doi: 10.1111/obr.12164

Obesity Prevention/Pediatric Obesity

Are field-based exergames useful in preventing childhood obesity? A systematic review

Z. Gao[1] and S. Chen[2]

[1]School of Kinesiology, The University of Minnesota, Minneapolis, Minnesota, USA; [2]Department of Kinesiology, Iowa State University, Ames, Iowa, USA

Received 27 December 2013; revised 25 January 2014; accepted 3 February 2014

Address for correspondence: Dr. Z Gao, School of Kinesiology, the University of Minnesota, 220 Cooke Hall, 1900 University Ave. SE, Minneapolis, MN 55455, USA.
E-mail: gaoz@umn.edu

Summary

Exergames have started to find their way into field-based settings, such as schools, communities and homes, as a possible solution to curbing physical inactivity and childhood obesity. However, a clear view of the effects of field-based exergaming on children's obesity-related outcomes is lacking. Hence, a systematic review on this topic is warranted. This review synthesizes the impact of field-based exergames on children's physical and psychosocial outcomes. A total of 34 articles conducted in field-based settings were identified from 104 peer-reviewed publications that investigated the effects of exergames. Upon screening, these articles met the inclusion criteria and a high inter-rater agreement for inclusion was reached between the authors. The effects of field-based exergames on children's habitual physical activity (PA) and obesity-related outcomes (e.g. weight loss, body composition) remain unclear due to design problems, measurement issues and other methodology concerns. In addition, exergame is appealing to children, although strategies are warranted to sustain their interests. In summary, exergames are desirable as a promising addition to promote PA and health. Professionals may integrate exergames at field settings to promote a physically active lifestyle among children with the goal of curbing childhood obesity.

Keywords: Body composition, energy expenditure, moderate-to-vigorous physical activity, weight loss.

obesity reviews (2014)

Introduction

As the increasing childhood obesity rate has become a public health issue in the USA, exergames that integrate exercise and gaming entertainment have emerged as an innovative approach to fighting childhood obesity. Exergames capitalize on children's interest in computerized video games and their needs to increase physical activity (PA). Recently, some exergames (e.g. Dance Dance Revolution [DDR], Wii Fit, and Kinect Sports) have been welcomed beyond homes and laboratories, and are beginning to find their way into schools and communities as apossibly new solution to curbing physical inactivity and childhood obesity (1).

A plethora of research studies have been conducted to evaluate the physical, psychological and cognitive effects of exergames (1–4). Evidence from these studies proves that exergames can generate some health benefits (e.g. improving physical fitness, weight loss, enhancing enjoyment) among children and adolescents. To date, the majority of these research studies were conducted in laboratory-based settings, which well-documented the positive effects of exergames on acute energy expenditure (EE) (2–4). For example, it was found that EE values of DDR were equivalent to 7.0 metabolic equivalents (METs), which is in the moderate-to-vigorous intensity PA (MVPA) level. Nevertheless, researchers (5) postulated that such impact would be best studied in natural living settings to reveal the practical implications of exergames for public health. Thus far, only a small portion of investigations have been conducted in field-based settings to examine the effects of exergames on children's PA levels and health (5–8). Furthermore, these field-based studies appear to have diverse research scopes with some supporting the benefits of exergames while others indicating no benefits.

Although a few systematic reviews (1,9) on exergaming are available, no known review has specifically addressed the effects of field-based exergaming on children's health outcomes. Given that exergames have been prevalent among children, it is of critical importance to synthesize research findings derived from field-based settings, with the goal of providing meaningful practical implications and recommendations for health professionals. In response, the purpose of this paper is to synthesize the exergame-related research carried out in less controlled field-based settings including homes, schools and communities (i.e. YMCAs, community centers, etc.), and discuss the effectiveness of exergames on children's obesity-related outcomes. More specifically, this review describes the characteristics of exergame studies in preventing childhood obesity. It also has synthesized the effects of exergames on children's obesity-related outcomes, including physiological and psychosocial outcomes.

Method

Literature search

The data collection began with intensive and systematic literature search. Published articles, professional reports, and dissertation/thesis related to exergaming were located through the following six databases (i) Academic Search Complete; (ii) ERIC; (iii); Medline; (iv) PubMed; (v) PsycINFO and (vi) SportDiscus. Each database was searched through two research universities in the mid-west region of the USA. with the following keywords: (exergam* or active video gam* or active gam* or physically active video gam*); and (children or youth or kids). Abstracts of the publications were reviewed and then relevant full-text papers were downloaded for inclusion. In addition, bibliographies of published review articles were cross-checked with the results from the search engines. The two authors carried out literature searches independently and then gathered the retrieved articles in a shared online folder.

To be considered for inclusion, each article must meet the following criteria established by the authors (i) peer-reviewed, data-based research articles; (ii) published in English from 1985 to 2013; (iii) studied some type of exergames (e.g. DDR, Eyetoy, Wii, etc.) in relation to obesity-related outcomes and (iv) studied children and/or adolescents (18 years and younger) in field-based settings. Review articles and research articles related to sedentary video games, videos and children with special needs were excluded to narrow down the scope of this review. The studies were independently evaluated by both authors for inclusion. Had any disagreement arisen between the authors, the adjudication from an external expert would be resorted to.

Outcome variables

The obesity-related outcome variables included both physiological and psychological outcome variables that are related to obesity prevention. The physiological outcome variables included, but not limited to EE, heart rate (HR), maximal oxygen consumption (VO_2), METs, PA levels, rate of perceived exertion (RPE), body composition, weight circumference and cardiovascular fitness. On the other side, the psychosocial outcome variables included intrinsic motivation, enjoyment, liking, situational interest, self-efficacy, self-worth, attitudes, intention, social support, outcome expectancy and social cognitive factors.

Literature organization

Literature organization involved two major steps. First, the articles stored in the shared folder were reviewed one by one to make sure that only relevant entries were included. This process rendered the final list of 104 published articles on the topic of exergaming or active video game. Second, the abstracts of the included articles were pasted into a Microsoft Excel database for categorization. Although it would be desirable to perform a meta-analysis for quantification, it seemed clear, after inspection of the articles, that it was impossible to conduct such an analysis because of the large numbers of outcome variables, the heterogeneous samples, inconsistent measurement instrument and various research designs. Thus, a systematic review was conducted.

Data extraction

The database categorized article entries by game settings: (i) home-based exergaming; (ii) school-based exergaming; and (iii) other setting-based exergaming (i.e. clinic, home and school). Two authors then extracted the data from each article including location of study, year of publication, study description, sample, design, measurements, intervention dose, exergame types and key study findings.

Data synthesis

The descriptive data of the exergames (e.g. location, sample, year, etc.) were calculated to describe the characteristics of the exergames at different settings. Although this review included several observational studies in addition to intervention studies to comprehensively investigate the impact of exergames on obesity-related outcomes, the effectiveness of exergames was assessed based upon intervention studies, especially randomized controlled trial (RCT) and control trials. Specifically, shown in Table 1, the intervention studies were classified into four levels through whether there were pre-post differences in obesity-related outcomes between the exergame intervention group and control/comparison group: (i) + indicates that significant difference favoured the exergame intervention group; (ii) 0 indicates that no significant difference between groups; (iii) – indicates that significant difference favoured the control/comparison group and (iv) I indicates indeterminate results because of lack of control/comparison group (Table 1).

Based upon previous literature (10,11), research design quality of each study was assessed independently by the authors with a 10-item scale (see Table 1). Each item was rated as positive, negative, or not applicable (unknown or not reported) (10). A design quality score ranging from 0 to 10 was calculated by summing up the positive rates. High quality was defined when a RCT or controlled trial scored above the median score 5.5.

