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Effects of Active Video Game Interventions on Physical Health and Development Among Healthy Preschool Children: A Systematic Review

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Abstract

Early physical activity (PA) interventions during preschool ages are necessary and critical to cultivate healthy movement behaviors for healthy growth and development. The increasing obesity rate among children is a major public health concern globally, which is largely due to poor adherence to participating in regular PA. Active video game (AVG) interventions have been increasingly used in promoting PA. The narrative review synthesized current literature regarding the effect of AVG interventions on physical health and development indicators among healthy preschoolers. A systematic review was performed in Academic Search Premier, CINAHL, ERIC, PubMed, SPORT Discus, and Web of Science, following the PRISMA guidelines. A total of seven experimental studies were included; two were home-based interventions and five were center-based interventions. Three studies confirmed AVG interventions had a positive effect on the targeted outcomes: fruit and vegetable acceptance, execution function, and perceived competence. All other studies found partially positive effects on PA levels, motor skill competence, fundamental movement skills, or cognitive flexibility. The available evidence suggests that AVGs could be a promising channel to promote PA outcomes that contribute to physical health and development in preschoolers. The results underline advantages and usages of AVG interventions in preschoolers although evidence provided limited robustness. There is a paucity of studies that investigated the effect of AVG PA interventions on physical health and development in healthy preschoolers. Future studies are needed to replicate findings and test feasibility and efficacy of AVG PA interventions.

Erratum

Erratum 5/23/2023: Correction made to abstract to indicate that of the seven experimental studies "five were center-based". The article content was adjusted to include the PROSPERO registration identification "CRD42023395175" under the Method section.

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Introduction

Physical activity (PA) contributes to healthy growth and development (e.g., promoting motor development, fostering healthy physical activity habits and movement behaviors, and reducing sedentary behaviors) among young children during early childhood, especially the preschool years. Recently many countries and organizations released PA guidelines for young children. For example, the Canadian 24-Hour Movement Guidelines for Early Years (0–4 years) recommend that young children should engage in at least 180 minutes of total PA (light to vigorous activity including energetic play) throughout the day and should not engage in sedentary behavior (e.g., sedentary screen time) or sitting (e.g., in car seat) for more than 60 minutes at a time (Tremblay et al., 2017). Physical Activity Guidelines for Americans recommend that preschoolers (age of 3-5 years) should be active throughout the day (Physical Activity Guidelines for Americans, 2018). In addition, SHAPE America recommends that preschooler should engage in at least 60 minutes of structured PA and 60 minutes of unstructured PA each day (SHAPE America, 2020). However, Carson et al. (2020) found that young children (19-60 months) spent 30.0, 23.1, and 6.9 minutes per hour engaging in sedentary behaviors, light intensity PA (LPA), and moderate to vigorous intensity physical activity (MVPA) in childcare times as measured by accelerometry. A systematic review found that sedentary time within childcare settings ranged from 12.38 to 55.77 minutes per hour, LPA time ranged from 2.94 to 29.96 minutes per hour via accelerometry, MVPA times ranged from 1.29 to 22.66 minutes per hour, and the total PA time ranged from 4.23 to 47.17 minutes per hour among young children (age of 2-5 years) (O'Brien et al., 2018). Surprisingly, accelerometer studied reported young children spent approximate13.99%, 43.77%, and 52.81% of their outdoor playtime in MVPA, total PA, and sedentary activity although they supposed to be highly active during childcare outdoor play sessions (Truelove et al., 2018). Therefore, effective early PA intervention is warranted in increasing PA and decreasing sedentary behaviors among preschoolers.

