were not different.	Unable to calculate specific MET for AVG. However, based on reported data (intensity of AVG was estimated to be similar to walking at the speed from 2.5 to 3.6 miles/h), MET of AVG should be between 1.5 and 3 METs.

Note. BS = between-subjects design; CB = conditions counterbalanced; F = number of female participants; M = number of male participants; MID = mixed design; N = Sample size; PR-PT = pretest to posttest design (resting/sedentary activity is treated as pretest); PT = posttest only; RO = conditions in random order; WS = within-subjects design; NA = not applicable; MET = metabolic equivalent.

Table 6. Summary of Intervention Study Characteristics

Authors	Sample	Study Design and Duration	Intervention Group	Control Group	Gender Difference	Key Outcome Measures	Key Results
Adamo, Rutherford, and Goldfield (2010)	N = 26 (M = 12, F = 14); Ages: 12-17; BMI > 95th	RD, TC, PR-PT	GameBike with PS2 race-based games	Standard biking with music	None reported	Exercise adherence (attendance), anthropometry, body composition, aerobic fitness, HR, RPE, EE, blood work (insulin, glucose, cholesterol), food diary	Both conditions had significant improvements of aerobic fitness and decrease of body fat percentage and total cholesterol.
	Lab based	Two 60-minute sessions/week; 10 weeks					Comparison group attended small but significantly more of the 20 sessions. No significant difference in groups for HR, workload, time to exhaustion, RPE, blood work, except for cholesterol. Biking with music group had higher rate of attendance, significantly higher peak HR, and distance pedaled.
Chin A Paw, Jacobs, Vaessen, Tizze, and van Mechelen (2008)	N = 27 (M = 2, F = 14, 11 dropped out); Ages: 9-12; Home and school based	RD, TC, PR-PT	Interactive Dance Video Game played at home and in group setting	Interactive Dance Video Game played at home only	Not reported	Self-reported PA and sedentary behavior; motivation of playing AVG (dropout rate)	Significant lower dropout rate in multiplayer compared with home group.
Fogel, Miltenberger, Graves, and Koehler (2010)	N = 4 (M = 2, F = 2); Ages: 9; School based, inactive children	WS	DDR, Gamerize PS with Batman and Robin, Three Rivers Game Cycle, Sports Dog Flight Simulator, Cateye Virtual Bike, Nintendo Wii Sports Baseball, Tennis, Boxing, Fitness XrBoard, Fit Interactive 3 Kick	NA	None reported	Total minutes of physical activity, opportunities to engage in physical activity, preference	No significant differences between groups for video game play time. Higher PA minutes and opportunities to engage in PA during exergaming than PE condition. Exergaming was preferred by students over PE.
Graves, Ridgers, Atkinson, and Stratton (2010)	N = 58 (gender distribution not reported); Ages: 8-10; Home based	RD, TC, PR-PT	Participants were provided 2 jog controllers to play AVG	Delayed treatment	Not reported	PA and sedentary behavior; preference, PA minutes (accelerometer), anthropometry, body composition	No statistically significant PA differences between control and treatment. Significant increase in active gaming and decrease in sedentary gaming in treatment group. No body fat changes. Nonsignificant decrease in step count from Weeks 6 to 12 in treatment group.
Madsen, Yen, Wlasiuk, Newman, and Lustig (2007)	N = 30 (M = 12, F = 18, 9 dropped out); Ages: 13 ± 2.6; Home based	6 weeks plus follow-up at 12 weeks PR-PT, WS	DDR	NA	Not reported	Self-reported DDR use, anthropometry	Use of DDR was not associated with change in BMI from baseline at either 3 or 6 months. Use of game decreased over time. Thirteen subjects (four of whom used DDR at least twice a week) reported finding DDR boring within as few as 4 weeks.