Results

Of the 104 articles included in the initial screen in this study, 70 were conducted in the laboratory settings. The authors read the full texts for the remaining 34 articles, and confirmed that all articles met the inclusion criteria. High inter-rater agreement for inclusion was reached between the authors (i.e. 95% agreement).

Descriptive analyses

Among the 34 included exergame studies, 20 studies were conducted in the school settings, followed by 11 studies in home settings, and three studies in other settings (i.e. clinic setting; see Tables 2, 3 and 4). USA was the primary venue for exergame studies ($n = 25$), in comparison with four studies in Europe, three studies in New Zealand, one study in Asia and one study in Canada.

The number of field-based studies increased dramatically after 2010. In particular, there are 28 studies published between 2010 and 2014 (7 home-based, 19 school-based and 2 other setting-based studies), and only six studies prior to 2010 (four home-based, one school-based and one other setting-based studies). There is a large variability on sample size across studies. Specifically, the sample varied from 12 to 322 for home-based studies, with six studies having less than 50 subjects and only one study having over 100 subjects. The sample ranged from 4 to 1,112 for school-based studies, and 50% of the studies ($n = 10$) had a sample of less than 100 subjects. All three other setting-based studies had sample size of less than 50 subjects.

In light of age group, 22 studies targeted both children (12 years and younger) and adolescents (9 home-based, 11 school-based and 2 other setting-based studies), followed by eight studies on children only (two home-based, five school-based and one other setting-based studies) and four studies on adolescents in school-based settings. With regard to game type, all studies used commercially available exergames except one computer-based game (12), with 22 studies employing DDR and 12 studies using Wii active games.

The effectiveness of exergames

In this review, 31 were intervention studies and three were cross-sectional observational studies (13–15). Of the intervention studies, 12 were RCT trials (seven home-based studies (5,16–20), three school-based studies (6,21,22) and two other setting-based studies (23,24)), six were school-based control trials (quasi-experimental design without randomization (25–30)), and 13 were pre-post designed studies (pre-experimental design with pre-test and post-test among same children; four home-based studies (31–34), eight school-based studies (35–42) and one other setting-based study (43)). The design quality of studies ranged from 3 to 10 for home-based studies, with seven studies being above the median score 5.5, which are deemed high-quality studies (Table 1). Meanwhile, the design quality scores ranged from 2 to 8 for school-based studies, with eight studies being above the median score 5.5. However, all three other setting-based studies scored below the median score. Taken together, there is a higher percentage of high-quality studies in home-based settings than those in school-based settings and other settings.

To determine the effectiveness of exergames on children's obesity-related outcomes, cross-sectional studies ($n = 3$) and pre-post studies ($n = 13$) were not included because these designs were inadequate to illustrate whether exergame intervention was effective because of the lack of a control or comparison group. Among the RCT and control trials ($n = 18$), the intervention dose varied considerably across studies. More specifically, the intervention duration ranged from 6 weeks to 52 weeks, with the majority ($n = 16$) having less than 30-week intervention. The duration of each exergame session ranged from 10–30 min to 50 min, and the frequency varied from once per week to five times per week.

At home-based settings, two studies indicated that exergame intervention was more effective than control/comparison group in increasing physiological outcomes, such as EE, PA and METs (17,18). Four RCT studies found no significant differences in physiological outcomes, such as PA, body mass index (BMI) and weight loss, between the intervention and control/comparison groups (5,16,17,44). One RCT yielded that exergame intervention children had

Table 1 Design quality analysis for the exergaming intervention studies

Articles	1 Randomization	2 Control	3 Isolate exergame	4 Pre-post	5 Retention	6 Baseline	7 Missing Date	8 Power analysis	9 Validity measure	10 6-month follow-up	Score	Effectiveness
Home												
Baranowski *et al.* (5)	+	+	+	+	+	+	–	+	+	–	8	0
Calcaterra *et al.* (32)	–	–	–	+	+	+	–	–	+	–	4	I
Christison & Khan (33)	–	–	+	+	+	+	–	–	+	–	5	I
Graves *et al.* (7,19)	+	+	+	+	–	+	+	–	+	–	7	0
Maddison *et al.* (44)	+	+	+	+	+	+	+	+	+	+	10	0
Madsen *et al.* (31)	–	–	+	+	+	–	–	–	+	+	5	I
Maloney *et al.* (16)	+	+	+	+	+	+	+	–	+	+	9	0
Maloney *et al.* (20)	+	+	+	+	+	+	–	–	+	–	7	+/0
Murphy *et al.* (18)	+	+	+	+	+	+	–	–	+	–	7	+
Ni Mhurchu *et al.* (17)	+	+	+	+	+	+	+	–	+	–	8	+
Owens *et al.* (34)	NA	–	+	NA	+	NA	NA	–	+	–	3	NA
School												
Duncan & Staples (25)	NA	+	+	+	NA	–	+	–	+	–	5	–
Fogel *et al.* (36)	–	–	+	+	+	–	+	–	–	–	4	I
Gao, Hannah, *et al.* (26)	–	+	–	+	+	+	+	+	+	+	8	+/0
Gao *et al.* (37)	–	+	+	–	+	–	+	+	+	–	6	I
Gao *et al.* (27)	–	+	+	+	+	–	–	–	+	+	6	+/0
Gao & Podlog (6)	+	+	+	+	+	+	+	NA	+	–	8	NA
Gao & Xiang (28)	–	+	–	+	+	+	+	NA	+	+	7	+
Gao, Zhang, Stodden (39)	–	–	+	+	+	+	+	–	+	+	7	I
Goran & Reynolds (22)	+	+	–	+	+	+	–	–	+	–	6	+
Lwin & Malik (30)	+	+	+	NA	–	–	NA	–	+	–	4	+/0
Miller *et al.* (41)	–	–	+	–	+	–	–	–	+	–	3	I
Quinn (35)	NA	–	+	NA	+	NA	NA	–	+	–	3	I
Sheehan & Katz (29)	–	+	+	+	+	+	–	–	+	–	6	+
Staiano *et al.* (21)	+	+	+	+	–	–	–	–	+	–	5	+
Sun (40)	–	–	+	+	+	+	–	–	+	–	5	I
Sun (42)	–	–	+	+	+	+	–	–	+	–	5	I
Whittman (38)	–	–	+	–	–	–	–	–	+	–	2	I
Other												
Bethea *et al.* (43)	NA	–	+	NA	+	NA	NA	–	–	+	3	NA
Paw *et al.* (23)	+	+	–	+	–	+	–	–	+	–	5	NA
Wagener *et al.* (24)	–	+	+	+	+	–	–	–	+	–	5	+

Note. 1 = randomization procedure were adequately described and carried out; 2 = research design allowed for comparison between the exergame intervention group and the control/comparison group; 3 = research design allowed for test of effectiveness of the exergames alone (not combined with other exercises) as compared with the control/comparison group; 4 = outcome variables were measured before and after the intervention; 5 = dropouts were described and not more than 30%; 6 = groups are comparable at baseline on key outcome variables through statistical analyses; 7 = data analyses were conducted while considering missing data; 8 = power analysis was conducted to determine the appropriate sample size; 9 = the reliability and validity of the measures were provided; 10 = participation were followed up for a minimum of 6 months. NA, not applicable.

