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Reviews

Effects of Active Videogames on Physical Activity and Related Outcomes Among Healthy Children: A Systematic Review

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Abstract

Objective: This review systematically evaluated the effects of active videogames (AVGs) on physical activity (PA) and related outcomes in healthy children.
Materials and Methods: Electronic databases were searched to retrieve articles published from January 2000 through August 2013. Included were original studies published in English, in peer-reviewed journals, that included at least one subgroup of healthy participants not older than 18 years, and that measured at least one PA-related cognitive, psychosocial, or behavioral outcome. All study designs were included, but only intervention studies with PA comparison between groups or across time were assessed for methodological quality. Evidence strength for intervention studies was stratified by settings (including the free-living home setting, the school, community, or primary care setting with structured AVG sessions [i.e., AVG play of participants was organized by teachers or researchers], and multiple settings).
Results: Fifty-four articles were identified, including 32 studies that examined the immediate PA effects (i.e., energy expenditure and PA levels during AVG play), one survey study, and 21 intervention studies aimed to promote PA. AVGs led to light- to moderate-intensity PA among studies of immediate PA outcomes. No effect was identified of AVGs on PA in the home setting. Moderate evidence was found that structured AVG play could improve PA. Inconclusive evidence was found for the effect of AVGs on PA in multiple settings.
Conclusions: The present review does not support using AVGs alone in the home setting to promote PA. Structured AVG play has the potential to promote PA in children.

Introduction

It has been evident that children have generally not reached their recommended physical activity (PA) levels.[1–4] However, children and adolescents spend substantial time engaging in sedentary activities,[5,6] such as television viewing, playing videogames, and computer use, which are thought to draw children away from PA.[7] Active videogames (AVGs) may provide innovative opportunities for PA to compete with these sedentary activities. In this review, AVG refers to any videogame requiring body movement, more than just finger usage, to control the avatar or on screen objects with or without peripheral equipment (e.g., a dance mat).

Several reviews have mainly or partially focused on the PA outcomes of AVGs in children.[7–13] All previous reviews suggested the potential of AVGs to increase PA or decrease sedentary behaviors, but found mixed or inconsistent evidence to demonstrate it. One review indicated it was more promising to use AVGs in structured exercise programs for group play.[12] However, none of these reviews has separately evaluated the effects of AVGs in structured or nonstructured play. Given that heterogeneity of study settings may facilitate or inhibit structured group play, evaluating the effects of AVGs stratified by settings may result in a clearer and more definite conclusion. The other limitations of the previous reviews were (1) including limited PA variables, (2) a mixture of children with different health statuses, and (3) not systematically reviewing the strategies used to promote PA. Also, the rapid increase in AVG studies indicates an up-to-date review is needed. The present review systematically and comprehensively evaluates the effects of AVGs on PA-related cognitive, psychosocial, and behavioral outcomes. Because health status may confound the effects, this review is restricted to healthy children only.

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Materials and Methods

Data source and search strategy

The key word strings of (child* OR adolescent* OR teenage* OR youth) AND (active video game OR exergame OR interactive game OR health game) AND (physical activity OR exercise OR fitness OR energy expenditure OR energy cost) were used to search for articles in ISI Web of Knowledge, Medline, SCOPUS, SPORTDiscus, and Ovid databases (including AMED, Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, Cochrane Central Register of Controlled Trials, Embase, and Ovid MEDLINE). Review articles were also searched for potentially useful references.

Selection criteria

Inclusion criteria were AVG articles that (1) had been published in peer-reviewed journals in English, (2) had been published from January 2000 to August 2013, because AVG technology did not exist before 2000,[9] (3) included at least one subgroup of healthy participants (including overweight and obese but without any reported dysfunction) not older than 18 years, and (4) measured at least one PA-related variable, which could be cognitive (e.g., PA self-efficacy), psychosocial (e.g., social support for PA), behavioral (i.e., energy expenditure [EE], steps, counts, or observed or self-reported PA levels), or physical fitness. Because AVG studies are still in their infancy, all study designs were included.

Studies that focused on weight control or loss but without any PA measurement were excluded. Studies that included participants who had metabolic complications, such as endothelial dysfunction, were excluded. If there were multiple publications from one AVG project, only the article with the PA outcomes was included.

Data extraction

Because of the substantial heterogeneity in AVGs, study designs, and measures of PA-related outcomes, we did not conduct a meta-analysis. Studies were divided by their PA outcomes: (1) the immediate PA effects of AVG (i.e., EE or PA levels during AVG play) and (2) the effects of AVG on habitual PA or change of PA.

To compare the EE results, different units were transformed to the same (kcal/kg/minute), and oxygen uptake (VO_2) was converted into EE using the constant of 1 L of $O_2 = 4.9$ kcal.[14] To compare the intensities of AVGs, the child-specific metabolic equivalent of task (MET) value (dividing activity VO_2 by resting VO_2) for each AVG was extracted.[15] AVG intensities are considered as light (<3 METs), moderate (3–6 METs), or vigorous (>6 METs).[16] For the intervention studies, study source, design, participant characteristics, intervention duration, setting, AVG, used strategy, and main findings were extracted.

Data synthesis

Effects of AVG interventions on PA. The effects of AVG interventions with PA comparison (between groups or across time) were examined. To compare the effects of AVG interventions on PA-related outcomes across studies, effect sizes (Hedge's *g*) were calculated when sufficient data were reported according to established formulas.[17,18] An effect size <0.5 was interpreted as small, 0.5–0.8 as medium, and >0.8 as large.[19]

Assessment of methodological quality. Methodological quality of intervention studies was assessed by one reviewer (Y.L.) and checked by another reviewer (P.W.C.L.) using a 10-item scale developed for a previous PA interventions review (Table 1).[20] Each item was rated as positive, negative, or

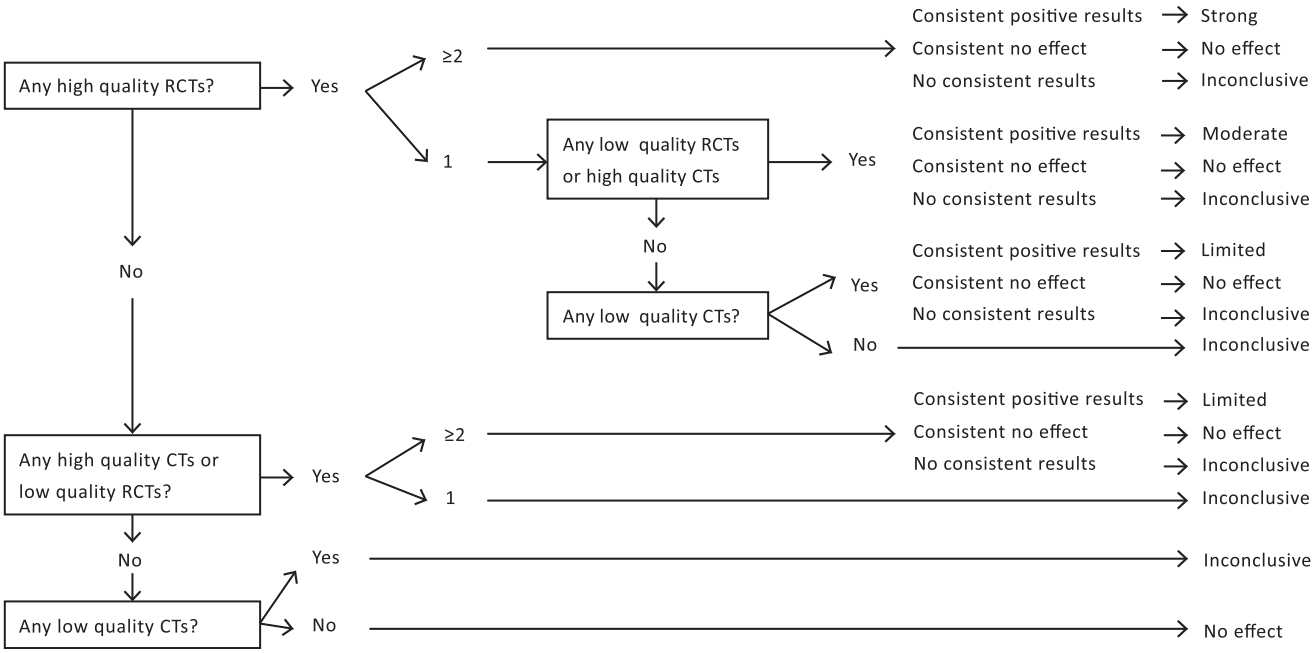

FIG. 1. Flowchart of the decision-making process for levels of evidence, based on study design and quality. CT, controlled trial; RCT, randomized controlled trial. Adapted from van Slujis et al.[20]

unknown. A methodological quality score (ranging from 0 to 10) was calculated by accumulating all the positive rates. Quality was defined as high when a randomized controlled trial (RCT) scored at least 6 or other kinds of study scored at least 5 (because there was a specific item on the randomization procedure).[20]