Emerging technologies, such as exergames and interactive video games, have been increasingly used in developing and delivering PA interventions for prevention of chronic disease and promotion of PA outcomes (Gao, 2017; Gao & Xiang, 2014; Sween et al., 2014; Warburton et al., 2007). Active video games (AVG), known as exergames, refer to a type of video games that requires bodily movement engaged in exercise (Gao, 2012; Gao et al., 2015), providing PA opportunity and engagement while being creative and unique. AVGs are designed to be attractive and motivative to participants that engage and exert physically and mentally during gameplay. These PA exertions and engagements achieve along with human-computer interaction and interface synchronously or asynchronously through electronic screen, camera, motion sensor, etc. A number of reviews found supportive evidence of the effectiveness of AVG PA intervention on PA, physical fitness, motor skill, weight-related outcomes, rehabilitation outcomes, physiological outcomes, and psychological outcomes among children and adolescence (Comeras-Chueca et al., 2021; Gao et al., 2015; Liu et al., 2020, Qian et al., 2020; Williams & Ayres, 2020; Zeng et al., 2017). Most importantly, the effectiveness of AVG intervention has been found to be the same as other forms of traditional PA interventions while adding the fun component to the programs. Remarkably, Hassan et al. (2022) revealed that exergaming is the most effective intervention for locomotor skills in children (ages of 3-12). However, the previous studies included subjects with obesity or needs for rehabilitation. This may lead to a failure on the intervention's feasibility or acceptability in healthy children, which leaves speculation, doubt, and hesitation on the applications of AVGs for PA interventions in children. Second, regarding the age range of the target population, we only focused on the effects of the gaming-PA intervention in preschooler (age 3-5). To our knowledge, this is the first narrative systematic review looking at AVG interventions in preschoolers. Thus, the application, feasibility, acceptability, and efficacy of AVG interventions for the preschoolers has not been reviewed yet. Another rationale for conducting this systematic review was to summarize the types of gaming that have been applied to integrate, facilitate, and promote PA in healthy preschoolers.

The purpose of the current literature review outlines and synthesizes existing literature regarding the effectiveness of AVG PA interventions on physical health and development among healthy preschoolers. Furthermore, this review also provides a theoretical basis of effectiveness of PA participation and options in future practical implications in the field of PA and public health. The findings may provide evidence-based recommendations for preschool stakeholders and policymakers regarding optimal PA promotion strategies.