Table 2 Summary of exergame studies at the home settings

Study and country	Study description	Sample and design	Measurement	Dose	Exergames	Key findings
1. Baranowski *et al.* (5) USA	To evaluate whether children receiving a new exergame spontaneously engage in more PA than those receiving an inactive video game, and whether the effect would be greater among underserved children.	78 children; 9–12 years old; 41 intervention children; 37 control children. RCT	Questionnaire; stadiometer; digital weight scale; Actigraph accelerometer	12 weeks of exergame play at naturalistic condition	Active Life-Extreme Challenge, EA Sports Active, DDR, Wii Fit Plus, Wii sports on Wii	Children receiving exergames were not more physically active than children receiving the inactive video games. Parent perceived neighbourhood safety, child BMI *z*-score or other demographic characteristics did not moderate this finding.
2. Calcaterra *et al.* (32) Italy	To evaluate an exergame-based recreation programme among sedentary obese children	22 children (13 boys); 9–16 years old; Pre-post study	Questionnaire; Stadiometer; weight scale; bioelectric impedance scale; tape; chemistry analyzer; treadmill; gas exchange analyzer; grip strength test; sit -and-reach test	12 weeks, 2 per week; 90 min per session	Wii Just Dance, Wii Fit (Plus), Samba de Amigo, Micharl Jason: the Experience	Children showed significant decrease in BMI, SDS-BMI, fat mass, WC, WC/height ratio, blood glucose, HOMA-IR, triglycerides and systolic pressure.
3. Christison & Khan (33) USA	To evaluate the effectiveness of a exergame-based weight intervention programme on children's health outcomes.	48 children (26 boys); 8–16 years old; Pre-post study	Questionnaire; Stadiometer; weight scale;	10 weeks, 120 min	DDR, exerbike, Wii sports, Xavix games	Children's self-worth improved; weekly exercise time increased; screen time and soda intake reduced, and BMI decreased (–0.48 kg/m^2)
4. Graves *et al.* (19) UK	To compare the physiological cost and enjoyment of exergaming among adolescents, young adults and old adults.	58 children (39 boys); 8–10 years; 20 intervention group, 29 control group RCT	Questionnaire; Portable MetaMax3B	12 weeks	Games on Sony PS2, PS3 with jOG ^{TM}	There were no differences in PA and body fat changes between groups. Intervention children increased exergame play time while decreased sedentary play time at 6 weeks, as compared with the control children.
5. Maddison *et al.* (44) New Zealand	To investigate the effect of exergame on children's weight, body composition, PA and physical fitness.	322 children (87 boys); 10–14 years old; 162 intervention, 160 control RCT	Questionnaire; Salter scales; stadiometer; anthropometrictape; Bioimpedence Monitor; 20 m shuttle run test; accelerometer	60 min d^{-1} × 7 per week × 24 weeks	Sony PS3 EyeToy, Kinetic, Sport, and Dance Factory	The change in BMI increased among control children but remained the same among intervention children. There was also a reduction in body fat among intervention children.
6. Madsen *et al.* (31) New Zealand	To evaluate the effect of DDR on obese youth's weight loss.	30 children (12 boys); 9–18 years old; Pre-post study	Stadiometers; weight scales; a video memory; questionnaire	30 min d^{-1} × 5 d week^{-1} × 24 weeks	DDR	DDR intervention did not affect changes in BMI from baseline at either 3 or 6 months.

Table 2 *Continued*

Study and country	Study description	Sample and design	Measurement	Dose	Exergames	Key findings
7. Maloney *et al.* (16) USA	To test the feasibility of DDR use in children's homes to increase PA and to decrease sedentary screentime.	60 children (30 boys); 7–8 years old 40 intervention, 20 control RCT	Questionnaire; accelerometer; stadiometer; weight scale; wrist sphygmomanometer; pedometer	30 min $d^{-1} \times 4$ d $week^{-1} \times 28$ weeks	DDR MAX2	Intervention children showed increased vigorous PA and a reduction in light PA; while the control children did not show increase in MVPA but showed a reduction in light PA. Intervention children reported a decrease in sedentary screen time; while the control children reported an increase.
8. Maloney *et al.* (20) USA	To determine if peer-led DDR could promote children's PA.	64 children (30 boys); 9–17 years; 33 intervention group, 31 control group	Questionnaire; accelerometer; pedometer	12 weeks	DDR	Self-reported MVPA increased for the intervention children and declined for the comparison children overtime. No significant differences were found on the accelerometer or pedometer data.
10. Murphy *et al.* (18) USA	To test the impact of DDR on overweight children's endothelial dysfunction (EDF) and other risk factors.	35 children (18 boys); 7–12 years old; 23 intervention, 12 control RCT	Stadiometers; weight scales; heart rate and ECG monitor; blood pressure cuff; ultrasound transducer; autoanalyzer; radioimmunoassay assay kits; Life Diagnostics Radioimmunoassay; metabolic cart	10–30 min per session × 5 per week × 12 weeks	DDR	Compared with control children, intervention children had significant improvements in flow-mediated dilation, exercise time on the graded exercise test, mean arterial pressure, weight and peak VO_2. Thirteen intervention children achieved normal EDF while 10 did not achieve.
11. Ni Mhurchu *et al.* (17) New Zealand	To examine the effect of exergames (EyeToy Knockout and exergames) on children's PA.	20 children (12 boys); 10–14 years old; 10 intervention, 10 control RCT	Questionnaire; accelerometer; stadiometer; weight scale; anthropometric tape	Approximately 60 min $d^{-1} \times 12$ weeks	EyeToy	Intervention children spent significantly higher average time spent in all physical activities as compared with control children. No significant anthropometric outcome change owing to low statistical power.
12. Owens *et al.* (34) USA	To examine changes in PA and fitness in eight families after 3 months of exergaming use.	12 children (6 boys); 8–13 years, mean age = 10 Pre-post study	Accelerometer, Balance Master, push-up, treadmill test, trunk flexion test	3 months	Wii Fit games on Nintendo Wii	Exergames had no effects on daily PA, muscular fitness, flexibility, balance and body composition. Children's peak VO_2 increased after 3 months. Their daily exergame use declined overtime.