(continued)

Table 6. (continued)

Authors	Sample	Study Design and Duration	Intervention Group	Control Group	Gender Difference	Key Outcome Measures	Key Results
Maloney et al. (2008)	N = 60 (F = 30, M = 30); Ages: 7.5 ± 0.5; Home based	6 months RD, TC, PR-PT	DDR	Delayed treatment	Not reported	PA minutes (accelerometer), self-reported sedentary screen time, body composition; anthropometry, seated blood pressure and pulse use of DDR, satisfaction of DDR (focus group and survey)	DDR play was highest during week 1 (89 min), and decreased by half by final week. No significant differences between control and treatment for vigorous, moderate, light, or sedentary physical activity. Significant increase in vigorous physical activity in intervention group from baseline. Significant decrease in sedentary screen time in intervention group compared with control group. 95% youth endorsed liking DDR. Participants in both group demonstrated increases in BMI. The average video game activity was 24 minutes and the average heart rate was 148 bpm. AVG resulted in an average of 11 minutes sustained MVPA. Children reported liking AVGs as an alternative to traditional PA.
McDougall and Duncan (2008)	N = 12 (M = 5, F = 7); Ages: 8-11; PT; WS School based	10 weeks Follow-up at Week 28	PlayStation EyeToy physically active video games	NA	Boys acquired significant more steps than girls.	Physical activity level during game (pedometer and heart rate monitor), liking (focus group)	
Ni Mhurchu et al. (2008)	N = 20 (M = 12, F = 8); Ages: 10-14; Home based	5 days RD, TC, PR-PT	PS2 EyeToy and dancepad games	Delayed treatment	Boys were more active than girls in aggregate PA.	PA minutes (accelerometer), estimated EE, anthropometry, body composition, Physical Activity Question-Children, activity log	No
Paez, Maloney, Kelsey, Wiesen, and Rosenberg (2009)	N = 60 (F = 30, M = 30); Ages: 7-8; Home based	12 weeks RD, TC, PR-PT	DDR	Delayed treatment	Not reported	PA minutes (accelerometer), anthropometry, body composition, DDR use, parent support, home assessment	Significant differences in time spent in MVPA between the two groups. AVG group played game an average of 41 minute/day. Significant decrease in playing all video games and inactive games compared with control. Body weight (0.13 kg) and waist circumference (1.4 cm) decreased in AVG group. No significant difference between the effects of high vs. low parental support on DDR participation. Home environment predicted participation in DDR. DDR playing decreased from 75% at Week 1 to 55% at Week 10. At Week 1, absence of other video games and parent participation was associated with child DDR participation. At Week 10, sibling and friend participation was associated with child DDR participation. 95% of parents reported that they liked DDR as a form of physical activity for their children.
		10 weeks					

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Table 6. (continued)

Authors	Sample	Study Design and Duration	Intervention Group	Control Group	Gender Difference	Key Outcome Measures	Key Results
Rhodes, Warburton, and Bredin (2009)	N = 32 (3 dropped out); Ages: M = 22.7, SD = 4; M = 29; Lab based	RD, TC, PR-PT	GameBike system with PS2 games (Smuggler's run, ATV offroad Fury, Gran Turismo 3, Nascar Heat, Need for Speed)	Standard bicycle. Participants were encouraged to bring personal music selection	NA	HR, Exercise adherence, Exercise attitude, Affective attitude, instrumental attitude, Perceived behavioral control, Exercise intention	Affective attitude and adherence across the 6 weeks significantly favored the AVG condition over the comparison condition.
Trout and Zamora (2006)	N = 26 (M = 12, F = 14); Ages: 18-30; Lab based	6 weeks PR-PT, WS 3 lab sessions per week over 8 weeks	PS2 EyeToy games; DDR	NA	Males burned more calories per 20-minute session playing DDR compared with females. Males competed with themselves or against the game more often than females.	HR, body composition, Physical Activity Enjoyment Scale, self-reported PA minutes, nutrition diary	Significant decrease in posttest body weight and percentage body fat from pretest. Most participants (81%) reported a high level of enjoyment for the AVG.
Warburton et al. (2007)	N = 14; Ages: 18-25; M = 14, Low active Lab based	RD, TC, PR-PT	GameBike system with PS2 games (Smuggler's run, ATV offroad Fury, Gran Turismo 3, Nascar Heat, Need for Speed)	Standard bicycle	NA	Body composition, anthropometry, blood pressure, aerobic and musculoskeletal fitness, exercise adherence (attendance)	Significant greater attendance in treatment group than control.
Wollersheim et al. (2011)	N = 11 (F = 11); Ages: 56-84; Community program	6 weeks PR-PT, WS two times per week for 6 weeks plus 6-week follow up	Nintendo Wii	NA	NA	PA minutes (accelerometer), focus group sessions about psychosocial effects	Significant increase in energy expenditure (cardiorespiratory exchange) for treatment group and power output. No significant difference in body composition and musculoskeletal fitness. Attendance mediated the relationships between condition and changes in health outcomes such as systolic blood pressure. No significant difference in physical activity over the course of the intervention, slight increase in inactivity. Wii sessions were brief bursts of moderate to vigorous activity. Psychosocial qualitative interviews showed that AVG provided a social venue and facilitated communication among players. Participant reported increased motivation for PA and cognitive benefits.