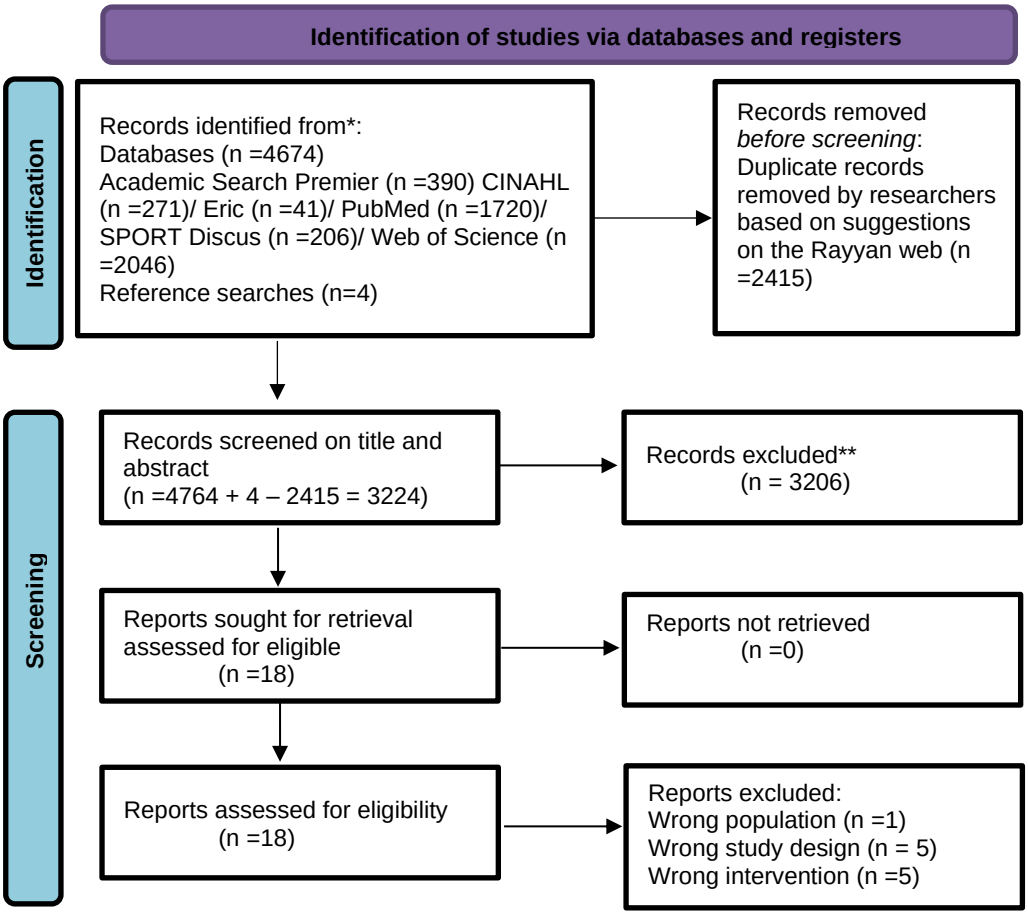
Method

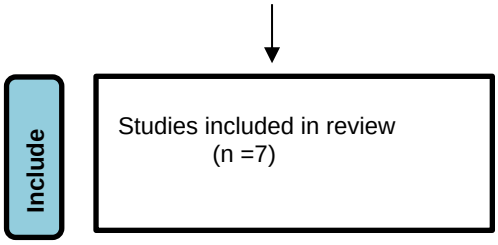
Search Strategies and Information Sources

We followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021) for reporting of this review and used the Rayyan web (Ouzzani et al., 2016) assisting data extraction. This systematic review is registered with the International Prospective Register of Systematic Reviews (PROSPERO), registration identification: CRD42023395175. We searched the following electronic databases for relevant literature through the Libraries of the University of Minnesota: Academic Search Premier, CINAHL, ERIC, PubMed, SPORT Discus, and Web of Science. All investigators (J.O., J.P., W.Z., Z.G.) collaborated and searched literature by using the following searching Boolean phrases: (“preschool” OR “preschooler” OR child) AND (active video game OR interactive video game OR exercise video game OR exergame OR exergaming OR exercise gaming OR virtual reality OR Wii OR Xbox OR Kinect OR PlayStation) AND (physical activity OR exercise).

Figure 1

PRISMA Flow Diagram of Studies through the Review Process





From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

Eligibility Criteria

We used the following inclusion criteria with reference to the participants, interventions, comparisons, outcomes, and study design (PICOS) principles: (1) study subjects consisted of healthy children (ages of 3-6 years) without motor or mental issues (such as motor development delay or autism spectrum disorders); (2) AVG interventions included PA or exercise components that elicit raising energy expenditure than resting; (3) the study applied a control group with control condition or conventional treatment; (4) types of outcomes included physical health and development indicators; and (5) the study applied experimental design such as randomized control trails (RCT) and quasi-experimental design. In addition, we only included peer-reviewed research published in English before December 2022.

Data Extraction and Synthesis

Three investigators (J.O., J.P., W.Z.) independently screened all potential studies through the title abstract using the Rayyan web. Data extraction was done by one investigator (W.Z.) and checked for accuracy by another (J.O.). The data extract form included studies were evaluated, and individual study was categorized into themes and research components. The interventions and its targeted outcomes were synthesized based on the concerned areas. The results of individual intervention were assessed with relation to targeted outcomes. We created a matrix table to extract the following information: (1) study description, (2) sample and setting, (3) type of AVG, (4) intervention supervisor and exposure, (5) design and measure timeline, (6) variable and instrument, and (7) findings. Moreover, we cross referenced the bibliographies of related articles to further search for relevant studies. We were not blinded to the authors or journals of the included studies. In addition, we did not attempt to contact the authors or correspondents to request extra information.

Risk of Bias Assessment

Four investigators (J.O., J.P., W.Z., Z.G.) independently assessed the risk of bias assessment for each included study and used an 8-item quality assessment tool used in previous review studies (McDonough et al., 2020; Qian et al., 2020; Zeng et al., 2018). As the Table 1 shows, we scored each within-study item as “positive” if the item was present and explicitly defined or “negative” if the item was absent or inadequately defined. Four investigators (J.O., J.P., W.Z., Z.G.) independently scored the risk of bias of each study within the quality assessment. If necessary, a disagreement would be adjudicated by a fourth reviewer (Z.G.). A fifth reviewer (K.A.) coordinated the study protocols. We summed up “positive” scores as the final quality scores for each study. Studies were considered high-quality when they scored above the median score, and studies were considered low-quality when they scored below the median score.

Results

Study Selection

A total of 4674 potential articles were located through the search of the databases, and 4 articles were identified through related reference crosschecks. After removing 2415 duplicate articles, three investigators (J.O., J.P., W.Z.) independently screened the titles and abstracts of the remaining 3224 articles to identify potentially relevant articles. After thorough assessment of 18 full-text articles, 7 studies met the inclusion criteria and were included in this systematic review (see Figure 1). Reasons for excluding potential articles included wrong population (e.g., children with diabetes), study design (e.g., case study), and wrong intervention (e.g., no PA or exercise component). Notably, we reached 100 % interrater agreement for included articles between the study investigators.