Table 3 Summary of exergame studies at the school settings

Study and country	Study description	Sample and design	Measurement	Dose	Exergames	Key findings
1. Duncan & Staples (25) UK	To compare children's PA levels during exergaming play and free play during recess.	30 children (12 boys); 10–11 years old; 15 intervention, 15 control; CT	Pedometers; heart rate monitors; stadiometers; weight scales;	30 min $d^{-1} \times 5$ d $week^{-1} \times 6$ weeks	Wii Sports Tennis, Sonic and Mario at the Olympics, Celebrity Sports Showdown	Intervention children accumulated significantly greater steps per day than control children during the first week of the intervention. This pattern was reversed at the mid and end points of the intervention.
2. Fogel *et al.* (36) USA	To examine the effects of exergaming on PA among four inactive children in physical education classes.	Four 5th grade students (2 boys); Mean age = 9 years old; Pre-post study	Observations; questionnaire	All attended exergaming unit and stardard physical education unit.	DDR, Gamercize, 3 rivers Game Cycle, Dog Fighter Vateye, Wii, iTech Fitness Xrboard, Fit Interactive 3 Kick	Exergaming produced substantially more minutes of PA and more minutes of opportunity to engage in PA than did the standard physical education. In addition, exergaming was socially acceptable to both students and teacher.
3. Gao (29) USA	To examine the relationships between students' mastery experiences, situational motivation and PA levels in DDR.	195 youth (100 boys); 12–15 years old; Cross-sectional study	Questionnaire; accelerometer	50 min per session $\times$ 5 d $week^{-1} \times 2$ weeks	DDR	Students were motivated to play DDR, but their MVPA was low. In addition, students with successful mastery experiences had significantly higher intrinsic motivation, idenfied regulation and MVPA.
4. Gao, Hannah, *et al.* (26) USA	To examine the impact of DDR-based exercise on urban Latino children's physical fitness and academic achievement.	208 Latino children (121 boys); Mean age = 10.32 85 intervention; 123 control CT	1 mile run; stadiometers; weight scales; reading and math scores	30 min $\times$ 3 d $week^{-1} \times 52$ weeks	DDR	The DDR-based exercise intervention improved children's cardiorespiratory endurance and math scores over time. Children's yearly pre-test and post-test BMI group changes differed only for the first year of intervention.
5. Gao *et al.* (37) USA	To examine the effects of three curricular activities (DDR, fitness, and football) on students' situational motivation (intrinsic motivation, identified regulation, external regulation, and amotivation) and PA levels, and examine the predictive strength of situational motivation to PA levels.	280 7-9th grade children (156 boys); 12–15 years old; All children attended all units in physical education classes. Pre-post study	Questionnaire; accelerometer;	50 min/session $\times$ 5 days/week $\times$ 2 weeks	DDR	Students spent significantly higher percentages of time in MVPA in fitness and football units than they did in DDR unit. Students reported higher intrinsic motivation and identified regulation towards fitness than DDR. In contrast, students displayed significantly lower amotivation towards fitness than football and DDR. Intrinsic motivation was the only positive predictor for, whereas amotivation was the negative predictor.
6. Gao *et al.* (27) USA	To investigate the effects of DDR on urban children's exercise correlates (i.e. self-efficacy, outcome expectancy, social support) and PA levels.	101 children (52 boys); 9–11 years old; 50 intervention, 51 comparison CT	Questionnaire	30 min per session $\times$ 3 d $week^{-1} \times 26$ weeks	DDR	Intervention children reported significantly greater increased self-efficacy, social support and daily PA levels than the comparison children over time.
7. Gao & Podlog (6) USA	To examine the effects of different levels of goal specificity and difficulty on Latino children's performance and PA levels in an afterschool programme incorporating a DDR programme.	98 urban Latino children (47 boys); 7–13 years old; 33 easy-goal intervention, 33 difficult goal intervention, 32 control RCT	Pedometers; DDR gaming systems	45 min per session $\times$ 4 d $week^{-1} \times 8$ weeks	DDR	Children who set specific (easy or difficult) goals had significantly greater increased PA levels and DDR performance than those in the control group. Children's increased PA levels in the difficult goal group were significantly higher than those in the easy-goal group.

Table 3 *Continued*

Study and country	Study description	Sample and design	Measurement	Dose	Exergames	Key findings
8. Gao, Podlog, Huang (15) USA	To examine the relationships between children's situational motivation and PA levels in a DDR programme, and perceived PA enjoyment.	215 children (112 boys);8–14 years old; Cross-sectional study	Questionnaire; accelerometer;	30 min week^{-1} × 18 weeks	DDR	Children's intrinsic motivation was the significant predictor for MVPA and PA enjoyment.
9. Gao & Xiang (28) USA	To examine the impact of a DDR-based programme on urban children's physical activity participation, body composition and perceptions of the programme.	185 children (105 boys); mean age = 10.34 years; 72 intervention; 113 comparison CT	Questionnaire; skin-fold calipers; interviews.	30 min × 3 per week × 26 weeks	DDR	Intervention children had significantly greater increased PA levels than comparison children. Intervention children did not differ significantly in percent body fat change from comparison children. Children interviewed reported positive attitudes towards the intervention.
10. Gao, Zhang, Stodden (39) USA	To compare children's PA levels, self-efficacy and enjoyment between DDR and aerobic dance units in physical education.	53 fourth grade children (24 boys); 10–11 years old; all attended both units; Pre-post study	Pedometers, questionnaire;	12 lessons for each unit	DDR	Children rated self-efficacy and enjoyment higher for DDR than in aerobic dance; but they spent significantly more time engaging in MVPA in aerobic dance.
11. Goran & Reynolds (22) USA	Investigate the efficacy of a computer-based exergame in promoting 4-grade children's PA.	122 children (49 boys), age 9–11 years old 63 intervention, 59 control RCT	Questionnaire; TBF 300/A analyzer, height rod, activity monitor	16 lessons × 45 min per lesson	Computer-based IMPACT game	There was a significant intervention effect in obesity reduction among girls but not boys.
12. Huang & Gao (14) USA	To examine the effect of previous experiences on students' situational interest and PA levels, and the relationships between situational interest and PA levels in DDR.	135 7th–9th grade children (70 boys); 12–15 years old; Cross-sectional study	Questionnaire; accelerometer;	50 min d^{-1} × 2 weeks	DDR	Children with DDR experiences scored significantly higher than those without experiences at following interest dimensions: challenge; exploration intention; instant enjoyment; and attention demand. Also, novelty emerged as the only significant predictor for MVPA.
13. Lwin & Malik (30) Singapore	To examine the effects of exergaming-based physical education on youth's social cognitive factors and PA behaviours.	1,112 youth; 10–12 years old; intervention: 6-week physical education lessons with Wii Control: physical education lessons without Wii CT	Questionnaire	45–60 min week^{-1} × 6 weeks	Wii DDR, tennis, boxing	Exergaming children were more likely to report more positive beliefs and PA behaviours. Also, age moderated outcome variables, with the effect of exergaming more pronounced among children than pre-adolescents in attitudes and PA behaviours.
14. Miller *et al.* (41) USA	To compare the energy expenditure of a tailored, interactive genre of e-gaming (Orbis), DDR and traditional physical education activities in meeting recommended levels of MVPA.	104 children (46 boys); grades 3–8; Pre-post study	Accelerometers	All children completed three randomly ordered 20-min bouts of DDR, Orbis and physical education.	DDR, Orbis (active adventure e-gaming)	Overall, children had significantly greater energy expenditure in physical education as compared with Orbis and DDR. After adjustment for sex, grade and BMI, children in grades 3–5 energy expenditure from all three activities was sufficient to meet recommended MVPA, while children in grades 6–8 were met only by boys and only with PE activities.

Table 3 *Continued*

Study and country	Study description	Sample and design	Measurement	Dose	Exergames	Key findings
15. Quinn (35) USA	To examine the effect of Wii-based exercise on children's participation in PE and active time	86 children (54 boys), age 10–12 years old Pre-post study	Questionnaire	6 weeks	Just Dance, DDR, Walk It Out on Nintendo Wii	Children were significantly more active in PE class after the intervention. But there was no difference in children's PA at home.
16. Sheehan & Katz (29) Canada	To examine the change in balancing ability in fourth grade students as a result of experiencing a 6-week long exergaming programme or an equal length Agility, Balance, and Coordination (ABC) programme or a typical physical education programme.	64 children (36 boys); 21 exergaming intervention, 19 ABC intervention, 21 control group; CT	HUR BT4™ assessing postural stability	Daily exergamine/ABC for 6 weeks	iDance, Wii Fit Plus, XR-Board Dueller system, Lightspace Play Wall	The exergaming and ABC interventions yielded significantly greater balance development than the typical physical education class; but no difference was found between the exergaming and ABC conditions.
17. Sun (40) USA	To investigate children's PA level, situational interest and motivation change over time in an exergaming unit as compared with those in a traditional fitness unit in physical education classes.	74 fourth grade children (34 boys); 9–12 years old; All attended exergaming and traditional fitness units. Pre-post study	Accelerometers; questionnaire	16 exergaming lessons and 16 fitness lessons	Gamebikes, Xavix Boxing, 3 kick, Dog Fight Flight simulator, Wii, DDR, Gamercize, Xrboards	Children's in-class PA in the exergaming unit was significantly lower than in the fitness unit. Results also indicated that students' situational interest in exergaming was significantly higher than in the fitness unit at the beginning and end of instruction. Children's interest declined significantly in both units and at the same rate.
18. Sun (42) USA	To examine the change in situational interest and PA level by following a group of fifth grade students in an exergaming unit and a conventional aerobic fitness unit.	70 children (30 boys); 9–12 years old; all attended exergaming and aerobic fitness units. Pre-post study	Accelerometers; Questionnaire	Three exergaming lessons and three aerobic fitness lessons	Gamebikes, Xavix Boxing, 3 kick, Dog Fight Flight simulator, Wii, DDR, Gamercize, Xrboards	Children's situational interest decreased over time. Although PA in exergaming in all measurement phases (pre-, post- and follow-up) did not reach the moderate intensity level, children became more and more active in the exergaming unit over time.
19. Staiano *et al.* (21) USA	To examine whether an exergame intervention could reduce weight and improve psychosocial outcome among overweight and obese African–American children.	54 children (24 boys), age 15–19 years old RCT	Stadiometers; weight scales; questionnaire	20 weeks	EA Sport Active on Nintendo Wii	The cooperative children had 31 sessions, and competitive children had 23 sessions. Cooperative children lost more weight than control children, whereas competitive children not. Both groups increased in peer support more than control children. The cooperative children had increased self-efficacy in comparison with control children, while the cooperative children not.
20. Whittman (38) USA	To compare the efficacy of exergaming (DDR, Wii boxing, Wii tennis) as compared with two traditional sports (capture the flag, kick ball) in an after-school PA programme.	25 4–6 grade children (16 boys), age 9–12 years old Pre-post study	Questionnaire; heart rate monitors; pedometers	20 min per session	Wii tennis, boxing, DDR	The majority of children had increased heart rates and pedometer steps. Self-reported enjoyment indicates that exergames playing is engaging and an effective method for increasing PA in youth.

