Active Video Games in schools and effects on physical activity and health: A systematic review

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Funding source: EN is funded by a University College London Crucible doctoral studentship.
Financial Disclosure statement: No authors have any financial relationships relevant to this work.
Conflict of Interest Statement: No authors have any conflicted interests.

Contributors' Statement

Ms Norris conceptualised and designed the review, drafted the initial manuscript and submitted the manuscript.
Prof Hamer checked data extraction and reviewed the manuscript.
Dr Stamatakis checked data extraction and reviewed the manuscript.

Abstract

Objective: To assess the quality of evidence for the effects of school Active Video Game (AVG) use on physical activity (PA) and health outcomes.

Study Design: Online databases (ERIC, PsycINFO, PubMed, SPORTDiscus & Web of Science) and grey literature were searched. Inclusion criteria were: the use of AVGs in school settings as an intervention; assessment of at least one health or physical activity outcome; and comparison of outcomes to either a control group or comparison phase. Studies featuring AVGs within complex interventions were excluded. Study quality was assessed using the Effective Public Health Practice Project (EPHPP) tool.

Results: Twenty two papers were identified: eleven assessed physical activity outcomes only, five assessed motor skill outcomes only and six assessed both physical activity and health outcomes. Nine out of fifteen studies found greater PA in AVG sessions compared to controls: mostly assessed by objective measures in school time only. Motor skills were found to improve with AVGs versus controls in all studies, but not compared to other motor skill interventions. Effects of AVGs on body composition were mixed. Study quality was low in sixteen studies and moderate in the remaining six, with insufficient detail given on blinding, participation rates and confounding variables.

Conclusions: There is currently insufficient evidence to recommend AVGs as efficacious health interventions within schools. Higher quality AVG research utilising Randomised Controlled Trial designs, larger sample sizes and validated activity measurements beyond the school day is needed.

Introduction

Children currently spend around 8.6 hours a day in sedentary behaviour (SB) [1]. Examples of SB include reading, watching television, using the computer and playing video games in a seated or reclined position [2,3]. Physically active time in children has been favourably associated with motor skills [4] and cardiometabolic profiles [5,6], whereas sedentary behaviour has been linked to reduced psychological wellbeing and academic achievement [7,8]. Sedentary habits formed in childhood may continue into adulthood [9].

Given the physical, social and psychological benefits of physical activity [10,11], interventions have attempted to replace children's SB with more active time [12]. A meta-analysis of children's interventions found significant overall SB reductions from baseline of 20.44 minutes a day and reduced BMI of -0.14 kg/m² [13]. Although screen-time is typically classified as SB [8], research has also studied the use of screen-based technologies as an intervention for reducing children's sedentary lifestyles. Active Video Games (AVGs) are one such intervention, requiring physical movements to interact with screen-based games [14-16].

Research has found AVGs to typically elicit light to moderate intensity activity in children [17,18], as well as significantly increased acute energy expenditure [19,20], heart rate and oxygen consumption compared to SB [17,18,21] and unstructured outdoor play [22]. However, the effects on AVGs on habitual improved activity are still unclear [23]. Additionally, there is evidence to suggest that children may compensate for active periods (such as AVGs) with increased SB [24-27].

Recent research has investigated the potential of AVGs as interventions within school settings: as an alternative to typical PE, recess or classroom teaching [28]. As school time is under many conflicting demands [29], it is important to assess the efficacy of school-based AVG interventions as a means to boost PA levels. The objective of this systematic review is to present current evidence on school-based AVGs and their relationship with health and physical activity outcomes including motor skills in children and youth aged five years and over.

Methods

The systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta- Analyses (PRISMA) statement [30].

Eligibility

To be included, studies needed to feature AVGs as an intervention exposure in school: within a lesson, during break-time or before or after the school day. To enable assessment against typical school practice, a study design featuring either a control group or comparison phase was required. Studies also required a specific measure of at least one health or physical activity-related outcome including motor skills and physical fitness: whether direct (e.g accelerometer, body composition measurement) or indirect (e.g self- or teacher-report). Studies featuring pupils of any health or disability status were included.

Studies were excluded if they featured participants aged 18 years and over, passive video games only, non-school settings or if AVGs were included only as a control group or as part of a complex intervention. Study protocols and reviews were also excluded. Due to feasibility, non-English language papers were excluded.