Study Characteristics

Characteristics of all included studies are shown in Table 2. Seven (6 RCT) experimental studies were included (Fu et al., 2018; Gao, Lee, Zeng, et al., 2019; Gao, Zeng, Pope, et. al., 2019; Liu et al., 2022; Trost et al., 2021; Vesalainen et al., 2022; Xiong et al., 2019). Among them, three studies confirmed that the AVG PA interventions had a significantly positive effect on targeted outcomes (Liu et al., 2022; Vesalainen et al., 2022; Xiong et al., 2019). All other studies indicated partially significant effects (Fu et al., 2018; Gao, Lee, Zeng, et al., 2019; Gao, Zeng, Pope, et. al., 2019; Trost et al., 2021). Especially, all studies were published in the last 5 years.

Table 1

Author	1	2	3	4	5	6	7	8	Score	Effectiveness
Fu et al., 2018	+	+	-	+	+	-	+	-	5	+/NA
Gao, Lee, Zeng, et. al., 2019	+	+	+	+	+	+	+	-	7	+/NA
Gao, Zeng, Pope, et. al., 2019	-	+	+	+	+	+	+	-	6	+/NA
Liu et al., 2022	+	+	+	+	-	+	+	-	6	Yes
Trost et al., 2021	+	+	-	+	+	-	+	-	5	+/NA
Vepsalainen et al., 2022	+	+	+	-	+	-	+	-	5	Yes
Xiong et. al., 2019	+	+	+	+	+	+	+	-	7	Yes

Notes: 1= Randomization, 2= Control, 3=Pre-Post, 4=Retention>80%, 5=Missing Data, 6=Power Analysis, 7= Validity Measure, 8= Follow-up; "+" refers to positive (explicitly described and present in details); "-" refers to negative (inadequately described and absent); "Yes" indicates significant positive effect; "NA" indicates no significant effect; "+/NA" represents significant improvements which were found on several measures while no significant effects were observed on other measures; median score =6.

Risk of Bias Assessment of Design Quality Analysis

Five studies were childcare-based interventions (Fu et al., 2018; Gao, Zeng, Pope, et. al., 2019; Liu et al., 2022; Vesalainen et al., 2022; Xiong et al., 2019), and two studies were family-based interventions. The studies were conducted in different countries: 3 in the USA (Fu et al., 2018; Gao, Lee, Zeng, et al., 2019; Gao, Zeng, Pope, et. al., 2019;), 2 in China (Liu et al., 2022; Xiong et al., 2019), 1 in Australia (Trost et al., 2021), and 1 in Finland and Poland (Vesalainen et al., 2022). We observed a relatively large variability across studies in sample size (n = 32 to 221) .

Interventions used AVGs or exergames (Fu et al., 2018; Gao, Lee, Zeng, et al., 2019; Gao, Zeng, Pope, et. al., 2019; Liu et al., 2022; Xiong et al., 2019), and device (or platform) specific application games (Trost et al., 2021; Vesalainen et al., 2022). The duration of the interventions ranged from 3 to 12 weeks, implementing at least once per week. Especially, either caregivers or parents were trained to supervise the intervention implementation and facilitation.

Various types of study outcomes regarding physical health and development indicators were targeted on. Three studies reported PA levels (Fu et al. 2018; Gao, Zeng, Pope, et. al., 2019; Trost et al., 2021), and three studies reported motor skills (Fu et al., 2018; Gao, Zeng, Pope, et al., 2019; Trost et al., 2021). Two studies reported executive function (Liu et al., 2022; Xiong et al., 2019), and two studies reported perceived competence (Gao, Zeng, Pope, et. al., 2019; Xiong et al., 2019). Other targeted outcomes included fruit and vegetable acceptance, enjoyment of AVGs, acceptance of AVGs, cognitive flexibility, energy expenditure, body mass index (BMI), and cardiovascular fitness (Fu et al., 2018; Gao, Lee, Zeng, et al., 2019; Liu et al., 2022; Vesalainen et al., 2022).