Table 4 Summary of exergame studies at other settings

Study and country	Study description	Sample and design	Measurement	Dose	Exergames	Key findings
1. Bethea *et al*. (43)*. USA	To examine whether the implementation of DDR would increase MVPA and physical fitness among African–American and Hispanic American children	28 children (18 boys); 9–11 years old; Pre-post study	Questionnaire; blood pressure monitor; stadiometer, biolelectric impedance scale; CardioCheck PA device; 20 m shuttle run test	30 min × 3 per week × 30 weeks	DDR Exteme	Children's physical fitness (VO_2max) increased and was sustained through 30 weeks. An average of 1.12 h d^{-1} of increased PA was maintained.
2. Paw *et al*. (23)**. The Netherlands	To test a weekly multiplayer class on the children's motivation to play an exergame (interactive dance simulation video game) at home.	27 children (2 boys); 9–12 years old; 13 intervention, 14 control; RCT	Questionnaire; 20 m shuttle run test; stadiometers; weight scales; caliper	Daily sessions over 12 weeks	Interactive dance simulation video games	The multiplayer group had significantly higher PA time than the home group. Dropout was significantly lower in the multiplayer group (15%) than in the home group (64%).
3. Wagener *et al*. (24),*** USA	To investigate the effect of dance-based exergaming on obese children's perceived competence, psychological adjustment and BMI.	40 children (13 boys); 9–12 years old; 21 intervention, 19 control; RCT	Stadiometers; weight scales; questionnaire	10 weeks	Dance-based exergames	Intervention children had significantly increased self-reported perceived competence to exercise as compared with control children. There were no pre-post differences in BMI within or between conditions.

Note. *home and school; **home, sport and fitness center; ***clinic setting.

greater increased self-reported PA, but not objectively measured PA, than control children (20). At school settings, two RCT studies and two control trials found exergame intervention was more effective than the control/comparison group in promoting a variety of obesity-related outcomes, including PA, cardiorespiratory fitness and weight loss (21,22,28,29). Three control trials suggested that exergame intervention had positive effects on some outcome variables (e.g. PA, self-efficacy, enjoy/liking, intrinsic motivation) but no significant effects on other outcomes (e.g. outcome expectancy) as compared with control/comparison group (26,27,30). In addition, one control trial revealed that exergame intervention was worse than the comparison group in influencing PA participation and EE (25). When comparing the effectiveness of exergames with traditional sports or PA, one study (38) indicated exergames were better while four studies (37,39–41) suggested otherwise. At other settings, one RCT (24) indicated positive effect, whereas the other two studies found no differences between the groups (23,43) (Table 1).

Discussion

In an intuitive sense, exergaming consoles are often deemed as home entertainments that are made available to children and adolescents. While many would expect more exergaming studies to be done at home, schools appeared to be a more popular venue to use exergames in preventing childhood obesity. Our data indicated that nearly two-thirds of the exergame intervention studies were conducted at schools. USA represents the primary location where exergame intervention took place. Considering the fact that over 80% of studies were published after 2010, we speculate that this trendis driven by the childhood obesity epidemic in the USA over the past decade.

Shown in our descriptive results, the majority of studies had small sample sizes, which limited the generalizability and practical implications of the findings. Also, the intervention doses of such studies were far from ideal, with most having short intervention durations and/or low frequencies per week. This reflects the challenging fact for researchers to repeatedly assess obesity-related outcomes among a large population over an extended period. In addition, children and/or adolescents were included in all studies, indicating that children have developed sufficient cognitive capabilities and movement skills to understand and play exergames. It may also owe to the fact that most commercial exergames, such as DDR and Wii Sports, are designed for children and adolescents.

Physiological and physical effects of exergames

Examining the physiological and metabolic effects of exergames seems to be the most focused line of laboratory-based research on exergames (2–4). Overall, the majority of exergames have been reported to increase children's exercise intensity to a point equivalent to light to moderate intensity PA, as measured by heart rate, oxygen consumption, and RPE (7,8). Despite this, the effects of exergames varied greatly due to the nature of different exergames (9). In particular, some exergames are designed to be more physically demanding than others. For instance, games that actively engage lower body require higher energy cost than those that only engage upper body (9) because of the involvement of larger muscle mass. Research shows that only a third of the 68 Wii Sports and Wii Fit Plus games are classified as moderate intensity because of the nature of the games (45). Thus, the more active exergames (e.g. DDR, Wii boxing) should be encouraged to use as interventions for obesity prevention purpose.

The effects of exergames utilized in the home on habitual PA and cardiovascular fitness is not clear. Some researchers suggested that exergame interventions had significantly positive effects on children's obesity-related outcomes, such as cardiovascular fitness, body composition and PA participation. For example, Bethea and colleagues (43) reported children's cardiovascular fitness was enhanced and sustained after a 30-week DDR intervention. Other researchers asserted that the exergame treatment effects on PA, BMI and body fat favoured the exergames (e.g. Eyetoy, Kinect Sport) intervention group (16,17,44) over control children. Working with overweight children, Murphy *et al.* (18) found that children in DDR group had a significant increase in total exercise time and VO_2 peak, and a decrease in body weight compared with control children. However, several studies have reported that exergame interventions had no effect on children's body composition (body mass index and percent of body fat) and PA levels (5,31,35). For instance, Baranowski *et al.* (5) found no differences in accelerometer-determined PA levels between exergame intervention children and sedentary video game control children.

It is plausible that intervention fidelity may cause the inconsistency on the findings across studies. Even with an RCT design, intervention fidelity may still be a concern. For example, Baranowski *et al.*'s (5) RCT had several drawbacks, which limits its findings for generalization to broader population of various contexts. These limitations include (i) no instructions or prescriptions on how to be physically active were offered for children and (ii) no home visits and phone calls were enforced to ensure the intervention fidelity. All these strategies are crucial and need to be utilized in population-based PA interventions. Therefore, limited by drawbacks, some population-based exergame interventions failed to yield positive findings. Hence, what should be done to ensure and improve the intervention fidelity becomes a new challenge for the researchers.