Strength of the evidence. Based on a previously used evidence synthesis method,[20–22] we evaluated the effects of AVG interventions on PA using an evidence rating system. Five levels (strong, moderate, limited, inconclusive, and no effect) were defined based on study design and methodological quality (Fig. 1). We stratified studies based on setting. Following a previous review,[20] if at least two-thirds of the relevant studies had significant results in the same direction, the overall results were considered consistent.

Results

Included studies

The flow of studies through the selection process is reported in Figure 2. Titles and abstracts of the 642 initially identified articles were screened. Seventy-two full-text articles were retrieved, and 18 articles were excluded for the following reasons: Not an AVG study,[23–28] duplicate publications,[29–36] or without any PA measurement.[37–40] Fifty-four studies (including 32 studies[41–72] that examined the immediate PA effects of AVGs and 22 studies[73–94] that examined the effects of AVGs on habitual PA or change of PA) were included in the review.

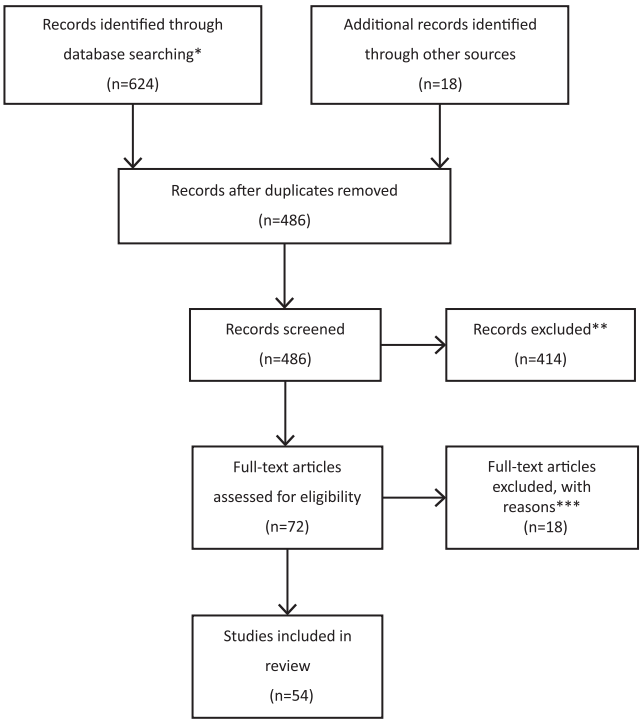

FIG. 2. Flow of articles regarding identification and selection. *Databases used were Medline ($n=54$), SPORTDiscus ($n=42$), Web of Knowledge ($n=426$), SCOPUS ($n=7$), and Ovid ($n=95$). **Studies may be excluded for multiple reasons, but for exclusive classification, they were excluded for only one of these reasons with sequence: Not an active videogame study ($n=327$), not target age groups ($n=35$), not healthy children ($n=16$), not original study ($n=23$), or without physical activity variable measurement ($n=13$). ***Studies were excluded for the following reasons: Not an active videogame study ($n=6$), duplicate publications ($n=8$), or without physical activity variable measurement ($n=4$).

TABLE 1. SCALE FOR METHODOLOGICAL QUALITY ASSESSMENT

Item	*Description*
A	Groups comparable at baseline on key characteristics (e.g., age, gender, weight, PA-relevant outcome measures) were statistically tested, and for all studies only positive when differences observed were controlled for in analyses
B	Randomization procedure clearly described and adequately carried out
C	Unit of analysis was individual (negative if unit of analysis was school level or school-level randomization not accounted for in individual-level analyses)
D	Validated measure of PA-related outcome used (positive if validation of measures was reported or referred to)
E	Dropout described and not more than 20 percent for studies with follow-up of 6 months or shorter and 30 percent for studies with follow-up of more than 6 months
F	Timing of measurements comparable between intervention and control groups
G	Blinding outcome assessment (positive if those responsible for assessing PA-related outcome were blinded to group allocation of individual participants)
H	Participants followed up for a minimum of 6 months
I	Intention to treat analysis used
J	Potential confounders accounted for in analyses

PA, physical activity.

Effects of AVGs on immediate PA outcomes

Studies on the AVG play only. These studies[41–69] focused on EE or PA during a short or several short sessions of AVG play (Table 2). Studies that reported MET values consistently indicated AVGs could elicit light to moderate intensities of PA. One study found a MET that marginally exceeded 6 by indirect calorimetry.[57] One study found two AVGs exceeded 6 METs by accelerometry.[68] However, this result was not consistent with other studies using indirect calorimetry.

Inconsistent findings in EE were obtained when samples were divided by body mass index (BMI) (body mass in kilograms divided by height in meters squared). Three studies indicated no difference in EE between normal weight and overweight children if analyses controlled for body mass.[41,42,56] However, in other studies, overweight children spent more energy to play AVGs when lean body mass was controlled,[57] participants with a higher BMI exerted more energy compared with those with a lower BMI,[60] and BMI had no significant effect on EE in the presence of the other covariables (age and gender).[68] Four studies found more EE in male participants than females on certain AVGs,[45,50,60,64] whereas others did not find or report gender differences. One study found that younger children

Table 2. Studies That Examined Association Between Active Videogame Session(s) and Immediate Physical Activity