Note. F = number of female participants; M = number of male participants; N = sample size; PR-PT = pretest-posttest design; PT = posttest only; RD = randomized design; TC = treatment to control comparison; WS = within-subjects design; NA = not applicable; AVG = active video game; PA = physical activity; HR = heart rate.

for the older adults, making them a more suitable tool of physical activity for the older adults than for children.

AVG Physical Activity Interventions

Thirteen intervention studies that used AVGs to promote physical activity among nonrehabilitative individuals were systematically reviewed. Overall, only three studies demonstrated that playing AVGs resulted in increased physical activity compared with the control group or the comparison group. Among these 13 studies, only six overlapped with Biddiss and Irwin's (2010) systematic review of AVGs to promote physical activity in children.

Children. Only one study with children found that the AVG was effective in increasing physical activity. Among the nine AVG-based interventions with children, four studies reported the participants' attitudes toward AVG, and one reported the parents' attitudes. Three studies reported that the children liked the AVG (Fogel Miltenberger, Graves, & Koehler, 2010; Maloney et al., 2008; McDougall & Duncan, 2008), and one study reported that most children found the AVG boring within 4 weeks (Madsen, Yen, Wlasiuk, Newman, & Lustig, 2007). More than 90% of parents liked AVG as a form of physical activity for their children. Overall, the nine AVG intervention studies with children demonstrated that usage of AVGs was low after the initial period. This implied that although studies found that AVGs are typically liked or enjoyed more than traditional exercise (Barkley & Penko, 2009; Graves, Ridgers, Williams, et al., 2010; Penko & Barkley, 2010; Sell, Lillie, & Taylor, 2008) in a short lab session, relying solely on self-directed use of an AVG over time might decrease the success of such interventions. It has been suggested that deploying AVGs in a group setting and incorporating multiplayer mode may contribute to sustained usage of an AVG (Daley, 2009; Russell, 2009). Additionally, rather than using one game, multiple games, especially games with story and plot development (Baranowski et al., 2011), might be needed for sustainability.

Only one study (Adamo, Rutherford, & Goldfield, 2010) specifically targeted overweight and obese children, employing the *GameBike* system. Unlike the studies with adults that found *GameBike* increased exercise adherence compared with standard biking training or biking training with music, this study found that biking with music was found to be more effective than *GameBike* (biking with video game play) in exercise adherence and time spent in vigorous intensity and distance among overweight children. Nevertheless, both biking with music and biking with video game play improved physical fitness similarly. Two studies using AVGs for overweight and obese children (Murphy et al., 2009; Radon et al., 2011) were not included in the systematic review because of their lack of physical activity measures (physical fitness and weight reduction were the main focus of these two studies). Although Murphy and her colleagues (Murphy et al., 2009) found that the AVG improved

aerobic fitness and other health-related outcomes among overweight adolescents compared with the delayed control group, Radon et al. (2011) found that obese children in a clinical setting had low interest in the devices when they were offered the options to freely choose to play AVGs. Thus, the suitability of using AVGs for weight reduction for adolescents cannot be ensured. The intervention protocol of Murphy et al. (2009) was not described in detail; therefore, it is unknown whether the AVG treatment was administered at home in a self-directed manner or in a lab with a structured program. However, the overall findings of this systematic review suggest that although AVGs have the potential to engage and motivate inactive individuals, especially those who log a significant portion of sedentary time in screens (e.g., video game play), relying on AVG alone for weight loss is not realistic, especially if AVGs are not used in a structured program but are only offered to the participants for self-directed use. Although active video gaming is generally considered as a nonprogrammed physical activity, researchers should study whether using these AVGs in a more structured manner may increase the usage.