Additionally, the relatively low effectiveness of exergame used in a non-structured or self-directed manner (i.e. home settings) for PA promotion among children may relate to one important aspect of child development: low self-regulation. Children are not as rational as adults to regulate their thoughts and behaviours while playing exergames. They would not contemplate, for example, what purposes to accomplish through exergames, how much time to allocate, and what benefits they could acquire from the exergame experiences. Instead, they may be simply attracted and carried away by the appealing features of the games. Recognizing this fact, we may wonder: what strategies can we use to make self-directed exergame use more successful? Recently, Gao and colleagues (6) have provided a good approach for exergame intervention, which is constantly helping children with goal setting in exergame play. In their study, Gao *et al*. (6). found children who set specific goals had better health outcomes than those who set vague and do-your-best goal. Specifically, setting up specific attainable goals (i.e. easy or difficult goals) can likely be attributed to the fact that such goals provide children with clear and objective aims, a focus of direction and subsequent eliciting clear behavioural intentions. Given the cognitive nature of goal-setting strategy, it is apparent that such a technique may be a cost-effective means for promoting PA in exergames. Consequently, it is recommended that health professionals employ specific goals as an effective means to improve children's sustained behaviour in exergame interventions.

Evidence of the effectiveness of school-based exergames is also inconclusive, with the majority of research indicating significantly positive effects (26–29,36), whereas a few other research studies (13,37) reporting the opposite. Specifically, two studies (29,36) reported that children engaged insignificantly more minutes of PA and had more balance development utilizing exergames than they did in the traditional physical education programmes. Three other intervention studies (26–28) reported a positive trend showing that the exergame interventions significantly improved children's cardiorespiratory fitness and PA over time. One study (25) found that exergame activities were worse in increasing PA participation and EE than the comparison group did.

In addition, it appears that playing exergames is not as physically active as traditional sports. Although Wittman (38) reported exergames increased more PA levels in children than two traditional after-school activities, Gao *et al*. (37) found adolescents had significantly higher percentages of time in MVPA in fitness and football units than they did in DDR unit in physical education classes. Two other studies (4,39) carried out among elementary school children demonstrated that children's in-class PA levels in the exergame unit were significantly lower than in the fitness or aerobic dance units in physical education classes. Miller *et al*. (41) further suggested children's EE was significantly greater in physical education compared with exergame classes. It is possible the contradictory findings may attribute to the nature of exergames (e.g. some games are more active than other), research design (e.g. convenient samples), target population (children vs. adolescents), instruments (e.g. objective or subjective measurement of PA) and other confounding factors (e.g. fidelity of the physical education or exergame programmes, familiarity with exergames). Thus, caution is advised when sorting out these mixed research findings.

While not all exergames are physically demanding enough to result in health benefits, it is widely acknowledged that exergames can be a viable replacement for many mundane sedentary behaviours, including sedentary video games. In his insightful editorial paper, Pate (46) argued that, unlike the 1950s when kids would go out to play if bored, today's societies are enriched by convenient technologies such as personal computers, video games, Internet, cellphones and televisions. These technologies have enabled people to live a sedentary lifestyle since a young age. Therefore, exergame, with its exercise utility, is believed to be a substitute for less active forms of entertainment (i.e. computer games, television); however, it may in fact be drawing kids away from physical activities that they already participate in. As exergames are beginning to be found in more and more homes, they have been reported to be naturally replacing adolescents' sedentary time on television viewing, Internet usage and non-active gaming (16,46).

Psychosocial effects of exergames

The most appealing aspect of exergames lies in its entertaining or motivating features. It is well documented that many exergames, besides their requirement of physical exertion, are perceived as enjoyable by children and adolescents (2,45). Such perceptions are critical to attract children to play exergames and, more importantly, sustain their continued participation in these games. While laboratory- or home-based exergame studies on psychosocial effect are limited, there are a handful of such studies carried out in school-based settings. The majority of these studies seem to suggest that, in general, children enjoy playing exergames (13,42). Gao (13) reported that adolescents were intrinsically motivated in playing DDR in physical education classes. Being provided with the opportunity to engage in DDR or other exergames, children and adolescents became more genuinely interested and self-efficacious compared with conventional physical education classes such as fitness or aerobic dance (39,40). Further, with a longitudinal perspective, Gao *et al*. (27) reported that exergame intervention could exert a positive effect on children's self-reported social support and self-efficacy over time. Hence, as a representation of modern technology, exergame challenges or complements conventional physical education classes in providing children enjoyable and psychosocially beneficial experiences. It holds potential as a technological tool in education as well as in public health promotion.

Although exergame is appealing to most children, it remains questionable whether this effect would sustain over time as only one longitudinal study (27) reported positive effect; let alone to claim its effect on long-term sustainable PA adherence. In particular, two studies reported that elementary school children's situational interest during exergame-themed physical education classes declined significantly between the beginning and end of instruction (40,42). These results suggest that exergames may have strong motivational power at the beginning of their use, but it is premature to claim they will help children develop a physically active and healthy lifestyle.

In fact, the sustainability of exergame use is a primary concern for the field-based PA interventions. Several studies illustrated that children's enthusiasm towards exergames waned as time passed by (6,25,40,42). As a result, some researchers have suggested that exergames play exerts only acute effects and is not a sustainable activity to promote children's PA (25). Unfortunately, this perspective has not taken into account confounding factors such as the design problems, measurement issues and other methodology concerns associated with those studies. Indeed, most exergame studies were not RCT and often lacked rigorous control of confounding factors. Specifically, previous studies have pinpointed a number of confounding factors (e.g. game types, game experience, age and gender) associated with exergame studies that limit the strength of evidence. For example, two studies (13,26) found that adolescents with higher DDR skill levels had significantly higher MVPA and enjoyment (13,26). Age was another factor that may influence intervention outcomes. Health outcomes (i.e. attitudes, cardiovascular fitness, moderate and mild exercise behaviours) as results of exergames are more pronounced among children than adolescents (30,41). Additionally, gender also serves as a moderator for exergame effect, with dance exergames being liked more by girls than boys (47,48). These confounding factors need to be taken into consideration in the research designs and exergame implementations to increase the generalizability of the research findings.

Observational studies identified the extent to which children's motivation (e.g. situational interest, situational motivation) predicts their MVPA in exergames (13,14,37). Research findings reported children's intrinsic motivation and perceived novelty effect of exergames positively predicted of their MVPA during exergame play, whereas a motivation was a negative predictor (13–15,37). The above evidence indicates that children who were intrinsically motivated towards exergames tend to be more physically active than children who are not motivated at all. Hence, health professionals should present and organize exergames in an interesting and enjoyable way to foster children'smotivation towards exergames play.

Engaging in exergames could bring about other psychosocial benefits. Specifically, playing exergames can significantly influence children's PA attitudes, subjective norms (i.e. perceived social pressure from significant others), intention and strenuous exercise behaviour (8). It provides opportunities for social support among children and teachers who are involved in the gaming experience together (36). For example, in one study, Paw *et al.* (23) implemented a dance exergame and compared the level of participation in the game between two different social groups. It was found that the multiplayer group (playing with peers) played approximately twice as many minutes as the home group (playing alone), and dropout was significantly lower in the multiplayer group. This study points out that the self-directed use of exergames overtime might compromise the success of exergame intervention and subsequent PA behaviour. It is, therefore, recommended to promote structured play among children by setting up multiple exergame stations in the same setting. With a structured programme, children rotate from one exergame station to another station with minimal waiting time. As such, all children would have the opportunity to play exergames simultaneously, and will be able to play different exergame activities during the programme. Another viable solution to enhance exergame maintenance might be procuring active family and friends' involvement. As mentioned earlier, exergames have the utility to promote social support among children and their peers (12,23,27,36). Thus, it is desirable to get their family members (parents and sibling) and friends involved in the exergame interventions. Also, once children are confident in their exergame skills, launching tournament may be a fun way for them to demonstrate their psychomotor skills. For example, children usually compete for higher scores or number of perfects in DDR; and compete on the spot or online when playing Wii. In fact, a few exergames like iDance developed the networking capacity, allowing for establishing online social group for gaming play. Therefore, it is recommended that in future research, professionals may help children build a global social network of exergaming players, which facilitate children share experiences, socialize online and find new friends who share similar interests.