Study Quality and Risk of Bias Assessment

Scores of study quality/risk of bias for all individual studies ranged from 5 to 7 with a median score of 6 (Table 1). An individual study was considered high quality/low risk of bias when it scored above the median score of 6, moderate quality/medium risk of bias if scored at the median score of 6, and low quality/high risk of bias if scored below the median score of 6. Two studies (28.57%) received an overall rating of strong quality/low risk of bias, 2 study (28.57%) received an overall rating of moderate quality/medium risk of bias, and 3 studies (42.85%) received an overall rating of weak quality/high risk of bias. Noteworthy is the fact that all studies did not conduct a follow-up test. Therefore, the most common issue with the study quality/risk of bias was a lack of follow-up measurement. Another concern were pre-post tests and power analysis. Two stronger point were all studies applied a control group condition and valid measure.

Type of AVGs PA Interventions

Five studies incorporated either AVGs or exergames for PA interventions (Fu et al., 2018; Gao, Lee, Zeng, et al., 2019; Gao, Zeng, Pope, et. al., 2019; Liu et al., 2022; Xiong et al., 2019). The non-immersive AVGs included GoNoodle, Advances to Fitness, Cosmic Kids Yoga, Nikelodeon Fit, Wii Sport, Just Dance Dance, and LeapTV sports and dance. The game consoles facilitated the AVG PA interventions were LeapTV, Wii Nintendo, Xbox One (or Xbox Kinect), and Xbox 360. Moreover, two studies applied device (or platform) specific

application games for PA interventions (Trost et al., 2021; Vesalainen et al., 2022). The Moovosity app was commercial application paid with membership use (Trost et al., 2021), and the Mole's Veggie Adventure app aims at educational purposes and are available to down from multiple digital app stores (Vesalainen et al., 2022).

The Effects of AVGs on PA, Motor Skills, and Cardiovascular Fitness

For PA outcomes, researchers reported that the intervention group increased MVPA measured by accelerometers (Gao, Zeng, Pope, et. al., 2019), and another study using pedometers reported daily step count was higher than control group (Fu et al. 2018). However, Trost and colleagues (2021) reported no significant effect on child PA and parental support PA by subjective measures. In addition, three studies suggested that PA interventions improve motor skills measured by the Test for Gross Motor Skill Development instrument (Fu et al., 2018; Gao, Zeng, Pope, et al., 2019; Trost et al., 2021). Furthermore, a studied reported exergaming did not improve cardiovascular fitness measured by the 3-minutes test (Gao, Lee, Zeng, et al., 2019).

Table 2

Characteristics of the Included Studies

Study Description	Sample and Setting	Intervention supervisor and Exposure	Types of AVG	Design and Measure Timeline	Variables and Instruments	Findings
Effect of an exergaming program on PA, motor competence, and enjoyment (Fu et al., 2018)	1) N = 65(age = 4.9 ± 0.7, 31 girls), INT = 36, CON = 29 2) Urban preschool, USA	1) Trained researchers and teachers supervised the school-based exergaming program in school routine for 12 consecutive weeks, 5 times per week, 30 minutes daily. 2) CON attended regular free-play routines.	1) GoNoodle, 2) Adventures to Fitness 3) Cosmic Kids Yoga	1) RCT 2) Posttest only	1) Step counts was measured by Yamax DigiWalker CW6000 pedometer. 2)Motor competence was measured by TGMD-3. 3) Enjoyment of movement was measured by the Intrinsic Motivational Inventory as preschooler rated assisting by caregivers.	1) INT showed higher motor skill competence and school-day steps. 2) No significant enjoyment was reported.
Effect of home-based exergaming PA on energy expenditure, fitness, body mass index, and cognition (Gao, Lee, Zeng, et al., 2019)	1) N = 32 (16 girls, age of 4.72 ± 0.37), INT = 18, CON = 14 2) Home-based settings, USA	1) Trained parents facilitated home-based educational exergaming beyond usual PA for 12 weeks, at least 30 min per session, 5 times per week. 2) CON maintained regular PA patterns without any exergaming gameplay.	1) LeapTV video gaming : sports and dance	1) RCT 2) Pre-post	1) Energy expenditure was measured by ActiGrap GT3X+ Accelerometer. 2) Cardiovascular fitness was measured by the 3-minute step test. 3) Cognitive flexibility was measured by DCCS.	1) INT demonstrated greater increases in cognitive flexibility and energy expenditure. 2) No significant effect showed on BMI and cardiovascular fitness.
Effect of exergaming on motor skill competence, perceived competence,	1) N = 56 (31 girls; 4.45 ± 0.46 years), INT = 20, CON = 36 2) Underserved urban preschool, USA.	1) Teachers facilitated the curriculum-incorporated intervention for 8 weeks, 20 minutes per day, 5 days a week. Researchers provided weekly supervision.	1) Wii Just Dance for Kids 2)Wii Nickelodeon Fit 3) Xbox 360 Kinect Just Dance for Kids	1) Quasi-experimental design 2) Pre-Post	1) PA level was measured by ActiGraph GT9X Link accelerometer. 2) Motor skill competence was measured by TGMD-2. 3) PC measured by PSPCSA.	1) INT displayed significantly greater increased MVPA. 2) No significant effect showed on PC and motor skill competence.