Search Strategy

A systematic search was carried out during April to May 2015 using ERIC, PsycINFO, PubMed, SPORTDiscus & Web of Science electronic databases. Titles and abstracts were searched with three separate strings representing: 1) AVGs generally, 2) specific AVG consoles and products and 3) school environment (Figure 1; online). Reference lists of included papers and grey literature [31,32] were also searched.

Data Extraction and Analysis

A standardised data extraction form was used to record information about each study, including study design, sampling strategy and AVG intervention details. Data extraction took place between April and June 2015 by one reviewer (EN) and checked by another for accuracy (ES or MH). Reported results were assessed in terms of their associations of school-based AVGs and health or physical activity outcomes. Studies were divided and presented according to the outcomes assessed. Effect sizes were reported as given in each study, commonly given as Cohen's *d*, partial eta squared η^2 or Glass' Δ. If these were not provided, Cohen's *d* was calculated with the means and standard deviations of AVG intervention and control groups where provided, using the formula $d = M_i - M_c / s_{pooled}$ [33,34]. We chose to present the results of the review descriptively as heterogeneity of outcomes measured was too large to realistically undertake a meta-analysis.

Quality Assessment

The Effective Public Health Practice Project (EPHPP) tool [35] was used to guide assessments of study quality. This intervention rating scale comprises of six components, assessing study design, selection bias, addressing of confounders, data collection methods (validity and reliability) and reporting of participant attrition and blinding. Strong, moderate or weak scores were awarded in each category. An overall rating was then applied for each study, with a 'Strong' rating representing no Weak ratings overall, a 'Moderate' rating representing one Weak rating and a 'Weak' rating representing two or more Weak ratings [35].

Results

A total of 9020 articles were identified (Figure 2). The 22 included studies presented data from 18 different interventions ([36,37] were from the same intervention and [38-40] were from the same intervention). 12 studies were performed in the USA, 5 in the UK, 2 in Canada, 1 in Greece, 1 in the Netherlands and 1 in Singapore.

Sample sizes and demographics

Sample sizes ranged from N=4 [36,37] to N=1112 [41], with four studies having sample too small to permit significance testing [36,37,42,43]. A total of N=3728 were studied across all 22 studies. Across all studies N=2332 (62.6%) participants took part in AVG conditions and N= 1997 (53.6%) in control conditions. N=1299 (34.8% overall sample) assessed health outcomes of BMI (N=1114; 29% overall sample) and body composition (N=682; 18.3% overall sample). N=3371 (90.4% overall sample) assessed physical activity outcomes and N=258 (6.9% overall sample) assessed motor skills. Across the studies, participants ranged from 5-15 years old [44], with 18 studies held in elementary schools, 1 in secondary schools[45] and 3 held across elementary and secondary school ages [41,44,46]. N=1723 (46.2%) of participants overall were girls and three studies featured students with balance disorders [43,47] or autism [44] (N=146; 3.9% overall sample).

Study design

Eight studies were forms of repeated measures designs, with all participants participating in AVG and control sessions [28,36,37,39,43,46,48,49]. Five studies were pre/post-test design, with all participants assessed before, during and/or after the intervention [38,42,47,50,51]. Seven studies were randomised controlled trials [41,44,52-56] and two studies were controlled trials [40,45].

AVG Interventions

The length of AVG intervention ranged from one-off sessions [42,46,48] to two academic years [39], with two studies not reporting length [36,37]. AVG sessions ran from one- [41] to up to five-times a week [56], or at the teachers' discretion [44]. Sessions typically lasted between 15 and 30 minutes and were delivered by teachers, research assistants [43,46,47] or a motor skills instructor [54]. AVG interventions were mostly run during PE lessons [28,36,37,41,46,48,49,51,55,56], with other studies running sessions during recess [38-40], lunch breaks [43,52,53], in free-time during school day at teachers' discretion [44], before school [50] and after school [42]. In all but one study [49], AVGs were provided on the widely-available consoles Nintendo Wii®, Sony Playstation 2® and Microsoft XBox 360®. Popular games included Dance Dance Revolution (DDR), Just Dance, Wii Fit and Wii Sports. One study did not provide details on the brand of exergaming dance mats provided [45].