Lastly, the premise of successful exergame use among children is the appropriate instructions and trainings, which many researchers have neglected in the population-based settings. That is, we should teach and guide children play exergames along the way as opposed to just 'roll out the ball' and let them play. As known, exergames do not define the learning objectives and contents for children. Rather, health professionals must first decide what we want children to learn and accomplish through exergames.

Otherwise, the positive effects of exergames will be marginal. Decisions on the progressions of skills, behavioural maintenance and learning environment should be carefully considered, arranged and monitored. Professionals should have the faith that they are capable of manipulating exergame activities and learning environment in a way to maximize children's perceptions of enjoyment, self-efficacy and motor skill development. For example, various exergames (e.g. DDR, Just Dance and Kinect Sports) can be incorporated into population-based settings to attract children's continuing interest and engagement. This flexibility with technology offers a friendly environment that provides choices and autonomy to all children, intrinsically motivating them to be physically active and fully engaged in exergames. Collectively, if practitioners carefully plan and provide opportunities for all children's engagement and quality learning, implementing motivating and sustainable exergames is feasible at homes, schools and communities.

In sum, although research design and other methodological issues of exergame studies need improvement, it is a fact that exergames have found their way into a broader venue, including schools, communities and homes. Research studies reviewed in this paper have supported some types of exergames, when implemented with careful planning and guidance, are efficacious to provide physical, psychosocial, cognitive and academic benefits. In this regard, exergame is more promising than disappointing in promoting children's PA and health outcomes. Nevertheless, given the limitations inherent in the empirical studies, researchers and practitioners still have a long way to go to conclude that exergames can effectively promote children's MVPA in fun and innovative ways. Based upon the synthesized findings, the following recommendations are offered to improve future exergame interventions:

1. Future study should investigate the effects of different exergame types (whole body vs. lower/upper body) and exergaming systems (e.g. Wii, Xbox, PS3) on children's health outcomes.

2. Future interventions should quantify the role of exergame accumulated PA in contributing to children's daily PA, as well as determine whether children use exergaming replace their screen times as opposed to traditional sports or PA.

3. Future study should investigate the extent to which exergaming can promote children's learning and maintenance of new movement skills and cognitive skills (e.g. concentration) and improve the understanding of the impact of exercise on their bodies (49).

4. Future study should continue to examine the long-term efficacy of exergame use in non-structured home settings for PA promotion using good-quality randomized control trials, and the potential benefits of family/group play and potential barriers in such settings.

5. Future study should take consideration of the moderating variables, such as gender, age and socioeconomic status, when evaluating the efficacy of exergames in changing children's health behaviours.

6. More research attention should be given to the process evaluation of exergaming programmes to ensure the intervention fidelity.

7. More research is needed to ascertain the effectiveness of using multiplayer mode in comparison to single player mode in school-/community-based settings as well as online settings.

8. The empirical studies targeted only older children and adolescents, missing an opportunity to apply the exergame interventions earlier in childhood to improve health outcomes. As developmentally appropriate exergames (e.g. Wii Nickelodeon Fit) are available for preschoolers, it is recommended to explore the exergaming use among preschool children and its subsequent effectiveness.

9. Few exergame research syntheses have quantified the empirical findings to a standard metric that allows statistical techniques for data analyses. Meta-analysis approach is warranted in the future to synthesize current literature concerning the effects of exergaming on children's health outcomes in comparison to sedentary behaviours, laboratory-based exercises and field-based physical activities.

Conclusions

In many states, exergames like DDR have been integrated into physical education classes, recess, after-school and fitness programmes at schools, communities and homes. However, a clear view of the effects of field-based exergaming on children's obesity-related outcomes is lacking. Thus, a systematic review in this area is needed. Additionally, although the largely increased publications in this field indicate exergame's increased popularity, field-based exergame research is still in its infancy given the rapid development of gaming industry. High-quality and well-designed research is warranted to investigate how various exergames may affect children's obesity-related outcomes from a longitudinal perspective.

PA as a result of exergame use can contribute towards daily recommendations of PA. Nevertheless, solely depending on exergames as a PA promotion strategy among children is not realistic because the light-to-moderate PA generated from exergame play is insufficient to help children meet the recommended PA levels. Having said that, exergames hold promise as an ideal intervention only if they replace sedentary activities like video games, surfing the Internet, watching TV as opposed to traditional PA and sports. Also, exergames can be one supplemental component of school-comprehensive PA programmes, but not replace physical education classes. Additionally, when implementing exergames, we should provide systematic instructions on exergame use for children, and provide PA opportunities for all children. The ultimate goal is to take advantage of enthusiastic nature of exergames, and achieve the long-term success in making playing exergames part of children's daily workout routine. It also needs to be recognized that the potential of exergames in field-based settings might have been underestimated because of a variety of limitations inherent in many published studies. Future research and practice should take into account these limitations to unravel and exploit the maximal efficacy of exergames.

Conflict of interest statement

The authors have no financial disclosures and declare no conflicts of interest.