Reference (year)	Participants' characteristics: Age (years)	n	Sex	BMI[a]	Console	Game	EE: Original	EE: Computed results (kcal/kg/minute)	REE	MET[b]	HR (bpm)	Pedometry, accelerometry, observation	Gender differences[c]
Lanningham-Foster et al.[41] (2006)	9.7 (1.6); 8–12	25	13 F (8 L); 12 M (7L)	20(4), 71.5% (24.7%); L, 18 (2), 57.6% (23.2%); O, 23 (4), 91.7% (4.5%)	Sony PS2 Eye Toy	"Nicktoons Movin' "	13.61 (4.20) kJ/kg/hour	0.05	6.47 (1.18) kJ/kg/hour	2.1			
					Sony PS2	DDR	17.26 (4.28) kJ/kg/hour	0.07	6.47 (1.18) kJ/kg/hour	2.7			
Unnithan et al.[42] (2006)	11–17	22	6 F (4 L); 16 M (8 L)	L, 18.6 (2.9); O, 27.4 (3.3)	Sony PS2	DDR	L: 21.3 (4.8) mL/kg/minute O: 18.3 (4.2) mL/kg/minute	L: 0.10 O: 0.09	L: 4.6 (1.5) mL/kg/minute O: 5.1 (1.0) mL/kg/minute	L: 4.6 O: 3.6	L: 146 (14) O: 143 (16)		
Maddison et al.[43] (2007)	12.4 (1.1); 10–14	21	10 F; 11 M	20.3 (4)	Sony PS2 Eye Toy	"Knockout"	24.5 (4.9) mL/kg/minute	0.12	4.9 (0.9) mL/kg/minute	5.0 (0.8)	142 (16)		No
					Sony PS2 Eye Toy	"Homerun"	23.0 (4.0) mL/kg/minute	0.11	4.9 (0.9) mL/kg/minute	4.8 (0.9)	138 (18)		
					Sony PS2 Eye Toy	"Groove"	11.2 (2.2) mL/kg/minute	0.05	4.9 (0.9) mL/kg/minute	2.3 (0.3)	111 (12)		
					Sony PS2 Eye Toy	"AntiGrav"	14.0 (3.8) mL/kg/minute	0.05	4.9 (0.9) mL/kg/minute	2.9 (0.6)	110 (13)		
					Sony PS2	"Dance UK"	18.9 (3.6) mL/kg/minute	0.07	4.9 (0.9) mL/kg/minute	3.9 (0.8)	127 (13)		
Straker and Abbott[44] (2007)	9–12	20	8 F; 12 M	Not reported	Sony PS2 Eye Toy	"Cascade"	26.54 (8.21) mL/kg/minute	0.13			130.2 (21.0)		No
Graves et al.[45] (2008)	14.6 (0.5); 13–15	11	5 F; 6 M	21.2 (2.5)	Nintendo Wii	"Wii Sports Bowling"	190.6 (22.2) J/kg/minute	0.05	81.3 (17.2) J/kg/minute	2.3			No
					Nintendo Wii	"Wii Sports Tennis"	202.5 (31.5) J/kg/minute	0.05	81.3 (17.2) J/kg/minute	2.5			EE: M > F
					Nintendo Wii	"Wii Sports Boxing"	198.1 (33.9) J/kg/minute	0.05	81.3 (17.2) J/kg/minute	2.4			No
Graves et al.[46] (2008)	15.1 (1.4); 11–17	13	6 F; 7 M	22.0 (2.6)	Nintendo Wii	"Wii Sports Bowling"	182.1 (41.3) J/kg/minute	0.04	84.0 (14.6) J/kg/minute	2.2 (0.5)	103.2 (16.7)		HR: F > M
					Nintendo Wii	"Wii Sports Tennis"	200.5 (54.0) J/kg/minute	0.05	84.0 (14.6) J/kg/minute	2.4 (0.7)	107.0 (15.2)		HR: F > M
					Nintendo Wii	"Wii Sport Boxing"	267.2 (115.8) J/kg/minute	0.06	84.0 (14.6) J/kg/minute	3.2 (1.4)	136.7 (24.5)		HR: F > M
Haddock et al.[47] (2008)	10.1 (2.2); 7–14	23	5 F; 18 M	26.7 (3.5); >85%	Xavix	"Jackie Chan Studio Fitness" game package	14.03 (3.54) mL/kg/minute	0.07	4.06 mL/kg/minute	3.5			Not reported
McDougall and Duncan[48] (2008)	8–11	12	7 F; 5 M	Not reported	Sony PS2 Eye Toy	Athletics games					F: 151 (19), 52.5% time >139 M: 145.7 (6.5), 41.7% time >139	F: 1303 (320.1) steps M: 1503 (453.3) steps	
Mellecker and McManus[49] (2008)	9.6 (1.7); 6–13	18	7 F; 11 M	18.1 (2.9)	Xavix	"Bowling"	0.06 (0.01) kcal/kg/minute	0.06	0.03 kcal/kg/minute	2.0	102 (20)		Not reported
					Xavix J-Mat	"Jackie's Action Run"	0.15 (0.03) kcal/kg/minute	0.15	0.03 kcal/kg/minute	5.0	160 (20)		Not reported

(*continued*)

TABLE 2. (CONTINUED)

Reference (year)	Participants' characteristics				Console	Game	EE		REE	MET[b]	HR (bpm)	Pedometry, accelerometry, observation	Gender differences[c]
	Age (years)	n	Sex	BMI[a]			Original	Computed results (kcal/kg/minute)					
Graf et al.[50] (2009)	11.9 (1.2); 10–13	23	9 F; 14 M	19.1 (3.1); 3%–98%	Sony PS2	DDR (beginner)	M: 13.7 (0.6) mL/kg/minute F: 10.2 (0.4) mL/kg/minute	0.06	M: 4.8 (0.3) mL/kg/minute F: 4.1 (0.3) mL/kg/minute	2.7	M: 111 (3) F: 106 (5)		EE: M>F HR: No
					Sony PS2	DDR (basic)	M: 15.8 (0.9) mL/kg/minute F: 13.2 (0.7) mL/kg/minute	0.07	M: 4.8 (0.3) mL/kg/minute F: 4.1 (0.3) mL/kg/minute	3.3	M: 121 (4) F: 124 (6)		EE: M>F HR: No
					Nintendo Wii	"Wii Sports Bowling"	M: 10.0 (0.7) mL/kg/minute F: 7.7 (0.6) mL/kg/minute	0.04	M: 4.8 (0.3) mL/kg/minute F: 4.1 (0.3) mL/kg/minute	2.0	M: 101 (4) F: 98 (3)		EE: M>F HR: No
					Nintendo Wii	"Wii Sports Boxing"	M: 13.8 (1.1) mL/kg/minute F: 13.5 (1.4) mL/kg/minute	0.07	M: 4.8 (0.3) mL/kg/minute F: 4.1 (0.3) mL/kg/minute	3.0	M: 127 (5) F: 140 (8)		No
Haddock et al.[51] (2009)	10.9 (2.2); 7–14	20	7 F; 13 M	30.9 (8.3); > 85%	GameBike with Sony PS2	"Disney Cars"	16.8 (4.2) mL/kg/minute	0.08	3.6 (0.9) mL/kg/minute	4.7	146.0 (21.4)		Not reported
Lanningham-Foster et al.[52] (2009)	12.1 (1.7); 9–15	22	11 F; 11 M	20.2 (3.3); 65.6 % (26.8%)	Nintendo Wii	"Wii Sports Boxing"	5.14 (1.71) kcal/kg/hour	0.09	1.22 (0.31) kcal/kg/hour	4.2			No
Fawkner et al.[53] (2010)	14.0 (0.3)	19	19 F	19.6 (3.3)	ZigZag Xer-Dance	"Dance Level 1"	14.4 (3.1) mL/kg/minute	0.07	4.7 (1.0) mL/kg/minute	3.08 (0.40)	17.4 (15.7)		
						"Dance Level 2"	14.7 (3.8) mL/kg/minute	0.07	4.7 (1.0)mL/kg/minute	3.10 (0.35)	24.4 (16.7)		
						"Dance Level 3"	16.5 (3.7) mL/kg/minute	0.08	4.7 (1.0) mL/kg/minute	3.52 (0.42)	34.0 (16.7)		
Fogel et al.[54] (2010)	9	4	2 F; 2 M	Not reported	10 different AVGs							30.7% time in PA	
Graves et al.[55] (2010)	15.1 (1.4); 11–17	14	4 F; 10 M	22.8 (3.3)	Nintendo Wii	"Wii Fit Yoga"	190.8 (34.6) J/kg/minute	0.05	111.7 (22.7) J/kg/minute	1.7 (0.3)	86.6 (16.2)		Not reported
					Nintendo Wii	"Wii Fit Muscle Conditioning"	236.8 (36.4) J/kg/minute	0.06	111.7 (22.7) J/kg/minute	2.2 (0.4)	90.2 (15.3)		
					Nintendo Wii	"Wii Fit Balance"	188.2 (31.0) J/kg/minute	0.05	111.7 (22.7) J/kg/minute	1.7 (0.4)	85.0 (15.6)		
					Nintendo Wii	"Wii Fit Aerobics"	348.1 (44.7) J/kg/minute	0.08	111.7 (22.7) J/kg/minute	3.2 (0.7)	101.9 (18.4)		
Penko and Barkley[56] (2010)	8–12	24	12 F; 12 M	LF: 66.1% (20.4%) OF: 95.4% (3.6%) LM: 71.0% (14.0%) OM: 92.3% (4.3%)	Nintendo Wii	"Wii Sports Boxing"	11.7 (3.4) mL/kg/minute	0.06	5.1 (1.2) mL/kg/minute	2.3	121.4 (20.3)		

(*continued*)

TABLE 2. (CONTINUED)