Only two studies gave theoretical justifications for their use of AVGs [49,55]. These described AVGs to alter children's activity environment: hence effecting the individual child and their behaviour under Social Cognitive Theory [57] and Constructivist Theory [58]. Additionally, only two studies described the use of theory to inform their outcome measurement choices: [38] using the Expectancy Value model of Achievement Choice [59] and [41] using the Theory of Planned Behaviour [60].

Process evaluation

Only 9 of the 22 included studies provided process evaluation findings. Six studies reported the attrition or absence rate during the study period [36,40,45,47,50,51] and two studies provided teacher self-report logs of taught AVG sessions [49,51]. Four studies performed student and/or teacher evaluations of AVG sessions [40,47,48,51], with between 89% [48] and 100% [40] of respondents reporting positive attitudes to AVG use in schools. One study reported a faulty AVG machine, adjusting their analyses to account for this [37].

Outcomes

Eleven studies assessed physical activity outcomes only [28,36-38,41,42,48-52], six assessed both health and physical activity outcomes [39,40,44,45,46,53] (Table 1) and five studies assessed motor skill outcomes only [43,47,54-56](Table 2). The calculation of effect sizes from published data was not possible in ten studies[34]: four had samples too small[36,37,42,43], three reported results as Mean ± SD only and with *p* values without significance testing figures [46,50,56], two did not provide SDs for individual group outcomes[48,54] and one study provided Median and z-scores only[44].

Physical activity and fitness

Physical activity was assessed by 15 studies, with 9 studies using activity monitors via accelerometry [28,45,46,49,50], pedometry [42,48,52,53] or heart rate monitoring [42,52,53](Table 1). Most studies using activity monitors assessed PA either only during school time [28,50] or only comparative sessions such as recess or PE [42,46,48,48,52,53], with only one assessing whole-day PA[45]. Accelerometer output was assessed for metabolic equivalent (MET) values [46,61] or activity intensity using Freedson [50,62], Evenson [28,45,63], Trost [49,64] cut-points: all calibrated in free-living and/or treadmill conditions. Four studies assessed physical activity using self-report questionnaires [38,40,41,51] and two via observations [36,37]. Specific questionnaires used were the Sports, Play and Active Recreation for Kids' (SPARK) questionnaire [40,65], Physical Activity Questionnaire for Older Children (PAQ-C; [38,66]) and Godin Leisure Time Exercise questionnaire [41]: validated with adults but used in a pupil sample [67]. One study featured a sub-group for their physical activity data [50], testing 31.3% of their total sample. Three studies had sample sizes too small to allow significance calculations[36,37,42].

Nine out of fifteen studies found AVGs to reduce overall sedentary time and increase light (LPA) and moderate to vigorous physical activity (MVPA) compared to controls during each study's given measurement period (Table 1). Findings were drawn via accelerometry [28,49,50], observations [36,37] and questionnaires [38,40,41,51] (total N=2378). Conversely, four studies found overall lower LPA, MVPA, energy expenditure and steps in AVG group compared to controls, assessed via accelerometry [45,46], pedometry [48,52,53] and heart rate monitoring [52] (total N=803). Two studies found significantly greater AVG session MVPA to not extend into overall school-time [50] or home activity [51]. Two studies found no overall difference in PA between AVG and control groups, assessed via heart rate monitoring [42,53] and pedometry [53](total N=65).

Of the eight studies comparing physical activity within AVGs to traditional PE, six found greater PA in AVG versus PE [28,36,37,41,49,51](total N=1733; Table 1). For example, 40% of AVG time was spent in MVPA compared to 31% of PE time in one study [28]. However, two studies finding this association had sample sizes too small for significance testing [36,37]. Conversely, two studies found physical activity to be lower in AVGs compared to typical PE: assessed via energy expenditure [46] and step-counts [48] (total N=129).

Physical fitness was assessed by three studies, using elements of the Eurofit physical fitness battery such as 10x5m shuttle test [44,68], 20m shuttle test [45], or a timed one-mile run [39](Table 1). Two studies found significantly greater fitness following AVG interventions versus controls[39,44] (total N=473) and one found no difference between intervention groups [45] (N=497).