References

1. Guy S, Ratzki-Leewing A, Gwadry-Sridhar F. Moving beyond the stigma: systematic review of video games and their potential to combat obesity. *Int J Hypertens* 2011; **179124**: 1–13. doi: 10.4061/2011/179124.
2. Bailey BW, McInnis K. Energy cost of exergaming: a comparison of the energy cost of 6 forms of exergaming. *Arch Pediatr Adolesc Med* 2011; **165**: 597–602.
3. Daley AJ. Can exergaming contribute to improving physical activity levels and health outcomes in children? *Pediatrics* 2009; **124**: 763–771.
4. Foley L, Maddison R. Use of active video games to increase physical activity in children: a (virtual) reality? *Pediatr Exerc Sci* 2010; **22**: 7–22.
5. Baranowski T, Abdelsamad D, Baranowski J *et al*. Impact of an active video game on healthy children's physical activity. *Pediatrics* 2012; **129**: e636–e642.
6. Gao Z, Podlog L. Urban Latino children's physical activity levels and performance in interactive video dance games: effects of goal difficulty and goal specificity. *Arch Pediatr Adolesc Med* 2012; **166**: 933–937. doi: 10.1001/archpediatrics.2012.649.
7. Graves LEF, Ridgers ND, Atkinson G, Gareth S. The effect of active video gaming on children's physical activity, behavior preferences and body composition. *Pediatr Exerc Sci* 2010; **22**: 535–546.
8. Maddison R, Mhurchu CN, Jull A, Jiang Y, Prapavessis H, Rodgers A. Energy expended playing video console games: an opportunity to increase children's physical activity? *Pediatr Exerc Sci* 2007; **19**: 334–343.
9. Biddiss E, Irwin J. Active video games to promote physical activity in children and youth: a systematic review. *Arch Pediatr Adolesc Med* 2010; **164**: 664–672.
10. Peng W, Crouse JC, Lin J-H. Using active video games for physical activity promotion: a systematic review of the current state of research. *Health Educ Behav* 2013; **40**: 171–192.
11. van Sluijs EMF, McMinn AM, Griffin SJ. Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. *BMJ* 2007; **335**: 703–707.
12. Staiano AE, Calvert SL. Exergames for physical education courses: physical, social, and cognitive benefits. *Child Dev Perspect* 2011; **5**: 93–98.
13. Gao Z. Motivated but not active: the dilemmas of incorporating interactive dance into gym class. *J Phys Act Health* 2012; **9**: 794–800.
14. Huang C, Gao Z. Associations between students' situational interest, mastery experience, and physical activity levels in interactive dance. *Psychol Health Med* 2013; **18**: 233–241.
15. Gao Z, Podlog L, Huang C. Associations among children's situational motivation, physical activity participation, and enjoyment in an interactive dance game. *J Sport Health Sci* 2013; **2**: 122–128.
16. Maloney AE, Bethea TC, Kelsey KS *et al*. A pilot of a video game (DDR) to promote physical activity and decrease sedentary screen time. *Obesity (Silver Spring)* 2008; **16**: 2074–2080.
17. Ni Mhurchu C, Maddison R, Jiang Y, Jull A, Prapavessis H, Rodgers A. Couch potatoes to jumping beans: a pilot study of the effect of active video games on physical activity in children. *Int J Behav Nutr Phys Act* 2008; **5**: 1–15.
18. Murphy EC, Carson L, Neal W, Baylis C, Donley D, Yeater R. Effects of an exercise intervention using Dance Dance Revolution on endothelial function and other risk factors in overweight children. *Int J Pediatr Obes* 2009; **4**: 205–214.
19. Graves LEE, Ridges ND, Williams K, Stratton G, Atkinson G, Cable NT. The physiological cost and enjoyment of Wii Fit in adolescents, young adults, and older adults. *J Phys Act Health* 2010; **7**: 393–401.
20. Maloney AE, Stempel A, Wood ME, Patraitis C, Beaudoin C. Can dance exergames boost physical activity as a school-based intervention? *Games Health J* 2012; **1**: 416–421.
21. Staiano AE, Abraham A, Calvert SL. Adolescent exergame play for weight loss and psychosocial improvement: a controlled physical activity intervention. *Obesity (Silver Spring)* 2012; **21**: 2011–2014.
22. Goran MI, Reynolds K. Interactive multimedia for promoting physical activity (IMPACT) in children. *Obes Res* 2005; **13**: 762–771.
23. Paw CA, Marijke J, Jacobs WM, Vaessen EP, Titze S, van Mechelen W. The motivation of children to play an active video game. *J Sci Med Sport* 2008; **11**: 163–166.
24. Wagener TL, Fedele D, Mignogna MR, Hester CN, Gillaspy SR. Psychological effects of dance-based group exergaming in obese adolescents. *Pediatr Obes* 2012; **7**: e68–e74.
25. Duncan MJ, Staples V. The impact of a school-based active video game play intervention on children's physical activity during recess. *Hum Mov* 2010; **11**: 95–99.
26. Gao Z, Hannan PF, Xiang P, Stodden D, Valdez V. Video game-based exercise, Latino children's physical health, and academic achievement. *Am J Prev Med* 2013; **44**(3S3): s240–s246.
27. Gao Z, Huang C, Liu T, Xiong W. Impact of interactive dance games on urban children's physical activity correlates and behavior. *J Exerc Sci Fitness* 2012; **10**: 107–112.
28. Gao Z, Xiang P. Effects of exergaming based exercise on urban children's physical activity participation and body composition. *J Phys Act Health* 2014; **11**. Retrieved from URL: http://www.ncbi.nlm.nih.gov/pubmed/23799240 (accessed 15 December 2013).
29. Sheehan DP, Katz L. The effects of a daily, 6-week exergaming curriculum on balance in fourth grade children. *J Sport Health Sci* 2013; **2**: 131–137.
30. Lwin MO, Malik S. The efficacy of exergames-incorporated physical education lessons in influencing drivers of physical

activity: a comparison of children and pre-adolescents. *Psychol Sport Exerc* 2012; **13**: 756–760.
31. Madsen KA, Yen S, Wlasiuk L, Newman TB, Lustig R. Feasibility of a dance videogame to promote weight loss among overweight children and adolescents. *Arch Pediatr Adolesc Med* 2007; **161**: 105–107.
32. Calcaterra V, Larizza D, Codrons E *et al*. Improved metabolic and cardiorespiratory fitness during a recreational training program in obese children. *J Pediatr Endocrinol Metab* 2013; **26**: 271–276. doi: 10.1515/jpem-2012-0157.
33. Christison A, Khan HA. Exergaming for health: a community-based pediatric weight management program using active video gaming. *Clin Pediatr (Phila)* 2012; **51**: 382–388.
34. Owens SGI, Garner JC, Loftin JM, van Blerk N, Ermin K. Changes in physical activity and fitness after 3 months of home Wii Fit use. *J Strength Cond Res* 2011; **25**: 3191–3197.
35. Quinn M. Introduction of active video gaming into the middle school curriculum as a school-based childhood obesity intervention. *J Pediatr Health Care* 2013; **27**: 3–12.
36. Fogel VA, Miltenberger RG, Graves R, Koehler S. The effects of exergaming on physical activity among inactive children in a physical education classroom. *J Appl Behav Anal* 2010; **43**: 591–600.
37. Gao Z, Hannon JC, Newton M, Huang C. The effects of curricular activity on students' situational motivation and physical activity levels. *Res Q Exerc Sport* 2011; **82**: 536–544.
38. Whittman G. Video gaming increases physical activity. *J Exten* 2010; **48**: 1–4.
39. Gao Z, Zhang T, Stodden DF. Children's physical activity levels and their psychological correlated in interactive dance versus aerobic dance. *J Sport Health Sci* 2013; **2**: 146–151.
40. Sun H. Exergaming impact on physical activity and interest in elementary school children. *Res Q Exerc Sport* 2012; **83**: 212–220.
41. Miller TA, Vaux-Bjerke A, McDonnell KA, DiPietro L. Can e-gaming be useful for achieving recommended levels of moderate-to-vigorous-intensity physical activity in inner-city children? *Games Health J* 2013; **2**: 96–102.
42. Sun H. Impact of exergames on physical activity and motivation in elementary school students: a follow-up study. *J Sport Health Sci* 2013; **2**: 138–145.
43. Bethea TC, Berry D, Maloney AE, Sikich L. Pilot study of an active screen time game correlates with improved physical fitness in minority elementary school youth. *Games Health J* 2012; **1**: 29–36.
44. Maddison R, Foley L, Mhurchu CN *et al*. Effects of active video games on body composition: a randomized controlled trial. *Am J Clin Nutr* 2011; **94**: 156–163.
45. Miyachi M, Yamamoto K, Ohkawara K, Tanaka S. METs in adults while playing active video games: a metabolic chamber study. *Med Sci Sports Exerc* 2010; **42**: 1149–1153.
46. Pate RR. Physically active video gaming: an effective strategy for obesity revention. *Arch Pediatr Adolesc Med* 2008; **162**: 895–896.
47. Goran MI, Reynolds K. Interactive multimedia for promoting physical activity (IMPACT) in children. *Obes Res* 2012; **13**: 762–771.
48. O'Loughlin EK, Dugas EN, Sabiston CM, O'Loughlin JL. Prevalence and correlates of exergaming in youth. *Pediatrics* 2012; **130**: 806–814. doi: 10.1542/peds.2012-0391.
49. Ennis CD. Implications of exergaming for the physical education curriculum in the 21st century. *J Sport Health Sci* 2013; **2**: 152–157.