Reference (year)	Participants' characteristics: Age (years)	n	Sex	BMI[a]	Console	Game	EE: Original	EE: Computed results (kcal/kg/minute)	REE	MET[b]	HR (bpm)	Pedometry, accelerometry, observation	Gender differences[c]
Bailey and McInnis[57] (2011)	11.5 (2.0); 9–13	39	20 F; 19 M	23.5 (5.5)	Nintendo Wii	"Wii Sports Boxing"	16.7 (6.2) KJ/minute		4.6 (1.6) KJ/minute	3.6			Enjoyment: M > F
					Sony PS2	DDR Thirteen	20.5 (6.0) KJ/minute		4.6 (1.6) KJ/minute	4.5			Enjoyment: F > M
					Cybex Trazer	"Goalie Wars"	22.9 (8.6) KJ/minute		4.6 (1.6) KJ/minute	5.0			Enjoyment: M > F
					Xavix J-Mat	"Jackie Chan Alley Run"	28.1 (8.5) KJ/minute		4.6 (1.6) KJ/minute	6.1			Enjoyment: M > F
Mitre et al.[58] (2011)	8–12	19	8 F (5 L); 11 M (6 L)	14–29	Nintendo Wii	"Sega SuperStar Tennis"	3.05 (0.93) kcal/kg/hour	0.05	1.47 (0.24) kcal/kg/hour	2.1			Not reported
Perron et al.[59] (2011)	9.4 (1.8)	30	11 F; 19 M	18.0 (2.4)	Nintendo Wii	"Wii Fit"					136.5 (9.6)	59.8% of time in MVPA	Not reported
					Nintendo Wii	"EA Sports Active"					144.0 (8.0)	64.6% of time in MVPA	
Staiano and Calvert[60] (2011)	14.45 (1.67)	74	45 F; 29 M	23.97 (5.58); 69.28% (28.06%)	Nintendo Wii	"Wii Sports Tennis"						62.93 (18.09) kcal/30 minutes for social play and 54.83 (11.74) kcal/30 minutes for solitary play	EE: M > F
White et al.[61] (2011)	11.4 (0.8)	26	26 M	19.5	Nintendo Wii	"Wii Sports Tennis"	14.1 (3.8) mL/kg/minute	0.07	6.9 (1.1) mL/kg/minute	2.16 (0.53)	106 (22)		
					Nintendo Wii	"Wii Sports Bowling"	14.0 (4.9) mL/kg/minute	0.07	6.9 (1.1) mL/kg/minute	2.03 (0.56)	107 (13)		
					Nintendo Wii	"Wii Sports Boxing"	20.2 (5.0) mL/kg/minute	0.10	6.9 (1.1) mL/kg/minute	3.05 (0.59)	140 (27)		
					Nintendo Wii	"Wii Sports Step"	17.0 (4.9) mL/kg/minute	0.08	6.9 (1.1) mL/kg/minute	2.43 (0.43)	122 (18)		
					Nintendo Wii	"Wii Sports Ski"	11.3 (3.2) mL/kg/minute	0.06	6.9 (1.1) mL/kg/minute	1.65 (0.59)	113 (22)		
Gao[62] (2012)	13.55 (0.94)	195	95 F; 100 M	Not reported		DDR						4.95% (7.31%) of time in MVPA, 28.77% (15.86%) of time in LPA	Intrinsic motivation: M > F External regulation: M < F
Roemmich et al.[63] (2012)	8–12	44	22 F; 22 M	<95%	Nintendo Wii	4 "Wii Sports" games	Traditional games > AVGs in 87%				AVGs < traditional games	Active play time: AVG > traditional games in 87%	EE: No HR: No Choice (3 games versus 1 game) had a greater effect on increasing girls' active time and activity intensity.
Smallwood et al.[64] (2012)	13.4 (1.2); 11–15	18	8 F; 10 M	21.3 (4.5); 59.7% (34.3%)	Xbox 360 Kinect	"Dance Central"	12.8 (3.3) mL/kg/minute	0.06	4.4 (0.8) mL/kg/minute	2.9	118		EE: No REE: M > F
					Xbox 360 Kinect	"Kinect Sport Boxing"	17.7 (5.1) mL/kg/minute	0.09	4.4 (0.8) mL/kg/minute	4.0	131		EE: M > F

(*continued*)

Table 2. (Continued)

Reference (year)	Participants' characteristics				Console	Game	EE		REE	MET[b]	HR (bpm)	Pedometry, accelerometry, observation	Gender differences[c]
	Age (years)	n	Sex	BMI[a]			Original	Computed results (kcal/kg/minute)					
Sun[65] (2012)	9–12	74	40 F; 34 M	Not reported	Eight different AVG stations					2.14 (0.65)			Not reported
Gao et al.[66] (2013)	10.3; 10–11	53	29 F; 24 M	Not reported		DDR						21% of DDR play in MVPA 31% of aerobic dance in MVPA	Not reported
Huang and Gao[67] (2013)	13.3 (1.0); 12–15	135	65 F; 70 M	Not reported		DDR						6.10% (9.31%) of time in MVPA	No
Miller et al.[68] (2013)	11 (2); 8–15	104	58 F; 46 M	F: 22.3 (5.5) M: 20.3 (5.1)		"Winds of Orbis"	0.13 (0.09) kcal/kg/minute	0.13		G3–5: 6.5 (0.7)[d] G6–8: 4.0 (0.4)[e]			No
						DDR	0.11 (0.09) kcal/kg/minute	0.11		G3–5: 6.7 (0.7)[d] G6–8: 3.2 (0.4)[e]			No
Reading and Prickett[69] (2013)	8.3 (2.0); 5–12	41	15 F; 26 M	18.3 (3.8); 68.0% (11.6%)	Xbox 360 Kinect	"Kinect Adventures"				4.4 (0.9)[f]		1921 (946) CPM	Not reported

Data are mean (standard deviation) values.
[a]Data reported with percentages represent body mass index (BMI) percentiles according to the populations which authors chose.
[b]Metabolic equivalent of task (MET) values that were reported without standard deviations were computed by the reviewers.
[c]No means no significant gender differences were found.
[d]MET values were computed using 5.9 mL/kg/minute as resting energy expenditure (REE).
[e]MET values were computed using 4.6 mL/kg/minute as REE.
[f]MET value was computed using 5.0 mL/kg/minute as the REE.
AVG, active videogame; bpm, beats per minute; CPM, counts per minute; DDR, "Dance Dance Revolution"; EE, energy expenditure; F, female; HR, heart rate; G3–5, Grades 3–5; G6–8,Grades 6–8; L, lean; LPA, light physical activity; M, male; MVPA, moderate to vigorous physical activity; O, overweight; PA, physical activity; PS2, PlayStation 2.

expended more energy per kilogram of body weight than older children.[68] In summary, AVGs have effects on the immediate PA outcomes, which led to light- to moderate-intensity PA. Demographic moderator effects have been examined, and no conclusive evidence favored larger BMI, males, or younger children.

Studies on the choices between AVGs and sedentary alternatives. It is not clear whether children would play AVGs as a substitute for sedentary time. Table 3 gives a summary of three studies that provided participants with the choice between AVGs and sedentary alternatives. One study found that the reinforcing value (i.e., where participants spent their time) depended on the content of the games,[70] whereas two studies indicated that children almost equally split their time between AVGs and content-matched sedentary videogames.[71,72] Thus, AVGs could compete with sedentary videogames in the short time of these studies.

Effects of AVGs on habitual PA or change of PA

A cross-sectional survey indicated a positive association between AVG play and PA.[88] Among the 21 intervention studies,[73–87,89–94] 13 were RCTs, and 4 RCTs[73–75,87] indicated they were pilot studies (Table 4).

Effects of AVG intervention on PA. One intervention study[87] was excluded from the evaluation because it measured PA levels in only 4 out of 58 participants at the end of the intervention. Effect sizes for the intervention studies are presented in Table 5. Compared with a control group, 8[83–86,89–91,94] of 15 intervention studies found positive effects of AVGs on PA-related outcomes (including cognitive and psychosocial variables,[83,85,89,94] behavioral outcomes,[83–86,91] and physical fitness[90]). Two studies found AVGs increased children's PA in early sessions but not in later sessions.[74,76] Without a control group, the remaining five studies all reported positive effects of AVGs on PA.[79,81,82,92,93]

Four[83,85,86,90] out of 11 studies reported positive intervention effects of AVGs on PA behavioral outcomes (including physical fitness) between an AVG and a non-AVG control group. Two self-reported PA measures had large effect sizes,[86] and one self-reported PA measure had a small effect size.[85] One study showed a positive effect favoring the non-AVG control group.[76] In addition, two studies compared AVG groups.[84,91] One study found that compared with the do-your-best group, PA levels increased in the difficult-goal group with a large effect size, whereas PA levels increased in the easy-goal group with a moderate effect size.[84] PA increased in the higher contingency (behavior-consequence) AVG group but decreased in the lower contingency AVG group; the effect size of the difference was small.[91]

All four studies[83,85,89,94] comparing an AVG and a non-AVG group reported positive intervention effects on the cognitive and psychosocial PA-related outcomes. Two effect sizes were small,[85] one was medium,[94] and one was large.[89] Thus, AVGs had larger effects on cognitive and psychosocial outcomes than behavioral outcomes.