Of the seventeen studies assessing physical activity or fitness, only three assessed the effects of AVG interventions on physical activity by gender[46,48,49] with none finding any significant difference in outcomes. Only two studies assessed the effects of AVG interventions by BMI category: finding no difference in outcomes[46,49]. Assessing all studies collectively, there were no observable differences in physical activity or fitness AVG outcomes by age-group or intervention length.

BMI and body composition

Of the six studies assessing health outcomes, BMI was measured by five studies [39,44,45,46,53] and body composition by two studies: assessed by percent body fat[40,45] (Table 1). BMI and body composition were found to be significantly lower in AVG intervention groups compared to controls in three studies [39,44,45] (total N=970); however, reduced BMI was only sustained for the first of two study years in one paper [39]. No differences in BMI or body composition were found between intervention groups in the remaining three studies [40,46,53] (total N=329).

Motor skills

Effects of AVG interventions on motor skills were assessed in five studies. Four of these comparing AVGs against both other motor skills programmes and controls [43,54-56] and two assessed students with balance disorders either exclusively[43] or purposively[47] in their samples (N=146) (Table 2). Three studies assessed motor proficiency using the full- [47] and short-form [43] Bruininks-Oseretsky Test (2nd edition: BOT-2) [69] and Test of Gross Motor Development 2 (TGMD-2)[54,70]. Balance was assessed in two studies using the HUR BT4™ portable assessment platform [55,56,71]. One study assessed motor performance using the Movement Assessment Battery for Children (2nd edition: MABC2) and one assessed perceived motor ability using the child-completed Co-ordination Skills Questionnaire [43,72].

All studies found improved motor skills following AVG conditions (total N=258; Table 2). For example, average BOT2-assessed balance scores in children with balance problems improved from 7.4/30 (below average) pre- to 10.6/30 (approaching average: 11/30) post-AVG intervention ($p<0.001$). However, one study had too small a sample to allow significance testing [43]. No studies found differences in motor skill improvements between AVG and other motor skill intervention programmes (total N=210).

Of the five studies assessing AVG effects on motor skills, two assessed effects by gender [55,56], with both finding significantly improved scores in girls compared to boys. Assessing all studies collectively, there were no observable differences in motor skill AVG outcomes by age-group or intervention length.

Risk of bias assessment

Study quality was generally poor (Table 3). Of the twenty two identified studies, six were assessed to be of moderate quality [40,43,44,47,52,53] and sixteen to be of low quality [28,36-39,41,42,45,46,48-51,54-56]. Blinding was unclear in all studies. As AVGs would be an innately novel school experience, it is likely that all participants would be aware of the exposure of interest. No studies reported on whether outcome assessors were blinded to intervention allocation, with most studies not reporting who outcome assessors were e.g researchers or teachers. Potential selection bias was common, with most studies not describing the number of invited schools and pupils agreeing to participant. Participation rates of eligible pupils ranged from 18.3% [48] to 97.1% [55] in the five studies that reported this. Studies also largely did not report participant attrition during AVG interventions or study conditions. Neither confounders nor baseline demographics between intervention groups were described in some studies [28,38,41,42,46,48,51,54-56]. Additionally, some studies did not comment on the validity or reliability of their outcome instruments [36,39,41,42,50].

Discussion

This systematic review is the first to summarise the literature assessing use of AVGs in school settings and effects on physical activity, motor skills and health outcomes. Twenty two studies were identified, with AVGs commonly used during PE and break-times.

Physical activity outcomes were assessed in the majority of identified studies, with most research finding PA to significantly increase in AVGs compared to typical teaching. However, the wide variety of measures prevented us from quantifying the effect size. There were a number of issues with physical activity measurement in identified studies. Firstly, objective assessment was restricted to in-school activity only in all but one study [45], preventing assessment of compensation effects into home and leisure time [26]. Secondly, positive associations were usually found with questionnaire or observational measures, whereas more objective pedometer and heart rate assessments found negative associations [52,53]. Additionally, although accelerometer data typically indicated positive effects of AVG interventions, the data analysis used may not be the most appropriate. The cut-points used were specifically derived for children but were calibrated using treadmill or ambulatory free-living activity [62-64]. No cut-points have been calibrated specifically for AVG. As AVGs are commonly restricted to small spaces and require more on-the-spot movement [18], typical calibrations for accelerometers that are primarily designed to capture ambulatory movement may not be applicable [73,74].