and PA (Gao, Zeng, Pope, et al., 2019)		2) CON received a standard care (usual care recess free play 20 minutes per day, 5 days per week).				
Usability and effectiveness of AVG intervention on EFs (Liu et al., 2022)	1) N = 48, INT = 14 (25 girls, age of 4.9 ± 0.28 years), CON = 14 (12 girls, age of 4.88 ± 0.34 years) 2) Kindergarten, China	1) Trained instructors facilitated 4 weeks of the intervention by integrating into the physical education curriculum, 30 min duration daily in schooldays. 2) CON maintained conventional PA.	1) Just Dance Game Series	1) RCT 2) Pre-post	1) EFs was measured by the Early Years Toolbox. 2) Acceptance of the PA intervention was measured by the Technological Acceptance Model.	1) INT increased test scores EFs (inhabitation, shifting, and working memory). 2) Overall acceptance rate of the intervention was greater than 80%.
Effectiveness of a novel digital application PA intervention on FMS (Trost et al., 2021)	1) N = 34; INT = 17 (52.9% girls, a wait-list CON = 17, 47.1% girls; age of 3 to 6 years 2) Family environmental settings, Australia	1) Parents used an interactive digital application to facilitate children and parent co-participation PA for 8 weeks, at least three times per week. 2) CON (a wait list) was maintained normal routine.	1) Moovosity application (an interactive digital app is designed for promoting PA and FMS through active games)	1) RCT 2) Posttest only	1) FMS was measured via TGMD-2. 2) Preschooler PA was measured via Burdette outdoor playtime checklist by parents. 3) Parental support PA was self-reported.	1) INT showed improvements on objective control skills and locomotor skills. 2) No significant effect showed on child PA. 3) No significant effect showed on parental support PA.
Effect of an app intervention on increasing FV acceptance (Vepsalainen et al., 2022)	1) N = 221 (120 girls, age of 5±1.2 years), INT =115, CON = 106 2) Early childhood education and care centers, Finland and Poland	1) Caregivers were instructed to implement the app intervention at least 1-2 times per week during the 3-4 weeks of intervention period. 2) CON maintained their regular routines.	1) Mole's Veggie Adventure app (learning through play, e.g., motor skills and interactive game)	1) RCT 2) Baseline and follow-up	1) Caregivers recorded the completion of the intervention activity via the app questionnaire.	1) INT increased FV acceptance scores at the follow-up test relatively.

Effect of Exergaming on executive functions and perceived competence (Xiong et al., 2019)	1) N = 60 (30 girls, age of 4.52), INT=30 (age of 4.65) CON=30 (age of 4.38) 2) Childcare center, China	1) Trained instructors facilitated 8 weeks exergaming intervention condition. Exergaming intervention was provided daily during the 20-min recess period 5 days per week. 2) CON participated the traditional PA.	1) Wii Sport 2)Just Dance for Kids 3) Nickelodeon Fit	1) RCT 2) Pre-Post	1) Executive function was assessed by DCCS 2) PC was measured by PSPCSA	1) INT displayed significantly greater improvements on EFs and PC.
Notes: AVG = active video game; INT = intervention group; CON = control group; TGMD-3 = Test of Gross Motor Development-Edition 3; PC = perceived competence; PSPCSA = the Pictorial Scale of Perceived Competence and social acceptance; DCCS = the Dimensional Change Card Sort; BMI = Body Max Index; TGMD-2 = Test of Gross Motor Development-Edition 2; EF = execution function; FMS = fundamental movement skills; FV = fruit and vegetable.						