Methodological quality. Methodological quality scores are presented in Table 5. Overall, nine studies (45 percent) exhibited high quality. Low methodological quality was attributed mainly to failure to report the blinding outcome assessment (90 percent), using intention to treat analysis (80 percent), comparable groups at baseline (75 percent), long-term follow-up (75 percent), the randomization procedure (65 percent), and accounting confounders in analyses (50 percent).

Strength of the evidence. Eight studies were conducted in the home setting, including five high-quality RCTs,[74,77,78,80,86] two low-quality RCT,[73,91] and one pre–post study.[79] Compared with a non-AVG group, only one study reported a significant intervention effect on PA.[86] Therefore, no effect of AVGs on PA was identified at home.

Ten studies were conducted in school, community, or clinic environments to provide structured AVG sessions (i.e., AVG play of participants was organized by teachers or researchers), including one high-quality RCT,[84] three low-quality RCTs,[85,89,94] two high-quality controlled trial (CT),[76,83] one high-quality pre–post study,[92] and three low-quality pre–post studies.[82,90,93] All the RCTs and one CT[83] reported a positive intervention effect, and another CT[76] reported a negative intervention effect, equating to moderate evidence of effectiveness of structured AVG play on PA promotion.

Two low-quality studies[75,81] provided inconclusive evidence for the effects of AVGs in multiple settings on PA.

In summary, we found no effect of AVGs on PA in the home setting. Moderate evidence was found that structured AVG play could promote PA.

Strategies used for promoting AVG use or PA. In the home setting, all eight studies provided participants with AVG(s) and/or consoles (including peripheral equipment). Three studies provided two peripherals to each participant to encourage non-solo play among families,[73,77,86] and two reported positive intervention effects on PA.[73,86] Three studies provided a specific prescription for playing AVGs,[73,74,78] and one study reported increased vigorous PA within the AVG group.[73] This study also provided coaching sessions and reported that it did not improve results.[73] One study provided children with game choices to enhance intrinsic motivation and reported no effect on PA.[80] Two studies offered one additional AVG or a package of AVGs to participants in the middle of the interventions.[78,80] Although one study found increased AVG play after an additional AVG was provided,[80] both studies reported no intervention effects on PA.[78,80]

In the structured AVG sessions, one study controlled the intensity by adjusting game difficulty, and the measured outcome (perceived exercise competence) favored the AVG group.[89] The results of one study favored the cooperative condition (pairs of participants were instructed to coordinate as a team) over the competitive condition (pairs of participants were instructed to compete against each other to earn the most points).[94] One study reported that PA levels increased after setting specific goals (step counts) for the AVG play.[84] We only identified one multicomponent intervention (including AVG-based exercise program, nutrition education, and behavioral management discussions), and it found exercise time increased after the intervention.[82]

Two interventions were conducted in multiple settings.[75,81] One invited participants to a weekly multiplayer class in addition to AVG home play and found the dropout rate in the multiplayer group was significantly lower than in

Table 3. Studies That Examined the Choices Between Active Videogames and Sedentary Alternatives

Reference (year), country	*Participants' characteristics*	*Study description*	*Console*	*Game*	*PA*	*Comparison between AVG and similar activities*
Epstein et al.[70] (2007), United States	17 NW (BMI ≤85%), 18 OW (BMI >95%); 8–12 years old; 17 F1, 18 M	Reinforcing value was studied when providing children a choice of either playing one video dance or bicycle game, using a hand-held controller or one of the three options: dancing or bicycling alone, dancing or bicycling while watching a video, or playing the interactive dance or bicycle game.	Sony PS2 Cateye cycle with Sony PS2	DDR "EA Freestyle"	NW: AVG> alternatives OW: No differences across conditions No difference was found on miles biked across conditions. Miles biked: F>M	Only interactive dance game was more reinforcing than the other alternative choices. There was no difference across bicycling conditions.
Sit et al.[71] (2010), China	50 NW, 20 OW; 9–12 years; 35 F, 35 M	Children were systematically observed when providing a choice between an AVG and an online content-matched electronic game.	Xavix Xavix	Bowling "Aerostep"	MVPA time: M>F MVPA time: NW>OW	Children spent 94% of session time to play games and split time between AVGs (52%) and online electronic games (48%).
Lam et al.[72] (2011), China	9–12 years; 39 F, 40 M	Children were provided a choice between an AVG and an online content-matched electronic game. Play pattern (frequency, duration, and intensity) was assessed from observation, accelerometry, and heart rate monitor.	Xavix Xavix J-Mat	Bowling "Jackie Chan Action Run"	Counts: M>F Counts: M>F	Children spent approximately half (48.0%) of the available time playing AVGs and a similar amount of time (46.2%) playing sedentary videogames.

AVG, active videogame; DDR, "Dance Dance Revolution"; F, female; M, male; NW, normal weight; OW, overweight; PA, physical activity; PS2, PlayStation 2.

Table 4. Studies That Examined the Effects of Active Videogames on Habitual Physical Activity or Change of Physical Activity

Reference (year), country	Design	Participants' characteristics				Intervention duration	Settings	AVG	Strategy used	Main findings
		Age (years)	Number	BMI[a]	Group difference					
Maloney et al.[73] (2008), United States	RCT	7.5 (0.5); 7–8	60 (I, 40; C, 20); 30 F, 30 M	17.6 (2.7); *z*-score 0.56 (0.92)	No differences	10 weeks, 28 weeks follow-up (both C and I get AVG at home between weeks 10 and 28)	Home	DDR on Sony PS2	Each participant was provided a console, DDR, and two dance mats to encourage social and competitive play. A brief handout was provided about operation of the AVG and strategies to improve skills. Half of the I group also received five weekly, 1:1, 30-minute coaching sessions. Hand controllers were not provided to restrict sedentary play. Participants were given a written physician prescription to play AVG 120 minutes/week.	Vigorous PA significantly increased, and sedentary screen time significantly decreased in the intervention group at 10 weeks and 28 weeks. No significant group differences were found. Coaching did not improve results.
Ni Mhurchu et al.[74] (2008), New Zealand	RCT	12 (1.5); 10–14	20 (I, 10; C, 10); 8 F, 12 M	19.7 (3.6)	Age: C > I Time playing electronic games: C > I	12 weeks	Home	Sony Eye Toy active games on PS2	An AVG upgrade package (Eye Toy camera, one dance mat, and AVGs) was provided. Participants and their parents or guardians were instructed to replace usual non-AVG play with AVG play.	PA was significantly higher in the I group compared with the C group at 6 weeks but not at 12 weeks. No group difference was found for time spent on MVPA. Waist circumference in the I group significantly decreased compared with the C group.
Paw et al.[75] (2008), The Netherlands	RCT	10.6 (0.8); 9–12	27 (14 F, 13 M)	Not reported	Not reported	12 weeks	Home and sport fitness center	Dance game	All participants were provided an AVG at home. Participants in the multiplayer group were also invited to play against each other weekly in a 60-minute multiplayer class under the supervision of an instructor at a fitness center.	Dropout in the multiplayer group was significantly lower than the home group.