A limited number of studies assessed BMI and body composition as health outcomes, with evidence unclear. As general evidence is undecided as to whether physical activity reduces body composition in children [5,75], changes via these discreet, light to moderate intensity AVG interventions would be highly unlikely. The five studies that assessed AVG effects on motor skills all found greater improvements compared to control groups. Positive effects of AVGs on motor skills were found for both studies assessing students with balance disorders[43,47](N=146), which has arguably contributed to these overly positive findings. These school-based findings are more positive than home-based research: finding AVGs to be no better than typical activities in improving motor skills [76]. However, no outcome differences were found between AVGs and other motor skill programmes. The decision to use either comparative approach in schools may be dependent on time and resource constraints. Additionally, only a small minority of studies assessed AVG outcomes by gender or BMI category. Assessment of outcomes by pupil demographics is essential to understand which pupils could be targeted by school-based AVG interventions.

Study quality was poor across all identified research. Common issues included insufficient blinding details, a lack of confounder reporting and no indication of the proportion of schools and participants that agreed to participate. Sample size in many studies was small, as low as N=4 [36,37]. The establishment of larger RCTs assessing AVGs is hugely dependent on financial resources, given the initial costs of purchasing the technology. Unlike all studies identified in this review; future larger-scale work should purposively use multilevel modelling to reflect the clustered nature of results between schools, classes and individual pupils[77]. Sample size calculations will also need to reflect this study design [78].

There was little process evaluation of AVG interventions, providing no indication as to the uptake of sessions and perceived efficacy of teachers and pupils. Previous school-based physical activity research has shown teaching staff concerns of time, space restrictions and safety to be essential in the uptake of physical activity interventions[79]. Adoption of AVGs within the school environment will ultimately be determined by school staff. For physical activity interventions such as AVGs to be integrated into regular school teaching, future research must aim to understand the facilitators and barriers of their use [80].

Conclusions

This systematic review has found that there is insufficient evidence for AVGs to be used as physical activity interventions in school settings. Existing evidence is inconsistent, based on poor study quality and features a lack of understanding on teacher and pupil perceptions of school-based AVGs. Higher quality AVG research utilising Randomised Controlled Trial designs, larger sample sizes and validated activity measurements beyond the school day is needed.

Abbreviations:
Active Video Games (AVGs)
Bruininks-Oseretsky Test, 2nd edition (BOT-2)
Light Physical Activity (LPA)
Moderate to Vigorous Physical Activity (MVPA)
Physical Activity (PA)
Sedentary Behaviour (SB)

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Table 1. School-based Active Video Game interventions assessing physical activity and health outcomes.

Paper	Country	Intervention	Study length	Study design	Sample	Outcome	Result
Adkins et al. (2013)	USA	Wii DDR, Wii Just Dance - Before school, 2x a week	14 weeks - 7 weeks intervention period	Pre- and post-intervention testing	1 school N=88 at pre- & N-144 at post-testing Sub-group N=45 7-10 years old	Sub-group: 1) PA: Accelerometer (Actigraph 7164)	1) + Greater MVPA in exergaming (M=9.3 minutes DDR; M=9.67 minutes Just Dance) vs control (M= 5.2 minutes) - No differences in daily MVPA between all intervention groups
Azevedo et al. (2014)	UK	Dance Mats – brand not given - During school day	14 months - 6 weeks structured intervention period	Controlled trial	7 schools N=497 11-13 years old	1) PA: Accelerometer (Actigraph GT3X) 2) Fitness (20m shuttle run) 3) BMI 4) Body composition: % body fat	1) X Less LPA in intervention group (p-0.02; *d*=-0.68) and no difference in sedentary time or MVPA between groups 2) – No difference between groups 3) + Lower in intervention group (p=0.0001; *d*=-0.21) 4) + Lower in intervention group (p=0.03; d=-0.20)
Dickinson & Place,	UK	Wii Mario & Sonic at the	1 academic year (10	RCT	3 schools N=100 autistic	1) Fitness: Elements of Eurofit physical	1) + Significantly improved VO² max, bleep test, shuttle run, broad jump, sit-