Adults. This review provides the first systematic summary of evidence regarding the potential of AVGs for physical activity promotion among adults. Adults had positive attitude toward AVGs and found AVGs to be enjoyable (Rhodes, Warburton, & Bredin, 2009; Trout & Zamora, 2006; Wollersheim et al., 2011). Only two interventions targeting adults employed the design of randomized controlled trial, and both studies demonstrated that AVG increased physical activity attendance. In fact, both studies employed the *GameBike* system. The *GameBike* requires the player to pedal and steer on a stationary bike to control the gameplay (e.g., car racing). Unlike the *Wii* system in which the body movement is completely self-directed, allowing the players to exploit energy saving strategies while playing games, the *GameBike* has resistance settings to ensure the energy expenditure for MVPA. It seems that the *GameBike* has the potential to be used in a more structured physical activity promotion program for adults, capitalizing on the motivating power of video game play.

Only one intervention study involved older adults. The finding suggests that although older adults perceived an improved sense of physical, social, and psychological well-being from playing *Wii*, the overall physical activity level did not change from baseline after the introduction of *Wii*. The lack of change may be explained that only two participants played the games standing up. All the other participants chose to play the games sitting down, either because of a lack of physical mobility or as a result of peer influence. Two participants even dropped out because of embarrassment about using the *Wii*. This finding suggests that researchers need to consider the setting of an AVG-based intervention for the target population, especially for special groups such as older adults and the obese and overweight population.

Implications

When introducing AVGs as a tool to increase physical activity, the following precautions need to be taken. First, AVGs are not a replacement of MVPA, especially authentic physical activities or sports. Although most of the studies demonstrated that all the AVGs tested are equivalent to moderate intensity physical activity, most of them just surpass the minimal threshold of 3 METs. However, such intensity of AVGs makes them good tools for physical activity promotion for special groups, such as older adults or patients in physical rehabilitation. In fact, one study has demonstrated the potential of using AVGs to increase physical activity among adolescents with spina bifida (Widman, McDonald, & Abresch, 2006).

Second, different types of AVGs are equipped with different hardware. Some are upper body movement focused, such as the games played on the *Wii* console; some are lower body movement focused, such as the games played on the dance pad or the *Wii* balance board; and some involve both the upper and the lower bodies, such as the games played on the *PlayStation2 EyeToy* and the *GameBike*. Overall, playing AVGs focusing on the lower body and the whole body has more energy expenditure than AVGs focusing on the upper body (Peng, Lin, & Crouse, 2011). Yet it is not always true that the AVG that has the greatest intensity and produces the greatest energy expenditure is always the best choice for all the populations. Those high-intensity AVGs usually require greater video game skills and increased levels of physical fitness to start with. One study (Lyons et al., 2011) found that AVGs with greater energy expenditure were perceived by adults to be less enjoyable than AVGs with less energy expenditure. It seems that starting an intervention program using high-intensity games for obese and inactive participants may not ensure high attendance and engagement.

Third, for different populations, the AVG may also have different impacts. For instance, one study (Lanningham-Foster et al., 2009) found that AVG play can count as moderate physical activity for children but can only count as light physical activity for adults. Gender difference was also found in 10 included studies, generally favoring the use of AVG play for males. Additionally, energy expenditure was found to be greater among experienced players than inexperienced players (Sell et al., 2008). Overweight participants were also found to enjoy AVGs more than non-overweight participants (Lyons et al., 2011). Therefore, when considering employing AVGs for physical activity interventions, the characteristics of the target population need to be considered.