(*continued*)

TABLE 4. (CONTINUED)

Reference (year), country	Design	Participants' characteristics				Intervention duration	Settings	AVG	Strategy used	Main findings
		Age (years)	Number	BMI[a]	Group difference					
Duncan and Staples[76] (2010), United Kingdom	CT	10.4 (0.5); 10–11	30 (I, 15; C, 15); 18 F, 12 M	18.6	Not reported	6 weeks	School	"Wii Sports Tennis," "Sonic and Mario at the Olympics," and "Celebrity Sports Showdown" on Nintendo Wii	The intervention group played AVGs twice weekly instead of their regular recess activities. Games were rotated in each session in order to avoid children being bored and also ensure that children played all games in each session.	Children in the intervention group had significantly greater PA than the control group during the first week; however, this pattern was reversed at the mid and end points. Irrespective of time point, the intervention group spent a lesser percentage of time engaged in MVPA than the controls during the recess time.
Graves et al.[77] (2010), United Kingdom	RCT	8–10	58 (I, 29; C, 29); 19 F, 39 M	I: 18.9 (4.5) C: 19.7 (4.3)	No differences ($P > 0.05$)	12 weeks	Home	Games on Sony PS2, PS3 with jOG	Two jOG devices were provided for home use to encourage multiplayer play.	No differences were found between groups for PA and body fat. Children in the I group increased AVG play while decreased sedentary videogaming at 6 weeks compared with the C group.
Maddison et al.[78] (2011), New Zealand	RCT	11.6 (1.1); 10–14	322 (I, 160; C, 162); 87 F, 235 M	I: 25.6 (4.1) C: 25.8 (4.3)	No differences	24 weeks	Home	Eye Toy active games on Sony PS2, PS3	An AVG upgrade package (Eye Toy camera, one dance mat, and AVGs) was provided. Participants were encouraged to meet PA recommendations (60 minutes of MVPA on most days of the week) by supplementing periods of inactivity with AVG play, and by substituting sedentary videogame play with AVG play. A package of new AVGs was provided at 12 weeks to ensure the sustainability of the intervention.	No differences were found between groups on PA outcomes. The changes of BMI and body fat were significantly different between groups. The treatment effect favored the I group.

(*continued*)

TABLE 4. (CONTINUED)

Reference (year), country	*Design*	*Participants' characteristics*				*Intervention duration*	*Settings*	*AVG*	*Strategy used*	*Main findings*
		Age (years)	*Number*	*BMI*[a]	*Group difference*					
Owens et al.[79] (2011), United States	Pre–post study	10.0 (1.6), 8–13	12; 6 F, 6 M	19.4 (4.4)	NA	3 months	Home	"Wii Fit" active games on Nintendo Wii	Consoles and AVGs were provided. The participating families were given a brief tutorial on the setup and use of AVGs: no recommendations were made to the families regarding how much AVG should be played.	No significant effects were found on daily PA, muscular fitness, flexibility, balance, or body composition. Daily AVG use per household declined by 82% from 21.5 ± 9.0 minutes/day during the first 6 weeks to 3.9 ± 4.0 minutes/day during the second 6 weeks. Children significantly increased peak VO_2 after 3 months.
Baranowski et al.[80] (2012), United States	RCT	11.3 (1.8)	78 (I, 41; C, 37); 38 F, 40 M	81.8% (50%–99%)	No differences ($P > 0.01$)	12 weeks	Home	"Active Life-Extreme Challenge," "EA Sports Active," DDR, "Wii Fit Plus," "Wii Sports" on Nintendo Wii	The same consoles were provided to all participants, with one active game to the I group, versus one non-AVG to the C group. After 6 weeks, another game for each group was provided. Participants could choose one game from among five to enhance intrinsic motivation. No prescription was provided to remain naturalistic circumstances, and no prohibitions were provided against purchasing or using other videogames.	There were no differences between groups at any time in terms of PA.
Bethea et al.[81] (2012), United States	Pre–post study	9.9 (0.7), 8–11	28; 10 F, 18 M	19.8 (3.9), 68.4% (28.7%)	NA	30 weeks	School and home	DDR on Sony PS2	Children had access to DDR up to 3 days a week for around 30 minutes during afterschool time, and had unlimited access at home. A game console, DDR, and two dance mats were provided for each child.	Physical fitness increased at 12 weeks and was sustained through 30 weeks. Trends suggested increased total MVPA, decreased LPA, and a modest increase in sedentary screen time. During the intervention, participants maintained an increase of DDR play. There were no significant changes in BMI, fasting lipids, or glucose.

(*continued*)

TABLE 4. (CONTINUED)

Reference (year), country	*Design*	*Participants' characteristics*				*Intervention duration*	*Settings*	*AVG*	*Strategy used*	*Main findings*
		Age (years)	*Number*	*BMI*[a]	*Group difference*					
Christison and Khan[82] (2012), United States	Pre–post study	11.2 (2.2); 8–16	40; 22 F, 18 M	31.07 (6.41); *z*-score 2.24 (0.41); ≥85%	NA	10 weeks	Community	Eight different games	This multidisciplinary program had three main components: AVG-based exercise, nutrition education, and behavioral management discussions. Parent/guardian involvement was required in the nutrition and psychosocial classes. They were also encouraged to do exercise with participants during the AVG-based sessions. There were five 1-hour AVG sessions in the first 5 weeks and five 1-hour combined AVG/traditional exercise sessions in the latter 5 weeks. The equipment was used on a rotational basis. Participants were also encouraged to engage in 3 additional hours of exercise per week.	Self-reported exercise hours per week increased, whereas screen time and soda intake were reduced. The average Global Self-Worth score improved. BMI decreased significantly.
Gao et al.[83] (2012), United States	CT	10.36 (0.98)	101 (I, 50; C, 51); 49 F, 52 M	Not reported	G4 was in the I group, whereas G5 was in the C group. No differences were reported.	9 months	School	DDR	The I group played DDR three times a week during recess. Daily recess is 30 minutes (two sessions of 15-minute recess) in the participating school. Four participants shared one AVG station to play DDR, with two master dance pads (connected to the monitor) and two practicing dummy dance pads. Children switched to another kind of pad song by song. Researchers monitored the program.	Children in the I group displayed significantly higher self-reported PA, and greater increased self-efficacy and social support after I. No difference was found on the change of outcome expectancy between groups.

(*continued*)

TABLE 4. (CONTINUED)

Reference (year), country	Design	Participants' characteristics				Intervention duration	Settings	AVG	Strategy used	Main findings
		Age (years)	Number	BMI[a]	Group difference					
Gao and Podlog[84] (2012), United States	RCT	8.46 (1.26); 7–13	98; 51 F, 47 M	Not reported	Not reported	8 weeks	School	DDR	Participants received feedback about their steps in the first week and were asked (1) to do your best, (2) to increase 10% of the baseline steps, or (3) to increase 30% of the baseline steps during AVG play. Children were instructed not to discuss their PA levels and goals with peers.	Children who set specific goals had significantly greater increased PA levels than those in the do-your-best group. In addition, children in the difficult-goal group increased PA levels significantly higher than those in the easy-goal group.
Lwin and Malik[85] (2012), Singapore	RCT	Children: 10.2 (0.55) PAS: 12.2 (0.54)	1112 (I, 557; C, 555); 510 F, 602 M	Not reported	Not reported	6 weeks	School	DDR, "Wii Sports Tennis" and "Wii Sports Boxing" on Nintendo Wii	The I group played Wii once weekly in one of their two PE lessons. Three consoles were provided to each class. Two participants took turns to play at one console. Three games were played in weekly rotation.	Participants in the I group more likely to had more positive beliefs towards PA attitude, subjective norm and intention, and undertook a higher level of strenuous exercise compared to the control group. Age significantly influenced outcome variables, with the effect of AVG more pronounced among children than PAS in attitude, moderate and mild exercise behaviors.
Maloney et al.[86] (2012), United States	RCT	9–17	64 (I, 33; C, 31); 34 F, 30 M	>85% I: 96.57% (3.69%) C: 96.64% (2.69%)	F: I<C Age: I>C Weight: I>C No differences in BMI, body fat, and VO_{2max}	12 weeks	Home	DDR	One console, DDR and two dance pads were provided to encourage non-solo play.	Self-reported MVPA increased significantly from baseline to 12 weeks for the I group and declined for the comparison group. There were no significant between-group differences based on the accelerometer or pedometer data. The decline in MPA was significant in the comparison group and not significant in the I group. Both groups had declines in VPA, but the trend was for the I group to decline less.