(2014)		Olympics - During school day in classroom at teachers' discretion	months)		children 5-15 years old	fitness battery 2) BMI	ups in intervention group at follow-up (all p<0.001) 2) + Significantly more reduced BMI in intervention group (39 improved vs 4 in control; p<0.001)
Duncan & Staples, (2010)	UK	Wii: Wii Sports, Mario & Sonic at the Olympics, Celebrity Sports Showdown - 30 minutes during lunch break, 2x a week	6 weeks	RCT	2 schools N=30 10-11 years old	1) PA: Pedometer (Yamax NL2000) 2) MVPA: Heart Rate Monitor (Polar RS400)	1) X Significantly more steps in intervention group in first week only (p=0.01; *d*=0.28), then significantly more steps in control group (p=0.01; *d*=-1.22) 2) X Less MVPA in intervention group (p=0.0001; *d*=-0.84)
Duncan et al. (2011)	UK	XBOX 360 Gamercize power stepper with rotated game titles - 30 minutes during lunch	6 weeks	RCT	2 schools N=40 10-11 years old	1) PA: Pedometer (Yamax NL2000) 2) MVPA: Heart Rate Monitor (Polar RS400)	1) X Significantly more steps in intervention group than control group in first week only (p=0.003; *d*=0.63), then no difference between groups 2) – No overall difference between groups

		breaks, 2x a week				3) BMI	3) – No difference between groups
Fogel et al. (2010)	USA	- 10 AVG options including Playstation DDR - 30 minute PE lessons	Not described	Alternating treatments design	1 school N=4 10-11 years old	1) PA: Observations logged with Personal Digital Assistants	1) + Greater PA during exergaming (M=9.2 minutes) vs PE (M=1.6 minutes; no significance testing) + Greater number of PA opportunities in exergaming (M=11.6 minutes) vs PE (M=3.8 minutes)
Gao, 2013	USA	- DDR (device not given) - 3x30 minutes a week during recess	1 academic year (9 months)	Pre- and post-intervention testing	1 school N=107 9-12 years	1) PA: PAQ-C questionnaire	1) + Increased score in intervention participants (+0.32) vs reduced score in control (-0.15; $p<0.05$; d=0.90)
Gao et al. 2013	USA	- DDR (device not given) - 3x30 minutes a week during recess	2 academic years (18 months) - Intervention length unclear	Repeated measures crossover	1 school N=208 Year 1 N=165 Year 2 9-12 years	1) Fitness: Timed 1-mile run 2) BMI	1) + Intervention children had greater reductions in time to complete 1-mile run in both years than controls (8.2% less time in Year 1; $p<0.01$; d=-1.67) 7.8% less time in Year 2; $p<0.01$; d=-1.79) 2) – No differences in BMI category improvements at Year 2

Gao & Xiang, 2014	USA	Playstation 2 DDR - 3x30 minutes a week during recess	1 academic year (9 months)	Controlled trial	1 school N=185 9-12 years old	1) PA: 'Sports, Play and Active Recreation for Kids' (SPARK) questionnaire 2) Body composition: % body fat	1) + Significantly more PA in intervention than control during intervention ($p<0.01$; $\eta^2 = .06$) 2) – No difference between groups
Gao et al. (2015)	USA	Wii: 8 games including Just Dance, Wii Fit, Wii Sports - alternating 3x30 minute or 2x30 minute PE sessions a week (PE 5x a week in total)	36 weeks	Alternating treatments design	1 school N=140 6-8 years old	1) PA: Accelerometer (Actigraph GT3X)	1) + Significantly less sedentary time in exergaming (52%) than PE (63% $p<0.001$; $\eta^2 = .16$) + Significantly more MVPA in exergaming (40%) than PE (31%, $p<0.001$; $\eta^2 = .17$)
Lwin & Malik, (2012)	Singapore	Wii: DDR, Wii Sports - 1x 45 minute PE lesson a	6 weeks	RCT	7 schools (4 secondary) N=1112 9-13 years old	1) PA: Leisure Time Exercise Questionnaire	1) + Significantly more reported strenuous exercise in intervention group versus control ($p<0.05$; $\eta^2 = .004$)