The Effectiveness of AVGs on Weight-related Health

For weight-related health outcomes, Vesalainen et al. (2022) indicated AVG intervention increased fruit and vegetable acceptance measured via parental report. Gao, Lee, Zeng, et al., (2019) reported exergaming have no effect on energy expenditure objectively measured via accelerometer. Similarly, Gao, Zeng, Pope, et al. (2019) reported exergaming have no effect on BMI measured via weight-height calculation.

The Effectiveness of AVGs on Psychological and Cognitive Aspects

For psychological and cognitive aspects, two studies reported AVGs improved executive function (e.g., inhabitation, shifting, and working memory) assessed by the Early Year Toolbox and the Dimensional Change Card Sort (Liu et al., 2022; Xiong et al., 2019). Consistently, two studies also reported AVGs improved perceive competence measured by the Pictorial Scale of Perceived Competence and social acceptance (Gao, Zeng, Pope, et al., 2019; Xiong et al., 2019). Additionally, a study reported AVGs improved cognitive flexibility measured by the Dimensional Change Card Sort (Gao, Lee, Zeng, et al., 2019).

Evaluations of Feasibility and Acceptability of Intervention

Two studies evaluated the feasibility and acceptability of Interventions. A school-based study reported overall acceptance rate of the intervention was higher than 80% (Liu et al., 2022). In contrast, another school-based study reported no significant enjoyment was observed (Fu et al., 2018). Although few studies defined approximate 90% of intervention fidelity or quality, the results were not reported as main outcomes (Gao, Lee, Zeng, et al, 2019; Gao, Zeng, Pope, et al., 2019; Xiong et al., 2019).

Discussion

The purpose of this review was to comprehensively synthesize and evaluate all published experimental studies examining the causal evidence and the effect of AVG PA interventions on physical health and development related outcomes in preschoolers. Seven studies met the inclusion criteria and were included in the narrative analysis. Overall, the findings from 3 studies confirmed that the AVG interventions had significant positive effects on targeted outcomes, and 4 studies found partially significant outcomes. Most studies examined traditional or conventional PA interventions compared to AVG interventions.

PA outcomes and motor skills seem to be the most common targeted outcome using AVG interventions. All included studies supported AVGs improved motor skills in preschoolers. While two studies defined significant effect on PA outcomes via subjective measures (Fu et al. 2018; Gao, Zeng, Pope, et. al., 2019), the nonsignificant on PA levels from another study may be due to inappropriate PA assessment or poor intervention fidelity (Trost et al., 2021). Should researchers not only emphasize on PA levels during gameplay but also the quality (types, diversity and richness) of PA assessed via systematic observation (Castañer et al., 2016). Further questions arise regarding effectiveness on targeted outcomes included, but not limited to PA outcomes measurement and the relationships among PA, games per se, and expected outcomes.

Weight-related health indicators, such as energy expenditure and BMI, seemed to not be affected, which needs more high-quality studies to duplicate and retest. In previous studies, AVG interventions had positive effects on energy expenditure in children and adolescence (Gao et al., 2017, Gribbon et al., 2015). AVGs did not have effect on BMI (Gao, Lee, Zeng, et al., 2019), which was consistent with a previous study (Gao & Xiang, 2014). While Game for Health has been advocated (Baranowski, 2015; Baranowski et al., 2019), many AVG interventions have been used in children (ages of 6-18 years). Some systematic and meta-analysis reviews have found that AVG have positive effects on obesity related factors among children and adolescents with overweight or obesity, including BMI, body fat

percentage and PA (Comeras-Chueca, Marin-Puyalto, Matute-Llorente et al., 2021a; 2021b; Gao et al., 2020). In healthy weight children, AVGs seemed to have a positive effect on BMI when the intervention is longer than 18 weeks (Comeras-Chueca, Marin-Puyalto, Matute-Llorente, et al., 2021b). Based on the findings from children, AVG PA intervention could be a good strategy to combat childhood obesity.

In clinical psychology, AVGs have been renovated with other formats (e.g., serious games and gamification) to affect or promise for mental health studies (Fleming et al., 2020). The current systematic review also found additional evidence to for psychological and cognitive outcomes, like executive function, perceive competence, cognitive flexibility, etc. Many unique features of AVGs, such as interactive and attractive, could be incorporate into prevention and prediction of psychological and cognitive health.