Fourth, it also remains unknown whether energy expenditure would be different in different settings (e.g., free play at home with friends and family; competitive play in a group setting). It would be interesting to examine whether energy expenditure would increase when individuals play in a multiplayer or competitive way. On the other hand, when the

players are too eager to win, they may adopt energy saving strategies to win the game without much energy expenditure (e.g., shaking the wrist to play *Wii Tennis*). In addition, the group-based AVG intervention may encourage participation for children, yet it may discourage participation for individuals who are embarrassed to exercise in front of other people such as older adults or overweight or obese individuals. Only one study (Bonetti et al., 2010) included in the review investigated playing against another player and found no difference of energy expenditure compared with solo play. Furthermore, although the energy expenditure of playing AVG in the laboratory demonstrated that AVG play is equivalent to light-to-moderate physical activity, energy intake during AVG play is an important issue to consider, particularly in the nonlaboratory setting, which is usually the case in the natural game play setting at home with friends and family. In fact, one study (Mellecker, Lanningham-Foster, Levine, & McManus, 2010) found that the participants consumed 383 cal/h of food during AVG play.

Limitations

This review highlighted some limitations of current research in AVG-based physical activity interventions. First, only one intervention study (Rhodes et al., 2009) specified a theoretical rationale (theory of planned behavior). However, research has shown that physical activity interventions designed and measured using behavioral theories are more likely to be successful. In fact, the AVGs in this review included only those available off-the-shelf and are not designed with the purpose to increase physical activity. As an increasing number of studies have begun to develop active games that are built for specific purposes but unavailable commercially (Betker, Desai, Nett, Kapadia, & Szturm, 2007; Housman, Scott, & Reinkensmeyer, 2009; Peng, Winn, Pfeiffer, Crouse, & Lin, 2010). More research is needed to study how health promotion practitioners, researchers, and game designers can work together to take advantage of the active platform of video gaming and specifically design physical activity promotion games. With guidance from health behavior change theories, it is reasonable to assume that active games specifically designed to promote physical activity may be more suitable to be used in physical activity interventions than the off-the-shelf AVGs. Second, the sample sizes of all the included studies were very small, limiting adequate power of these research studies. Third, 6 of the 13 intervention studies did not provide an adequate design to test for effectiveness of the AVG intervention because of lack of a control group without AVG treatment.

In conclusion, the current research shows that AVGs are capable of providing light-to-modest physical activity for both children and adults. However, little support is found regarding the long-term efficacy of using AVGs in nonstructured and self-managed manner for physical activity promotion. It seems that it is more promising to employ AVG in

structured exercise programs in a group, given that the target population is comfortable exercising in a group setting. In addition, specifically designed physical activity promotion AVGs guided by behavior change theories are needed.

Although AVGs are not new conceptually (Sinclair, Hingston, & Masek, 2007), the use of such games that provide physical activity in daily life is just beginning to be evaluated. Since 2006 when Nintendo debuted the *Wii*—a home video game console system with a controller that requires physical activity for many of its games—the at-home AVG options have significantly increased. Recently, Microsoft and Sony released active play accessories to the *Xbox 360 (Kinect)* and *PlayStation 3 (Move)*, respectively. This means that the three most popular video game systems have AVG options for people to play at home. It stands to reason that these too will be used in physical activity interventions. Additionally, mobile smart phones, tablet computers, and other portable gaming devices are emerging as possible AVG platforms. Besides their portability, these platforms also offer functions such as geospatial location tracking, pedometers, location-based knowledge presentation, and many other technologically sophisticated features that will make AVGs increasingly accessible and easily incorporated into daily life.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article:

This research was supported by a grant from the Robert Wood Johnson Foundation's Pioneer Portfolio through its national program, Health Games Research.

Note

1. Metabolic equivalent (MET) is a physiological measure expressing the energy expenditure of physical activities as multiples of the resting metabolic rate. The MET of an AVG was calculated by dividing energy expenditure during AVG play by resting energy expenditure. Only a few studies reported MET. For those studies that did not report MET, we calculated MET based on the reported physiological data at rest and during AVG play. If no physiological data at rest were reported, we estimated MET. The last column of Table 5 specifies how the MET values were obtained.

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