(*continued*)

TABLE 4. (CONTINUED)

Reference (year), country	Design	Participants' characteristics				Intervention duration	Settings	AVG	Strategy used	Main findings
		Age (years)	Number	BMI[a]	Group difference					
Maloney et al.[87] (2012), United States	RCT	13.7 (0.6)	58 (I, 29; C, 29); 29 F, 29 M	69.5% (29.3)%	Not reported	20 weeks	School	Dance game (''In the Groove'') on Sony PS2	Two consoles and two dance mats were provided for each participating school. No hand controllers were provided to discourage students from playing other games on the consoles. Participants were encouraged to play AVG 10 minutes (two rounds) per day on 4–5 school days per week. If participants danced behind the dance pads but not on the dance mats, they could still document this time as time dancing to allow more than two students to play at a time and encourage social play.	The average self-reported dance time per child was 49 minutes per week in the first 10 weeks, versus 54 minutes per week in the second 10 weeks (in the first 10 weeks, only the I group was allowed to play AVG, whereas all participants played AVG in the second half of the study). Mean BMI percentile decreased by 5.6 for the intervention group, compared with 0.2 for the control group. At end point, accelerometers showed that (four randomly selected participants) over half of the dance time was spent in MVPA.
Simons et al.[88] (2012), The Netherlands	Cross-sectional survey	13.9 (1.3); 12–16	179; 90 F, 89 M	Not reported	Age: Regular gamers < non-regular gamers No differences in gender, education level (adolescents and parents), ethnicity, and sedentary behaviors ($P > 0.05$)	NA	NA	Any AVG	NA	11% of adolescents who had an AVG console never played. For the adolescents who played AVG, mean time spent on AVG was 80 (136) minutes a week. Including AVG play, regular gamers engaged in PA more than non-regular gamers. According to the participants, AVG mainly replaced sedentary screen time.
Wagener et al.[89] (2012), United States	RCT	14 (1.66); 12–18	40 (I, 21; C, 19); 27 F, 13 M	>95%	No differences ($P > 0.05$)	10 weeks	Clinic	Dance-based AVG	Participants played the AVG according to the target heart rate (75% maximum) by adjusting the difficulty level of the game.	Compared with the C group, participants in the AVG group significantly increased perceived competence to exercise. No pre–post differences in BMI were found within or between conditions.

(*continued*)

Table 4. (Continued)

Reference (year), country	Design	Participants' characteristics				Intervention duration	Settings	AVG	Strategy used	Main findings
		Age (years)	Number	BMI[a]	Group difference					
Gao et al.[90] (2013), United States	Crossover trial	Year 1: 10.32 (0.91) Year 2: 10.28 (0.90) 10–12	Year 1: 208; 87 F, 121 M Year 2: 165; 68 F, 97 M	Year 1: I (G4): 19.5 (4.45) C: G3, 19.3 (3.56); G5, 21.15 (4.33) Year 2: I: (G4) 20.69 (4.37) C: G5, 21.33 (5.20); G6, 20.83 (4.27)	Not reported	9 months	School	DDR	Children participated in a 30-minute, DDR-based exercise program three times per week. Two children shared one DDR station. Classroom teachers supervised the AVG play.	Significant difference was found between groups in the 1-minute run and favored the I group. Children's BMI group changes differed only for the first year and favored the AVG I group.
Norman et al.[91] (2013), United States	RCT	13.21 (1.30); 11–15	63; 24 F, 39 M	Not reported	Obese participants: The higher contingency group > the lower contingency group No differences in other demographic characteristics	4 weeks	Home	The higher contingency group: "Xavix Bowling," "Xavix Tennis" The lower contingency group: "Xavix Boxing," "Xavix J-Mat"	One of four games was randomly installed on a television at each participant's home. Participants were given an overview on how to play the game. They were asked to play the AVG as much as they liked.	Sedentary and light activities were stable over time, whereas MVPA time increased in the higher contingency group and decreased in the lower contingency group. Reported gameplay decreased in both groups.
Sun[92] (2013), United States	Pre–post study	9–12	70; 40 F, 30 M	Not reported	NA	Two semesters	School	Eight different AVG stations	Over two semesters, students had an AVG class every 2 weeks. In this class, children rotated between the eight stations (games that require only arm movement were eliminated from the study).	PA levels during AVG classes increased over two semesters. Three (challenge, exploration, and novelty) out of five dimensions of situational interest decreased over time. There were no gender differences in these three dimensions and in attention. However, boys felt AVGs were more enjoyable than girls.
Quinn[93] (2013), United States	Pre–post study	10–12	86; 32 F, 54 M	Not reported	NA	6 weeks	School	"Just Dance," DDR, and "Walk It Out" on Nintendo Wii	PE teachers were trained before providing AVG-based PE lessons. Four students' plays were projected on the screen. All students were required to participate by following the on-screen clues. Students rotated to allow additional participants to have time on the dance mats.	After I, participants were significantly more active in PE classes than before, whereas no difference of PA at home was found.

(*continued*)

TABLE 4. (CONTINUED)

Reference (year), country	Design	Participants' characteristics				Intervention duration	Settings	AVG	Strategy used	Main findings
		Age (years)	Number	BMI[a]	Group difference					
Staiano et al.[94] (2013), United States	RCT	15–19[b]	54; 30 F, 24 M	33.10; 94.7% (6.0%)	No differences ($P > 0.05$)	20 weeks	School	"EA Sport Active" on Nintendo Wii	Participants in the two AVG conditions could play 30–60 minutes every school day during the lunch or after school time. AVG routines were designed to increase gradually in intensity, length, and difficulty to create continued challenge for participants. Cooperative and competitive groups were in separate classrooms, each led by an adult coordinator. Participants were encouraged through periodic verbal reinforcement to complete AVG sessions. In the competitive group, pairs of participants were instructed to compete against each other to earn the most points. In the cooperative group, pairs of participants were instructed to coordinate to earn the most points as a team.	Over the 20-week I, students attended 31 sessions in the cooperative condition and 23 sessions in the competitive condition, which was not significantly different. The cooperative players lost more weight than the C group, whereas the competitive players did not. The cooperative players increased in self-efficacy compared with the control group, whereas the competitive players did not. Both AVG groups increased in peer support more than the control group.

[a]Data reported with percentages represent body mass index (BMI) percentiles according to the populations which authors chose.
[b]This study included participants who were older than 18 years of age. However, we decided to include it in this review. In addition, excluding it will not change the result regarding the effects of the structured active videogame (AVG) play on physical activity (PA).

C, control; CT, controlled trial; DDR, "Dance Dance Revolution"; F, female; G3, grade 3; G4, grade 4; G5, grade 5; G6, grade 6; I, intervention; LPA, light physical activity; M, male; MPA, moderate physical activity; MVPA, moderate and vigorous physical activity; NA, not applicable; PAS, pre-adolescents; PE, physical education; PS2, PlayStation 2; PS3, PlayStation 3; RCT, randomized controlled trial; VO_2, oxygen uptake; VO_{2max}, maximal oxygen uptake; VPA, vigorous physical activity.