		week					- No difference between intervention groups for adolescents
Miller et al. (2013)	USA	Wii: DDR, Winds of Orbis - 20 minute session of each in PE	One-off sessions over 2 weeks	Repeated measures	1 school N=104 8-15 years old	1) PA: Energy Expenditure (EE) Accelerometer (Actical) 2) BMI	1) X Greater EE in PE than both intervention sessions (p<0.01 respectively) - No difference in AVG activity by gender or BMI category 2) – No difference between sessions
Quinn, (2013)	USA	Wii: DDR, Just Dance, Walk it out, Wii Sports - 5x42 minute PE lesson a week	6 weeks	Pre- and post-intervention testing	1 school N=86 10-12 years	1) PA: 2 items from PAQ-A	1) + Significantly more activity reported in PE lesson post-intervention ($p<0.05$; $d=0.25$) - No difference in home activity before and after intervention
Shayne et al. (2012)	USA	- 10 AVG options including Playstation DDR - 2x 30 min PE sessions a	Not described	Alternating treatments design	1 school N=4 8-9 years old	1) PA: Observations logged with Personal Digital Assistants	1) + Greater observed PA during exergaming (no significance testing) + Children engaged more in PA when had opportunity to do so in exergaming (82.5% of time) than control (48.8%)

		week					
Wadsworth et al. (2014)	USA	Wii Tennis - 1x 20 minute PE session	One-off sessions	Repeated measures	1 school N=132 8-9 years old	1) PA: Pedometer (Yamax NL2000)	1) X Less steps in exergaming (M=322.73) than PE (M=965.67; p<0.001) - No difference in AVG activity by gender
West & Shores, (2014)	USA	HOPS - 2x PE sessions a week (length not given)	4 months	Repeated measures with crossover treatment	3 schools N=387 9-14 years old	1) PA: Accelerometer (Actigraph GT1M)	1) + Greater MVPA in exergaming (M=14.75 minutes) than control (M=9.5 minutes; p<0.01; Δ=5.25) - No difference in AVG activity by gender or BMI category
Wittman, (2010)	USA	Wii: DDR, Wii Fit - 1x 20-minute after-school session per game	One-off sessions	Pre- and post-intervention testing	1 school N=25 9-12 years old	1) PA: Pedometer (model not given) 2) PA: Heart Rate (method not described)	1) - Varied PA for exergaming sessions (M=802 & 746 steps) vs non-exergaming (M=789 & 1171 steps; no significance testing) 2) - Varied 11-point raises to heart rate for exergaming sessions (44% & 52% of participants) vs non-exergaming (37% & 59% of participants)

Notes: '+' denotes a positive reported relationship, '-' denotes no relationship and 'X' denotes a negative relationship between AVG and the given outcome

Table 2. School-based Active Video Game interventions assessing motor skill outcomes.

Paper	Country	Intervention	Study length	Study design	Sample	Outcome	Result
Hammond et al. (2013)	UK	Wii Fit - 3x 10 minutes a week during lunch	1 month	Repeated measures crossover with 3 programmes: AVG, 'Jump Ahead' motor skills & control	2 schools N=18 children with Developmental Co-ordination Disorder 7-10 years old	1) Motor proficiency: Short form Bruininks-Oseretsky Test 2nd Ed (BOT-2) 2) Perceived motor ability: Co-ordination Skills Questionnaire (CSQ)	1) + 3 children achieved meaningful progress (>/- 1 level of change) during intervention vs only 1 child in control (no significance testing) 2) – No difference between AVG and Jump Ahead groups
Jelsma et al. (2014)	Netherlands	Wii Fit - 3x 30 minutes anytime during school	6 weeks	Pre- and post-intervention testing	3 schools (2 SEN) N=48 (N=28 with balance problems) 6-12 years olds	1) Motor proficiency: Bruininks-Oseretsky Test 2nd Ed (BOT-2) 2) Motor performance: Movement Assessment Battery for Children 2nd Ed (MABC2)	1) + Children with balance problems improved bilateral co-ordination ($p=0.007$; $\eta^2_\rho = .47$) and running speed and agility ($p=0.001$; $\eta^2_\rho = .64$) after intervention; 2) + Children with balance problems improved total MABC2 score ($p=0.20$; $\eta^2_\rho = .38$) and balance