Feasibility and acceptability could be associated with efficacy of the AVG interventions. Liu et al. (2022) reported overall acceptability of the intervention was higher than 80% in preschoolers. Although AVGs are supposed to be fun, a school-based study reported no significant enjoyment was observed among preschoolers (Fu et al., 2018). Since the intervention sessions were set up using a projector in a spacious classroom, and preschoolers all played at the same time, the interaction levels between exergaming and preschoolers and the attractions vanish gradually. Fu et al. (2018) explained that it was due to the decreasing enjoyment following the length of the intervention duration. In the future, demanded studies could test whether the interactive level of AVG interventions correlate with PA levels or other outcomes. Process evaluation studies may be used to assess feasibility and acceptability of the intervention, for example the study fidelity: adherence, compliance, and integrity of study design.

As a relatively new and novel format of PA interventions, caregivers in preschools trained in leading exergaming interventions could utilize these technological tools to deliver and facilitate PA engagement and participation in center-based AVG interventions. Although a systematic review found insufficient evidence to suggest applying AVGs for health promotion in school settings (Norris et al., 2016), this systematic review included 5 center-based PA interventions, and the caregivers were trained to implement the interventions and led the interventions at the childcare center. Two studies found increased PA outcomes (step counts and PA levels) during the childcare time but also increased structured PA times (Fu et al. 2018; Gao, Zeng, Pope, et. al., 2019). As known, caregivers or teachers are always busy caring for the emotional learning of their students, AVG provides more opportunity and option to preschoolers for that development. On the other hand, two home-based PA intervention were included in this review. The home-based intervention also provides more options and choices for parents to engage preschoolers to being active in their home environments, making this a convenient and easy way to utilize the space in their home, and include their family. Another benefit is that this provides more pathways for parents and children to communicate and learn together. This may also be helpful to resolve the issues of short duration in PA interventions. It may be feasible to increase the PA intervention duration although 5 included studies had durations of 8 weeks and 12 weeks. If an intervention was developed using the home environment, preschoolers generally tend to receive one-to-one care from at least one parent to engaging with the PA intervention.

One weakness of this study is that only 7 articles was included, so it is a relatively small numbers of available studies to induce limited evidence for this pediatric population. The second limitation is AVG interventions are relatively new and developing, so its definition may lack consistency. For that reason, we may miss potential articles during the literature search. Another limitation is that we only included peer-reviewed articles published in English for a logical reason, and thus we potentially missed articles from non-English publication. The additional limitation is that there was a homogeneity among the included

studies, 3 studies were conducted by a group of researchers from similar research background (Gao, Lee, Zeng, et al., 2019; Gao, Zeng, Pope, et. al., 2019; Xiong et al., 2019). Also, since the risk of bias assessment indicated (1) shortage of available studies on AVG in preschooler, (2) study homogeneity, and (3) limited generalizability. More future studies are needed to evaluate the feasibility and efficacy of AVG interventions in preschoolers.

The first strengthen of this study is that, to our knowledge, this is the first systematic review to examinate the effects of the AVG intervention on physical health and development in healthy preschoolers. Second, we synthesized and summarized the current available research regarding the effect of AVG interventions which shows support that AVG interventions have a potential to be generalizable and become meaningful home-based and center-based PA interventions for young children who still need care and supervision. Additionally, preschoolers can potentially benefit from AVG interventions for executive function, cognition, motor skill, enjoyment, and perceived competence, etc. Lastly, although AVG interventions are relatively new and novel in preschools, adopting AVG is a trend that takes advantage of technology by utilizing interactive, creative, motivative, and enjoyable exergaming PA interventions to prevent childhood obesity and promote PA outcomes.

Conclusion

Overall, the current findings suggested a positive relationship between AVG and improved targeted outcomes regarding physical health and development in preschoolers. Promoting the application and utilization of effective PA interventions to enrich PA options and promote PA participation is paramount to the promotion of physical health and development and the prevention of chronic diseases in early childhood. Center-based or home-based AVG interventions have gained attention in the field of PA and public health since several studies have confirmed the positive effects on PA outcomes and nutrition. While center-based AVG interventions continue to grow, parents, childcare providers and public health professionals should take advantage of AVG PA interventions as a new opportunity for childhood obesity prevention.

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