Table 5. Methodological Quality Scores and the Effects of Active Videogame Intervention Studies on Physical Activity-Related Outcomes

Reference (year)	Item										Score	PA outcome measure	Effect[a]		
	A	B	C	D	E	F	G	H	I	J			Within-group	Between-group	Effect size
Home setting															
Maloney et al.[73] (2008)	—	—	+	+	+	+	?	—	—	—	4	LPA	↓	○	0.36
												MPA	→	○	−0.08
												VPA	↑	○	0.25
Mhurchu et al.[74] (2008)	+	—	+	+	+	+	?	—	+	+	7	CPM	Not reported	○	NA
												MVPA	→	○	NA
												Self-reported PA	→	○	NA
Graves et al.[77] (2010)	+	+	+	+	—	+	—	—	+	+	7	CPM	Not reported	○	−0.17
												MVPA	Not reported	○	−0.13
Maddison et al.[78] (2011)	+	+	+	+	+	+	—	+	+	+	9	MVPA	Not reported	○	0.03
												LPA	Not reported	○	NA
												CPM	Not reported	○	NA
												Physical fitness	Not reported	○	NA
Owens et al.[79] (2011)	NA	NA	+	+	+	NA	?	—	NA	—	3	MPA	→	NA	0.03
												VPA	→	NA	−0.22
												Physical fitness	↑	NA	0.42
Baranowski et al.[80] (2012)	+	+	+	+	+	+	?	—	—	+	7	LPA	→	○	0
												MVPA	→	○	−0.14
												CPM	→	○	−0.03
Maloney et al.[86] (2012)	+	+	+	+	+	+	—	—	—	+	7	Self-reported mild PA	→	○	−0.36
												Self-reported MPA	→	+	1.09
												Self-reported strenuous PA	→	+	1.47
												Steps/week	→	○	−0.72
												LPA	→	○	−0.18
												MPA	→	○	0.27
												VPA	→	○	0.48
Norman et al.[91] (2013)	—	—	+	+	+	+	—	—	—	—	4	LPA	→	○	0
												MVPA	↑	+	0.47
School															
Duncan and Staples[76] (2010)	—	NA	+	+	?	+	+	—	+	+	6	SPM (in session)	↓	—	−1.19
Gao et al.[83] (2012)	—	NA	+	+	+	+	?	+	—	—	5	Self-reported PA	Not reported	+	NA
												Self-efficacy	Not reported	+	NA
												Social support	Not reported	+	NA
												Outcome expectancy	Not reported	○	NA
Gao and Podlog[84] (2012)	—	+	+	+	+	+	—	—	—	+	6	SPM (in session)	↑	+	1.37[b]

(*continued*)

TABLE 5. (CONTINUED)

Reference (year)	Item										Score	PA outcome measure	Effect[a]		
	A	B	C	D	E	F	G	H	I	J			Within-group	Between-group	Effect size
Lwin and Malik[85] (2012)	—	+	+	+	—	?	?	—	?	—	3	Attitude	NA	+	0.16
												Subjective norm	NA	+	0.11
												Perceived behavior control	NA	○	−0.02
												Intention	NA	○	0.07
												Self-reported mild PA	NA	○	0.06
												Self-reported MPA	NA	○	0.02
												Self-reported strenuous PA	NA	+	0.06
Gao et al.[90] (2013)	—	NA	—	—	+	+	—	+	—	+	4	Physical fitness	Not reported	+	NA
Sun[92] (2013)	NA	NA	+	+	+	NA	—	+	—	+	5	MET value	↑	NA	0.99
Quinn[93] (2013)	NA	NA	+	—	+	NA	?	—	NA	—	2	Self-reported PA in PE	↑	NA	0.25
												Self-reported PA at home	→	NA	0.19
Staiano et al.[94] (2013)	—	+	+	+	—	+	?	—	—	+	5	Self-efficacy	Not reported	+	0.61
Community															
Christison and Khan[82] (2012)	NA	NA	+	—	+	NA	?	—	—	—	2	Self-reported exercise time	↑	NA	0.72
Clinic															
Wagener et al.[89] (2012)	—	—	+	+	+	+	+	—	—	—	5	Perceived competence in exercise	Not reported	+	0.83
Multiple settings															
Paw et al.[75] (2008)	?	—	+	?	—	+	?	—	—	—	2	Self-reported PA	Not reported	Not reported	NA
												Perceived competence in sports	Not reported	Not reported	NA
Bethea et al.[81] (2012)	NA	NA	+	+	+	NA	—	+	NA	—	4	Physical fitness	↑	NA	0.38
												Parental-reported PA	Not reported	NA	NA

[a]The pre–post difference in physical activity (PA)-related outcome in the active videogame (AVG) intervention group was coded as "↑" for significant positive change, "→" for no change, and "↓" for significant negative change. The pre–post difference in PA-related outcome between the AVG intervention group and comparison group was coded as "+" (significant difference favoring the AVG intervention group), "o" (no difference), and "—" (significant difference favoring the comparison group).

[b]Compared with the do-your-best comparison group, effect size for the difficult-goal group is 1.37, and effect size for the easy-goal group is 0.59.

CPM, counts per minute; LPA, light physical activity; MET, metabolic equivalent of task; MPA, moderate physical activity; MVPA, moderate and vigorous physical activity; NA, not applicable; SPM, steps per minute.

the home group.[75] In the other study, participants had access to a dance game at home and also in an afterschool program.[81] This study also provided each participant two dance mats at home and reported improved physical fitness and increased AVG play.[81]

None of these strategies has been used sufficiently to reach a firm conclusion regarding the effects. However, encouragement of non-solo play and a combination of strategies may be effective to promote PA.

Discussion

Effects of AVGs on immediate PA outcomes

AVG play consistently led to light- to moderate-intensity PA with some exceptions. Two studies that reported vigorous intensity levels of AVGs were not consistent with other studies.[57,68] Although the more intensive AVGs deserve more attention, the fact that most AVGs cannot reach vigorous intensity does not inhibit their potential to promote PA in children.

Indirect calorimetry and accelerometry have been used to estimate the MET values. One study found that accelerometry underestimated the intensity of AVG play compared with indirect calorimetry.[69] However, another reported much higher intensity of one AVG (''Dance Dance Revolution''; Konami, El Segundo, CA) using accelerometry than other studies using indirect calorimetry.[68] The inconsistent findings need to be further examined.

No consistent findings supported the proposal that AVGs favored specific demographic groups. Future studies are needed to examine whether AVGs are truly neutral in terms of these demographic characteristics for immediate and habitual PA outcomes.

Effects of AVGs on habitual PA or change of PA

In the free-living home setting, AVGs did not increase children's PA. This may be because the fidelity of the AVG intervention was poor, or because children decreased other activities to compensate the AVG play. Generally, AVG use declined during the interventions. It seems hard for the current AVGs to keep the interest of players over the long term. Given the cost of AVG consoles and games, this review raises doubt about whether introducing AVGs to non–videogame-playing children for home use could promote PA. Alternatively, providing peripheral equipment, such as jOG™ (New Concept Gaming Ltd, Liverpool, UK), the PlayStation® Eye™ (Sony, Tokyo, Japan), or the Kinect® (Microsoft®, Redmond, WA) sensor, to children who already have videogame consoles may decrease sedentary videogame play and increase PA.

Several strategies have been used in the home setting to promote PA. However, these strategies were not effective in influencing habitual PA. It is hard to monitor the compliance to these interventions, which inhibits a conclusion on the effects of the strategies used. Although some researchers noted the social function of AVG play and encouraged non-solo play in their interventions, few relevant outcomes, such as social support for PA, have been reported on the effect of doing so, except for one study.[73]

In settings where structured AVG sessions could be implemented, no high-quality study has assessed the effect of AVGs on habitual PA. The only high-quality RCT examined the change in steps of AVG play in an afterschool program.[84] In addition, no AVG studies objectively measured habitual PA in these settings. Therefore, the moderate evidence of structured AVGs on PA needs to be interpreted with caution.

One multicomponent intervention and two multiple-setting interventions have been conducted. These designs may have a stronger effect on PA[20,95] and thereby warrant future examination.

Only five studies[80,82,84,85,91] used behavior theories in their AVG interventions, and four[82,84,85,91] reported improved PA. More AVG studies should use behavioral theories to promote PA.

Many researchers have used AVGs for obesity prevention and intervention.[37,78,82,86,89,93,94] Because our review focused on the effects of AVGs on PA, interested readers are recommended to read other reviews[96,97] regarding the effect of AVGs on body weight.

Strengths and limitations

The strength of this systematic review was using an established evidence synthesis method to examine the effects of AVGs on PA. Following a previous review,[98] most PA-related outcomes were included for a comprehensive review.

The main limitation of this review is that we did not include sample size for the evidence syntheses. In one review,[20] the sample size of >250 subjects was considered as large, and studies of a large sample were given more weight than the small ones. However, in the existing AVG interventions, most studies have not reached this standard, and few studies provided sample size justification. Therefore, the conclusion regarding the evidence strength needs to be interpreted with caution. Eleven of the 21 intervention studies included used dance games partially or mainly. This fact limits the conclusions of this review because other technologies may have different results.

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