							(p=0.12; η^2_ρ =.42) after intervention
Sheehan et al. (2012)	Canada	Wii Fit - 3x 34 minute PE sessions a week	6 weeks	RCT 3 groups: AVG, balance-based PE teaching (ABC) & control	1 school N=65 9-10 years old	1) Balance: HUR BT4™ portable assessment platform	1) + Significant improvement from pre-test in AVG intervention ($p<0.001$; *d*=.74) but not control - Significantly more improvement in girls compared to boys ($p<0.01$; d=.71) - No difference between AVG and ABC groups
Sheehan et al. (2013)	Canada	4 AVG options - 4-5x 34 minute PE sessions a week	6 weeks	RCT 3 groups: AVG, balance-based PE teaching (ABC) & control	1 school N=61 9-10 years old	1) Balance: HUR BT4™ portable assessment platform	1) + Significant improvement from pre-test in AVG intervention ($p<0.001$) but not control - Significantly more improvement in girls compared to boys ($p<0.05$) - No difference between AVG and ABC groups
Vernadakis et al. (2015)	Greece	Xbox Kinect Sports & NBA Baller Beats - 2x 30 minute sessions a week	8 weeks	RCT 3 groups: AVG, typical object control skills training (TA) & control	3 schools N=66 6-7 years old	1) Motor proficiency: Test of Gross Motor Development 2 (TGMD-2)	1) + Greater improvement in AVG vs control ($p<0.001$) - No difference between AVG and TA groups

Notes: '+' denotes a positive reported relationship, '-' denotes no relationship and 'X' denotes a negative relationship between AVG and the given outcome; SEN stands for Special Educational Needs

Table 3. Risk of bias of identified studies

Study	Selection Bias	Study Design	Confounders	Blinding	Data Collection Methods	Withdrawals & Drop-Outs	Overall
Adkins et al. (2013)	Weak	Moderate	Strong	Weak	Weak	Weak	Weak
Azevedo et al. (2014)	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Dickinson & Place, (2014)	Moderate	Strong	Strong	Weak	Strong	Moderate	Moderate
Duncan & Staples, (2010)	Moderate	Strong	Strong	Weak	Strong	Moderate	Moderate
Duncan et al. (2011)	Moderate	Strong	Strong	Weak	Strong	Moderate	Moderate
Fogel et al. (2010)	Moderate	Moderate	Weak	Weak	Weak	Moderate	Weak
Gao, (2013)	Moderate	Moderate	Weak	Weak	Moderate	Moderate	Weak
Gao et al. (2013)	Moderate	Moderate	Strong	Weak	Weak	Moderate	Weak
Gao & Xiang, (2014)	Moderate	Moderate	Strong	Weak	Moderate	Strong	Moderate
Gao et al. (2015)	Moderate	Moderate	Weak	Weak	Strong	Strong	Weak
Hammond et al. (2013)	Strong	Moderate	Strong	Weak	Strong	Moderate	Moderate
Jelsma et al. (2014)	Moderate	Moderate	Strong	Weak	Strong	Moderate	Moderate
Lwin & Malik, (2012)	Moderate	Strong	Weak	Weak	Weak	Weak	Weak
Miller et al. (2013)	Moderate	Moderate	Weak	Weak	Strong	Weak	Weak
Quinn, (2013)	Moderate	Moderate	Weak	Weak	Strong	Weak	Weak
Shayne et al. (2012)	Moderate	Moderate	Weak	Weak	Weak	Weak	Weak

Sheehan et al. (2012)	Strong	Strong	Weak	Weak	Moderate	Weak	Weak
Sheehan et al. (2013)	Strong	Strong	Weak	Weak	Moderate	Strong	Weak
Vernadakis et al. (2015)	Weak	Strong	Weak	Weak	Strong	Weak	Weak
Wadsworth et al. (2014)	Weak	Moderate	Weak	Weak	Strong	Weak	Weak
West & Shores. (2014)	Moderate	Moderate	Strong	Weak	Strong	Weak	Weak
Wittman, (2010)	Weak	Moderate	Weak	Weak	Weak	Weak	Weak

Note: Assessed using Effective Public Health Practice Project (EPHPP) tool (National Collaborating Centre for Methods and Tools, 2008)

Figure 1. Search strategy

1. Active video gam* or AVG* or video gam* or exergam* or dance simulation

OR

2. Nintendo* or Wii* or Xbox* or Kinect or Playstation* or EyeToy or DDR or Dance Dance Revolution or interactive whiteboard* or PC

AND

3. school* or lesson* or class* or curricul* or physical education or PE or P.E* or physical* or activit* or exercise*

Figure 2. Record flow of systematic review.